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Über die Wasserbewegung

IN

Böden

VON

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Es haben sich schon viele tüchtige Forscher, wie Meister,* Liebenberg† u. A. mit der Wasserbewegung in den Böden beschäftigt und zwar hauptsächlich mit der Aufsaugung des Wassers. Selbst Liebenberg, der wohl die ausgedehnteste Untersuchung in dieser Hinsicht durchgeführt hat, hat es nicht vermocht, Gesetzmässigkeit in der Bewegung der Wassers in Böden zu entdecken, ausser einigen Thatsachen, welche praktisch von hohem Werth sind. Ein Versuch auf dem Wege der Theorie in der Sache Wandel zu verschaffen, ist, so viel ich weiss, noch nicht unternommen worden.

Es soll im Folgenden eine Theorie der Flüssigkeitsbewegung in einem Medium entwickelt werden, welches, wie ein Boden, aus kleinen discreten durch Wasser benetzbaren Theilchen besteht, und die Lösung des Problems in einem speciellen Fall in ihrer Anwendung auf den Boden näher geprüft werden.

Die Massentheilchen, welche ein Medium, wie Boden, zusammensetzen, setze ich, und damit die capillaren Räume zwischen den Theilchen nicht als gleichmässig gross voraus; sie sollen der Grösse nach zwischen gewissen Grenzen schwanken, und noch so gross sein, dass der hydrostatische Druck sich fort-

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* Meister: Jahresbericht für Agriculturchemie 1859–60.

† Liebenberg: Über das Verhalten des Wassers in Boden. 1873.

pflanzen könne, aber so klein, dass die Summe aller einzelnen Querschnitte der capillaren Räume, welche auf je eine Flächenheit einer durch das Medium gelegten Ebene fallen, als constant betrachtet werden darf. Wir denken uns durch das Medium zwei unendlich nahe parallele Ebenen gelegt, und betrachten Stücke der capillaren Räume zwischen den beiden Ebenen als cylindrisch, und sehen zu, was geschieht, wenn einer dieser cylindrischen Räume mit Wasser in Berührung kommt, indem wir die Wandung derselben als porös und benetzbar denken. Es sei σ die Axe dieses unendlich kleinen cylindrischen Räums, und seine Länge werde der Einfacheit wegen $= 1$ gesetzt, und es soll mit dem Ende $\sigma = 0$ mit Wasser in Berührung kommen. Ehe das Wasser durch den cylindrischen Raum fliesst, wird sich eine gewisse Wassermenge in der porösen Wandung lagern, und sobald eine Stelle gesättigt wird, wird eine gewisse Wassermenge darüber hinweg nach der nächst liegenden weniger gesättigten Stelle entlang der Wand fliessen. Der Druck, der diese Wasserbewegung verursacht, rührt von der Feuchtigkeitsdifferenz in dem cylindrischen Raum her, und verschwindet und wächst offenbar mit derselben. Es sei ε die Wassermenge, welche in der Wand von der Länge Eins festgehalten wird, m die Wassermenge, welche im Querschnitt $\sigma = 0$ durch eine Flächeneinheit in der Zeiteinheit fliesst, und m' diejenige, welche in Querschnitt $\sigma = 1$ durch eine Elächeneinheit in der Zeiteinheit fliesst, so wird die Feuchtigkeit in Querschnitt $\sigma = 0$, $= m + \varepsilon$ sein, und in Ouerschnitt $\sigma = 1$, $= m' + \varepsilon$. Der Druck, der diese Eeuchtigkeitsdifferenz hervorgerufen hat, kann nur eine Funktion derselben sein, und darf wohl direct proportional dem Feuchtigkeitsgefälle selbst gesetzt werden, so dass der Druck, der diese Wasserbewegung entlang der Wand des capillaren Raumes hervorrft, durch

$$\mu'(m - m')$$

dargestellt ist, wo μ' ein Coefficient ist. Der Werth dises

Coefficienden ist aber von der Richtung des cylindrischen Capillarraumes gegen die Richtung der Schwerkraft abhängig, da die entlang der Wand fliessende Wassermenge doch der Schwere unterworfen ist. Denken wir uns den cylinderischen Capillarraum vertical aufgerichtet, so dass das Wasser aufgesogen wird. Der Adhaesionsdruck, der das Wasser zum Steigen bringt, wird offenbar kleiner sein müssen, als wenn keine Schwere gewirkt hätte, was der Fall ist, wenn der Capillarraum horizontal liegt. Es muss daher ein grösseres Feuchtigkeitsgefälle dazu nothig, sein um denselben Druck vertical aufwärts zu erzeugen, als bei dem horizontal liegenden Capillarraum.; mithin muss μ' bei der Richtung verticalaufwärts kleiner sein, als béi der Richtung horizontal. Wenn dagegen der cylindrische Capillarraum vertical abwärtsgerichtet ist, also dass das Wasser herabfliesst, so wirkt die Schwere in demselben Sinne, wie die Adhaesionskraft und um denselben Druck zu erzeugen, gehört offenbar ein kleineres Feuchtigkeitsgefälle, als in dem horizontal liegenden Capillarraum; mithin muss μ' in der Reichtung verticaltabwärts grösser sein, als in der horizontalen Richtung.

Man kann sich sonach den Adhaesionsdruck in einen gegen die Richtung der Schwere (g) um den Winkel ($g\sigma$) geneigten Capillarraum, in der Form

$$\left(\mu' + \mu'' \cos (g\sigma)\right)(m - m')$$

dargestellt denken, oder, indem man sich m als eine Function von σ denkt,

$$\left(\mu' + \mu'' \cos (g\sigma)\right)\frac{\vartheta m}{\vartheta \sigma}$$

Zu diesem Adhaesionsdruck kommt noch die Wirkung der Schwerkraft auf Wassertheilchen hinzu, welche nicht an den Wänden der cylinderischen Capillarräume adhaeriren und auch nicht unter dem Einfluss der Adhaesionskraft fliesst, sondern

unter dem Einfluss der Schwerkraft vertical abwärts durch die Capillarräume sickert; d. h. der hydrostatische Drück

$$-\delta V \cos(\sigma g)$$

wo V das Potential der Schwerkraft, und δ die Dichte des Wassers bedeutet. Nennt man den resultirenden Druck auf ein fliessendes Wassertheilchen p, so ist,

$$p = -\left(\mu' + \mu'' \cos(go)\right)\frac{\vartheta m}{\vartheta \sigma} - \delta V \cos(\sigma g) \qquad \text{(I)}$$

Es seien $u, v, w,$ die Componenten der Geschwindigkeit des Wassers, h die Cohaesionsconstente der Wassers, i die Adhaesionsconstante desselben. Wenn wir uns die Geschwindigkeit der Wassers unendlich klein, und das Wasser als incompressibel denken, so haben wir

$$\begin{aligned}
&\frac{\vartheta u}{\vartheta t} + \frac{1}{\delta}\frac{\vartheta p}{\vartheta x} - \frac{h}{\delta}\left(\frac{\vartheta^2 u}{\vartheta x^2} + \frac{\vartheta^2 u}{\vartheta \varphi^2} + \frac{\vartheta^2 u}{\vartheta z^2}\right) = 0\\
&\frac{\vartheta v}{\vartheta t} + \frac{1}{\delta}\frac{\vartheta p}{\vartheta y} - \frac{h}{\delta}\left(\frac{\vartheta^2 v}{\vartheta x^2} + \frac{\vartheta^2 v}{\vartheta y^2} + \frac{\vartheta^2 v}{\vartheta z^2}\right) = 0 \qquad \text{(II)}\\
&\frac{\vartheta w}{\vartheta t} + \frac{a}{\delta}\frac{\vartheta p}{\vartheta z} - \frac{h}{\delta}\left(\frac{\vartheta^2 w}{\vartheta x^2} + \frac{\vartheta^2 w}{\vartheta y^2} + \frac{\vartheta^2 w}{\vartheta z^2}\right) = 0\\
&\frac{\vartheta w}{\vartheta z} + \frac{\vartheta w}{\vartheta y} + \frac{\vartheta w}{\vartheta x} = 0
\end{aligned}$$

Die Bedingungen, die an der festen unbewegten Grenze zu erfüllen sind, sind.

$$\begin{aligned}
&\frac{\vartheta u}{\vartheta x}\cos(nx) + \left(\frac{\vartheta v}{\vartheta x} + \frac{\vartheta u}{\vartheta y}\right)\cos(ny) + \left(\frac{\vartheta w}{\vartheta x} + \frac{\vartheta u}{\vartheta z}\right)\cos(nz) = \frac{i}{h}u\\
&\left(\frac{\vartheta u}{\vartheta y} + \frac{\vartheta v}{\vartheta x}\right)\cos(nx) + \frac{dv}{dy}\cos(ny) + \left(\frac{\vartheta w}{\vartheta y} + \frac{\vartheta v}{\vartheta z}\right)\cos(nz) = \frac{i}{h}v \qquad \text{(III)}\\
&\left(\frac{\vartheta w}{\vartheta x} + \frac{\vartheta u}{\vartheta z}\right)\cos(nx) + \left(\frac{\vartheta v}{\vartheta z} + \frac{\vartheta w}{\vartheta y}\right)\cos(ny) + \frac{\vartheta w}{\vartheta z}\cos(nz) = \frac{i}{h}w.
\end{aligned}$$

wo n die nach Innen gezogene Normale an der festen Grenzfläche bedeutet.

Indem wir diese Gleichungen für reibende Flüssigkeit auf die Wasserbewegung in dem unendlich kleinen cylindrischen Capillarraum anwenden, denken wir uns die positive z Achse in die Axenrichtung dieses unendlich kurzen Cylinders gelegt, und nehmen an, dass die Componenten der Geschwindigkeit senkrecht zur Cylinderaxe verschwindend klein seien, so dass

$$u = v = 0.$$

gesetzt werden könne. Hierdurch erhält man aus (II)

$$\frac{\vartheta p}{\vartheta x} = \frac{\vartheta p}{\vartheta y} = 0 \qquad \frac{\vartheta w}{\vartheta z} = \frac{\vartheta w}{\vartheta \sigma} = 0$$
$$\frac{\vartheta w}{\vartheta t} + \frac{1}{\delta}\frac{\vartheta p}{\vartheta \sigma} - \frac{h}{\delta}\left(\frac{\vartheta^2 w}{\vartheta x^2} + \frac{\vartheta^2 w}{\vartheta y^2}\right) = 0 \tag{IV}$$

Die Grenzbedingungen (III) reduciren sich unter diesen Umständen auf die eine

$$\frac{\vartheta w}{\vartheta n} = \frac{i}{h} w \tag{V}$$

Multiplicirt man die zweite Gleichung in (IV) mit $d\omega$ dem Querschnittelement des Capillarraums, und integrirt über den ganzen Querschnitt (Ω), so erhält man, da p vermöge der ersten Gleichung in (IV) eine Function von σ und t allein ist

$$\frac{\vartheta \int w\, d\omega}{\vartheta t} - \frac{h}{\delta}\int\left(\frac{\vartheta^2 w}{\vartheta x^2} + \frac{\vartheta^2 w}{\vartheta y^2}\right) d\omega = -\frac{\Omega}{\delta}\frac{\vartheta p}{\vartheta \sigma}. \tag{VI}$$

das Integral $\int w d\omega$ bedeutet nichts anderes, als die Wassermenge, welche in der Zeiteinheit durch den Querschnitt Ω fliesst. Es ist daher

$$\int w d\omega = m.$$

Diese Grösse ist augenscheinlich unabhängig von σ vermöge der Bedingung $\frac{\vartheta w}{\vartheta \sigma} = 0$. Denken wir uns indessen den unendlich kleinen cylindrischen Raum, für den m gilt, und in dem m

von σ unabhängig ist, im Abstand $\Delta\sigma$ durch einen anderes gestalteten gleichfalls unendlich kleinen cylindrischen Raum fortgesetzt, in dem m einen anderen Werth m' hat, so können wir dem Ausdruck

$$lim\ \frac{m-m'}{\Delta\sigma}=\frac{\vartheta m}{\vartheta\sigma}$$

einen endlichen angebbaren Werlh beilegen, wenn gleich in den beiden eylindrischen Räumen $\frac{\vartheta w}{\vartheta\sigma}=0$ erfüllt ist, indem wir uns $m-m'$ als unendlich kleine Grösse von derselben Ordnung vorstellen, wie $\Delta\sigma$.

Nennt man ein Umfangselement des Querschnittes du, und die Normale an der Umfangscurve n, so kann man das zweite Integral in (VI) auch so schreiben

$$\frac{h}{\delta}\int\left(\frac{\vartheta^2 w}{\vartheta x^2}+\frac{\vartheta^2 w}{\vartheta y^2}\right)d\omega=-\frac{h}{\delta}\int\frac{\vartheta w}{\vartheta n}du.$$

oder mit Rücksicht auf die Grenzbedingung (V)

$$\frac{h}{\delta}\int\left(\frac{\vartheta^2 w}{\vartheta x^3}+\frac{\vartheta^2 w}{\vartheta y^2}\right)d\omega=-\frac{i}{\delta}\int wdu.$$

Es ist dieses einer Wassermenge proportional, die theils an der Wand des Capillarraums haften bleibt, theils in Folge der Reibung zurückbleibt. Indem wir die Reibung eines Wassertheilchens an der Wand der Capillarraums proportional seiner Geschwindigkeit annehmen, und die Wassermenge, welche in der Zeit Eins durch den Capillerraum fliesst, und in der Fläche Eins, und in der Zeit Eins in der Wand zum Haften kommt ε nennen, so können wir wohl setzen

$$\frac{i}{d}\int wdu=\varepsilon+\varkappa^2\int wd\omega=\varepsilon+\varkappa^2 m.$$

Von dieser Grösse ε wollen wir annehmen, dass sie in jedem Capillarraum constant sei, womit angenommen ist, das es eine verschwindend kleine Zeit dazu nöthig sei, um die Poren

jedes Bodentheilchens mit Wasser zu sättigen. Da die Poren in einem Bodentheilchen offenbar mit seiner Zertheilung abnehmen, so werden wir uns ε als eine Grösse denken, welche mit der Verringerung des Querschnittes des in Rede stehenden cylindrischen Raumes abnimmt.

Die Gleichuug (VI) nimmt dann die Form an

$$\frac{\vartheta m}{\vartheta t}+\varepsilon+\varkappa^2 m=-\frac{1}{\delta}\frac{\vartheta p}{\vartheta \sigma}\Omega.$$

Nun denken wir uns eine Ebene von *Flächeneinheit* durch das Medium gelegt, welche eine unendlich grosse Anzahl der cylindrischen Capillarräume durchsetzt. Es sei C die Wassermenge, die durch diese Flächeneinheit in der Zeiteinheit fliesst, so können wir setzen

$$m=\frac{\Omega}{\Sigma\Omega}C.$$

wo die Summation über alle Querschnitte der Capillarräume auszudehnen ist, welche in diese Flächeneinheit fallen. Wir erhalten dann für einen Capillarraum, dessen Querschintt Ω ist

$$\frac{\Omega}{\Sigma\Omega}\cdot\frac{\vartheta C}{\vartheta t}+\varepsilon+\frac{\varkappa^2\Omega}{\Sigma\Omega}C.=-\frac{1}{\delta}\frac{\vartheta p}{\vartheta \sigma}\Omega.$$

Wenn wir uns Gleichungen, wie diese für jeden Capillarraum, der von der Ebene von der Fläche Eins geschnitten wird, aufgestellt denken, und zusammenaddiren, so kommt

$$\frac{\vartheta C}{\vartheta t}+E+\varkappa^2 C=-\frac{1}{\delta}\Sigma\frac{\vartheta p}{\vartheta \sigma}\Omega. \qquad \text{(VII)}$$

wo $$\Sigma\varepsilon=E.$$

gesetzt ist.

Bisher war die Axenlege der Coordinaten ganz wüllkürlich geblieben. Wenn wir uns nun bei übrigens willkürlichem Anfang die positive Z-Axe vertical abwärts gerichtet denken, so hat man

$$\operatorname{Cos}(g\sigma)=\frac{dz}{d\sigma} \qquad V=\delta g z$$

und

$$p = -\left(\mu' + \mu'' \frac{\vartheta z}{\vartheta \sigma}\right) \frac{\Omega}{\Sigma \Omega} \frac{dC}{d\sigma} - \delta g z.$$

ist, oder

$$p = -\frac{\Omega}{\Sigma \Omega}\left(\mu' + \mu'' \frac{dz}{d\sigma}\right)\left(\frac{\vartheta C}{\vartheta x}\frac{dx}{d\sigma} + \frac{\vartheta C}{\vartheta y}\frac{dy}{d\sigma} + \frac{\vartheta C}{\vartheta z}\frac{dz}{d\sigma}\right) - \delta g z.$$

Die Cosinusse $\frac{dx}{d\sigma}, \frac{dy}{d\sigma}, \frac{dz}{d\sigma}$ können für jeden Capillarraum als Constant betrachtet werden, und sind nur durch die Lage des betreffenden Capillarraums gegen die Richtung der Schwerkraft bestimmt. Da die Capillarräume alle nur mögliche Lagen haben können, so haben $\frac{dx}{d\sigma}$, und $\frac{dy}{d\sigma}$ alle nur mögliche Werthe zwischen -1 und $+1$. Etwas anderes verhält sich aber mit $\frac{dz}{d\sigma}$. Wenn der betreffende Capillarraum sich über der Stelle des Mediums befindet, wo die Wasserzufuhr stattfindet, wenn also das Wasser aufgesogen wird, so kann $\frac{dz}{d\sigma}$ alle nur mögliche Werthe zwischen 0 und -1 haben. Befindet sich hingegen der Capillarraum unter der Stelle der Wasserzufuhr, sickert also das Wasser durch, so kann $\frac{dz}{d\sigma}$ alle nur mögliche Werthe zwischen $+1$ und 0 haben.

Es ist

$$\frac{\vartheta p}{\vartheta \sigma} = -\delta g \frac{dz}{d\sigma} - \left(\mu' + \mu'' \frac{dz}{d\sigma}\right) \frac{\Omega}{\Sigma \Omega} \left[\frac{\vartheta^2 C}{\vartheta x^2}\left(\frac{dx}{d\sigma}\right)^2 + \frac{\vartheta^2 C}{\vartheta y^2}\left(\frac{dy}{d\sigma}\right)^2 + \frac{\vartheta^2 C}{\vartheta z^2}\left(\frac{dz}{d\sigma}\right)^2\right.$$
$$\left. + 2\frac{\vartheta^2 C}{\vartheta x \vartheta y}\frac{dx}{d\sigma}\frac{dy}{d\sigma} + 2\frac{\vartheta^2 C}{\vartheta y \vartheta z}\frac{dy}{d\sigma}\frac{dz}{d\sigma} + 2\frac{\vartheta^2 C}{\vartheta z \vartheta x}\frac{dz}{d\sigma}\frac{dx}{d\sigma}\right]$$

Bildet man den Ausdruck $\frac{1}{\delta} \Sigma \Omega \frac{\vartheta p}{\vartheta \sigma}$, so kommt

$$\frac{1}{\delta} \Sigma \Omega \frac{\vartheta p}{\vartheta \sigma} = -g \Sigma \Omega \frac{\vartheta z}{\vartheta \sigma} - \frac{\vartheta^2 C}{\vartheta x^2} \Sigma \frac{\mu'}{\delta} \frac{\Omega^2}{\Sigma \Omega}\left(\frac{dx}{d\sigma}\right)^2 - \frac{\vartheta^2 C}{\vartheta y^2} \Sigma \frac{\mu'}{\delta} \frac{\Omega^2}{\Sigma \Omega}\left(\frac{dy}{d\sigma}\right)^2$$

$$-\frac{\partial^2 C}{\partial z^2}\Sigma\frac{\mu'}{\delta}\frac{\Omega^2}{\Sigma\Omega}\left(\frac{dz}{d\sigma}\right)^2-\frac{\partial^2 C}{\partial x^2}\Sigma\frac{\mu''}{\delta}\frac{\Omega^2}{\Sigma\Omega}\left(\frac{dz}{d\sigma}\right)\left(\frac{dx}{d\sigma}\right)^2-\frac{\partial^2 C}{\partial y^2}\Sigma\frac{\mu''}{\delta}\frac{\Omega^2}{\Sigma\Omega}\left(\frac{dz}{d\sigma}\right)\left(\frac{dy}{d\sigma}\right)^2$$

$$-\frac{\partial^2 C}{\partial z^2}\Sigma\frac{\mu''}{\delta}\frac{\Omega^2}{\Sigma\Omega}\left(\frac{dz}{d\sigma}\right)^3-2\frac{\partial^2 C}{\partial x\partial y}\Sigma\frac{\mu'}{\delta}\frac{\Omega^2}{\Sigma\Omega}\frac{dy}{d\sigma}\frac{dx}{d\sigma}-2\frac{\partial^2 C}{\partial y\partial z}\Sigma\frac{\mu'}{\delta}\frac{\Omega^2}{\Sigma\Omega}\frac{dy}{d\sigma}\frac{dz}{d\sigma}$$

$$-2\frac{\partial^2 C}{\partial z\partial x}\Sigma\frac{\mu'}{\delta}\frac{\Omega^2}{\Sigma\Omega}\frac{dz}{d\sigma}\frac{dx}{d\sigma}-2\frac{\partial^2 C}{\partial x\partial y}\Sigma\frac{\mu''}{\delta}\frac{\Omega^2}{\Sigma\Omega}\frac{dx}{d\sigma}\frac{dy}{d\sigma}\frac{dz}{d\sigma}$$

$$-2\frac{\partial^2 C}{\partial y\partial z}\Sigma\frac{\mu''}{\delta}\frac{\Omega^2}{\Sigma\Omega}\frac{\partial y^2}{d\sigma}\left(\frac{dz}{d\sigma}\right)^2-2\frac{\partial^2 C}{\partial z\partial x}\Sigma\frac{\mu''}{\delta}\frac{\Omega^2}{\Sigma\Omega}\frac{dx}{d\sigma}\left(\frac{dz}{d\sigma}\right)^2$$

Da nun $\frac{dx}{d\sigma}, \frac{dy}{d\sigma}$ innerhalb des Bereiches der Summation alle nur mögliche Werthe zwischen -1 und $+1$, und $\frac{dz}{d\sigma}$ alle nur mögliche Werthe entweder zwirchen $+1$ und 0, oder zwischen 0 und -1 haben sollen,so können wir uns die Coefficenten der Differentialquotienten $\frac{\partial^2 C}{\partial x\partial y}, \frac{\partial^2 C}{\partial y\partial z}, \frac{\partial^2 C}{\partial z\partial x}$ als verschwindend klein denken und da eine Symmetrie der Wasserbewegung um die Z.Axe angenommen werden kann, können wir setzen

$$\Sigma\frac{\mu'}{\delta}\frac{\Omega^2}{\Sigma\Omega}\left(\frac{dx}{d\sigma}\right)^2=\Sigma\frac{\mu'}{\delta}\frac{\Omega^2}{\Sigma\Omega}\left(\frac{dy}{d\sigma}\right)^2=\Sigma\frac{\mu'}{\delta}\frac{\Omega^2}{\Sigma\Omega}\left(\frac{dz}{d\sigma}\right)^2=a^2$$

$$\Sigma\frac{\mu''}{\delta}\frac{\Omega^2}{\Sigma\Omega}\left(\frac{dz}{d\sigma}\right)\left(\frac{dx}{d\sigma}\right)^2=\Sigma\frac{\mu''}{\delta}\frac{\Omega^2}{\Sigma\Omega}\left(\frac{dz}{d\sigma}\right)\left(\frac{dy}{d\sigma}\right)^2=\Sigma\frac{\mu''}{\delta}\frac{\Omega^2}{\Sigma\Omega}\left(\frac{dz}{d\sigma}\right)^3=\pm b^2$$

wo das positive Vorzeichen beim Durchsickern, und das negative beim Aufsaugen zu nehmen ist. Wir erhalten indem wir setzen

$$\Sigma\Omega\frac{dz}{d\sigma}=\mu$$

und diese Grösse als eine Constante betrachten und zur Abkürnung setzen

$$a^2\pm b^2=\alpha^2$$

$$\frac{1}{\delta}\Sigma\Omega\frac{\partial p}{\partial\sigma}=-\alpha^2\left(\frac{\partial^2 C}{\partial x^2}+\frac{\partial^2 C}{\partial y^2}+\frac{\partial^2 C}{\partial z^2}\right)-g\mu.$$

Die Einführung dieses Ausdrucks in (VII) ergiebt

$$\frac{\partial C}{\partial t}=a^2\left(\frac{\partial^2 C}{\partial x^2}+\frac{\partial^2 C}{\partial y^2}+\frac{\partial^2 C}{\partial z^2}\right)+g\mu-E-\varkappa^2 C. \qquad (\mathrm{VII}_a)$$

als Differentialgleichung für die Menge des fliessenden Wassers im Punkt xyz des Mediums zur Zeit t, wobei für die verticalaufwärts oder horizontal gerichtete Wasserbewegung $\mu=0$ zu setzen ist. Man kann diese Gleichung auf eine lineare homogene Differentialgleichung zweiter Ordnung zurückführen. Man setze

$$C=Z+e^{-\varkappa^2 t}\varphi$$

wo Z eine Funktion von $x\,y\,z$ allein, und φ eine Funktion von $x\,y\,z$ und t ist. Es kommt

$$-\varkappa^2 e^{-\varkappa^2 t}\varphi+e^{-\varkappa^2 t}\frac{\partial\varphi}{\partial t}=a^2\left(\frac{\partial^2 Z}{\partial x^2}+\frac{\partial^2 Z}{\partial y^2}+\frac{\partial^2 Z}{\partial z}\right)+g\mu-E-\varkappa^2 Z$$

$$+a^2 e^{-\varkappa^2 t}\left(\frac{\partial^2\varphi}{\partial x^2}+\frac{\partial^2\varphi}{\partial y^2}+\frac{\partial^2\varphi}{\partial z^2}\right)-\varkappa^2 e^{-\varkappa^2 t}\varphi$$

was erfüllt wird, indem wir setzen

$$\frac{\partial\varphi}{\partial t}=a^2\left(\frac{\partial^2\varphi}{\partial x^2}+\frac{\partial^2\varphi}{\partial y^2}+\frac{\partial^2\varphi}{\partial z^2}\right) \qquad (\mathrm{VIII})$$

$$a^2\left(\frac{\partial^2 Z}{\partial x^2}+\frac{\partial^2 Z}{\partial y^2}+\frac{\partial^2 Z}{\partial z^2}\right)+g\mu-E-\varkappa^2 Z=0.$$

Die Gleichung für φ ist genau diesslbe, welche bei der Theorie der Wärmeverbreitung im festen isotropen Körper vorkommt. Die Gleichung für Z lässt sich allgemein integriren. Man setze zur Abkürzung

$$\frac{g\mu-E}{a^2}=\gamma \qquad \frac{\varkappa^2}{a^2}=K^2 \qquad Z=W+\frac{\gamma}{\varkappa^2}$$

so dass die zu integrirende Gleichung

$$\frac{\partial^2 W}{\partial x^2}+\frac{\partial^2 W}{\partial y^2}+\frac{\partial^2 W}{\partial z^2}-K^2 W=0 \qquad (\mathrm{VIII}_a)$$

ist.

Ein particuläres Integral ist

$$\frac{Ae^{Kr}+Be^{-Kr}}{r}$$

wo $r=\sqrt{(x-\xi)^2+(y-\eta)^2+(z-\zeta)^2}$, A und B willkürliche Constanten sind. Stellt man sich A und B als willkürliche Functionen der Coordinaten $\xi\,\eta\,\zeta$ vor und nennt ein Raumelement $d\tau$, das durch $\xi\,\eta\,\zeta$ bestimmt ist, so ist

$$W=\int\frac{Ae^{Kr}+Be^{-Kr}}{r}d\tau$$

ausgedehnt üben einen beliebigen Raum, das allgemeine Integral der Gleichung (VIII$_a$). Mithin hat man

$$C=\frac{\gamma}{\chi^2}+\int\frac{Ae^{Kr}+Be^{-Kr}}{r}d\tau+e^{-\chi^2 t}\varphi.$$

Es handelt sich nun darum φ so zu bestimmen dass sie der Gleichung (VIII) genügt, und gewisse gegebene Bedingungen befriedigt.

Wir denken uns; die Wasserzufuhr finde in einer gewissen gegebenen Fläche F statt, und soll auch gegeben sein, als eine Function der Zeit t. In Bezug auf den Werth der Constante a können wir drei Gebiete in dem Medium unterscheiden, ein Gebiet der Durchsickerung, ein Gebiet der Aufsaugung, und ein Gebiet der horizontalen Leitung. Denken wir uns nun, eine cylindrische Fläche (S) in der Richtung der Schwerkraft so gelegt, dass sie die Fläche F in einer Linie berührt, ohne sie durchzuschneiden, so theilt die Fläche S das Medium in drei Gebiete A, B, und C. Die Wassermenge, die durch A verticalaufwarts fliesst, kann nur aufgesogen sein, und diejenige, welche durch C herabfliesst, nur durchgerickert sein, während die Wassermenge, die durch B fliesst, sich nur horizantal verbreitet haben kann. Man hat daher für das Gebiet A

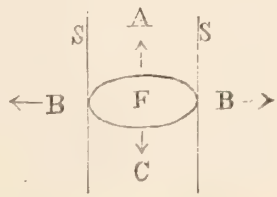
$$\alpha^2=a^2-b^2 \qquad \mu=0$$

für das Gebiet C

$$\alpha^2=a^2+b^2 \qquad \mu>0$$

und schliesslich für das Gebiet B

$$\alpha^2=a^2 \qquad \mu=0$$



zu setzen, und die Function C so zu bestimmen, dass sie entlang der Fläche (S) continuirlich in einander übergeht da die Wasselbewegung durchaus continuirlich von sich gehen muss.

Es sei C_0 der gegebene Werth von C auf der Fläche der Wasserzufuhr, so muss C in jedem Gebiet so bestimmt werden, dass an der Fläche F für jeden Werth t

$$C = C_0$$

wird. Ist das Medium zur Zeit $t=0$ überall trocken, so muss C ferner der Bedingung genügen.

$$C = 0 \qquad \text{für} \quad t = 0$$

Wenn das Medium hingegen zur Zeit $t=0$ mit Wasser gesättigt war, und an der Fläche F fortwährend trocken gehalten wird, so muss C den Bedingungen genügen

$$C = C_0 \qquad \text{für} \quad t = 0$$

$$C = 0 \qquad \text{für jeden Punkt der Fläche } F$$

wo C_0 die Wassermenge bedeutet, welche bei der völligen Sättigung durch das Medium fliesst. In diesem Fall wird das Wasser in dem Gebiete C aufgesogen, und sickert im Gebiete A herab. Man hat daher in diesem Eall für das Gebiet A $\alpha^2 = a^2 + b^2$, und für das Gebiet C $\alpha^2 = a^2 - b^2$ zu setzen.

Hat das Medium eine Fläche, die frei an der Luft grenzt, und findet dort Verdampfung des Wassers statt, so hat C entlang dieser freien Fläche einer gewissen Bedingung zu genügen, deren Ableitung jedoch schwierig ist, da wir um die Verdampfungsvorgänge an der Grenzschichte eines Mediums, wie Boden, eigentlich so gut, wie nichts wissen.

Es wird indessen nicht ganz werthlos sein, zu versuchen, diese Grenzbedingung abzuleiten, und zwar unter gewissen Annahmen über die Verdampfungsvorgänge an der Grenzschichte eines Medium wie der Boden; Annahmen, welche sich wohl nicht allzu sehr von der Wirklichkeit entfernen dürften. Wir nehmen an, dass der Adhaesionsdruck in jedem unmittelbar an der Luft grenzenden Querschnitt der capilaren Hohlräume verschwindend klein sei, so dass dort

$$\frac{m}{\sigma}=0 \qquad \text{also } \frac{\vartheta C}{\vartheta \sigma}=0$$

indem das heraustretende Wasser sich in eine gewisse durch den Dampfgehalt der Luft, und die Temperatur der Grenzschichte bedingte Dampfmenge verwandelt. Von dieser Dampfmenge wollen wir ferner annehmen, dass sie der heraustretenden Wassermenge proportional sei, und eine dünne Schichte gesättigten Dampfes unmittelbar auf der Grenzschichte bilde, also dass man als die von der Flächeneinheit in der Zeiteinheit verdampfte Wassermenge gesetzt werden könne

$$-\eta(F-f)\,C.$$

wo F die Menge des gesättigten Dampfes bei der Vemperatur des Grenzschichte, f die Menge des Dampfes in der Luft und η eine Constante ist. Die verdampfte Wassermenge verschwindet so wohl für $C=0$, als $(F-f)=0$, und wächst mit C und mit $(F-f)$. *d. h.* entweder mit der Trockenheit der Luft, oder mit der Temperatur der Grenzfläche. Der Ausdruck führt demnach zu keinerlei Widersinnigkeit,so dass wir wohl berechtigt sind, zu behaupten, dass er, wenn auch in erster Annährung der Wirklichkeit entspreche.

Es sei $d\omega$ ein Element der natürlich von allen durch Korngrösse des Bodentheilchens bedingten kleinen Vertiefungen und Erhebungen abstrahirten Grenzfläche des Mediums, und n die Normale an derselben. Wir denken uns eine unendlich kleine Strecke auf dieser Normale abgetragen, und eine zweite Fläche von der Grenzfläche um dn entfernt, so dass das Volumelement dieses unendlich dünnen Raumes

$$d\tau=d\omega\, dn.$$

Wir bilden

$$\int\frac{\vartheta C}{\vartheta t}d\tau=a^2\int\left(\frac{\vartheta^2 C}{\vartheta x^2}+\frac{\vartheta^2 C}{\vartheta y^2}+\frac{\vartheta^2 C}{\vartheta z^2}\right)d\tau+\int(\rho g-E)d\tau-\varkappa^2\int C d\tau.$$

und denken uns die Integration über den eben erwähnlen unendich dünnen Raum ausgedehnt. Nun ist

$$\int \frac{\vartheta C}{\vartheta t} d\tau$$

Veränderung der Wassermenge in dem unendlich dünnen Raum, indem eine gewisse Wassermenge in der Zeiteinheit aus der einen Grenzfläche heraustritt und verdampft. Man darf daher wohl setzen

$$\int \frac{\vartheta C}{\vartheta t} d\tau = -\int \eta (F-f) C.\ d\omega.$$

Bei der Bildung des ersten Integrals rechter Hand bezeichnen wir mit n_0 die Normale an der Fläche, wo die Luft unmittelbar grenzt, und mit n diejenige an der um dn entfernten Fläche, und denken uns so wohl n_0 als n nach Innen der unendlich dünnen Raumes gezogen, so haben wir

$$\alpha^2 \int \left(\frac{\vartheta^2 C}{\vartheta x^2} + \frac{\vartheta^2 C}{\vartheta y^2} + \frac{\vartheta^2 C}{\vartheta z^2} \right) d\tau = +\alpha^2 \int \frac{\vartheta C}{\vartheta n} d\omega - \alpha^2 \int \frac{\vartheta C}{\vartheta n_0} dw.$$

indem das Flächenintegral über die duch dn gebildeten übrisens beliebig gestalteten Begrenzung mit verschwindendem dn verschwindet. Da aber der Adhaesionsdruck an der freien Fläche verschwinden soll, und daher

$$\frac{\vartheta C}{\vartheta n_0} = 0.$$

sein muss, so folgt

$$\alpha^2 \int \left(\frac{\vartheta^2 C}{\vartheta x^2} + \frac{\vartheta^2 C}{\vartheta y^2} + \frac{\vartheta^2 C}{\vartheta z^2} \right) d\tau = +\alpha^2 \int \frac{\vartheta C}{\vartheta n} dw.$$

Mithim erhalten wir

$$-\int d\omega \left(\eta (F-f) C + \alpha^2 \frac{\vartheta C}{\vartheta n} \right) = \int d\tau (\mu g - E) - \varkappa^2 \int d\tau.\ C.$$

Die Grössen $(\mu g - E)$ und $\varkappa^2 C$ sind endlich, die beiden Integrale rechter Hand werden darum verschwindend klein, mit verschwindenden dn. Mithin muss

$$\eta (F-f) C + \alpha^2 \frac{\vartheta C}{\vartheta n} = 0. \qquad \text{(VIII)}$$

sein. Diese Bedingung, der C an der freien Fläche des Mediums zu genügen hat, ist also linear in Bezug auf C und hat dieselbe Form, wie die Bedingung, welcher die Wärme bei ihrer Verbreitung an der Grenzfläche eines festen isotropen Körpers im diathermanen Medium zu genügen hat.

Wir wollen jetzt C für einige einfache Fälle aufsuchen, indem wir uns die Eläche der Wasserzufuhr als eine unendliche Ebene denken. Nehmen wir diese zu der (xy) Ebene, so sickert das Wasser im Gebiete $+z$ herab, und in dem Gebiete $-z$ wird es aufgesagen. Nehmen wir die (xz) Ebene zu der Fläche der Wasserzufuhr, so wird das Wasser rein horizontal fortgeleitet. In diesen drei Fällen wird C nur von einer Coordinate abhängig sein. Wir haben demnach im Fall der Durchsickerung

$$\frac{\vartheta C}{\vartheta t}=a^2\frac{\vartheta^2 C}{\vartheta z^2}+\gamma-\varkappa^2 C \qquad \begin{matrix} a^2=a^2+b^2 \\ \gamma=\mu g-E \end{matrix} \qquad \text{(IX)}$$

im Fall der Aufsaugung

$$\frac{\vartheta C}{\vartheta t}=a^2\frac{\vartheta^2 C}{\vartheta z^2}-\gamma-\varkappa^2 C \qquad \begin{matrix} a^2=a^2-b^2 \\ \gamma=E \end{matrix}$$

und endlich im Fall der horizontalen Leitung

$$\frac{\vartheta C}{\vartheta t}=a^2\frac{\vartheta^2 C}{\vartheta z^2}-\gamma-\varkappa^2 C \qquad \begin{matrix} a^2=a^2 \\ \gamma=E \end{matrix}$$

Wir fassen zunächst den Fall in's Auge, wo $\varkappa^2$ verschwindend klein ist. Man hat dann

$$\frac{\vartheta C}{\vartheta t}=a^2\frac{\vartheta^2 C}{\vartheta z^2}+\gamma$$

zu integriren. Man setze behufs dieses

$$C=\varphi-\frac{\gamma z^2}{2a^2}+Az+B$$

wo A und B zwei Constanten sind. Dann erhält man für φ die Gleichung

$$\frac{\partial c}{\partial t} = a^2 \frac{\partial^2 c}{\partial z^2}$$

Eine Lösung dieser Gleichung ist

$$e^{-a^2 v^2 t} \sin vt.$$

wo v ganz willkürlich bleibt.

Die Function

$$\frac{2}{\pi} \int_0^\infty \sin zu du \int_0^\infty f(v) e^{-a^2 v^2 t} \sin vu dv$$

genügt auch der Differentialgleichung, und hat die Eigenschaft für $z=0$ zu verschwinden, und für $t=0$

$$=f(z)$$

zu werden.

Es soll C so bestimmt werden, dass

$$C=0 \qquad \text{für} \quad t=0$$
$$C=C_0 \qquad \text{für} \quad z=0$$

d. h. der Boden soll zur Zeit $t=0$ trocken und in der Ebene $z=0$ constant gesättigt gehalten sein. Diesen Bedingungen genügt man, indem man setzt

$$C=C_0\left(1-\frac{2}{\pi}\int_0^\infty \sin zu du \int_0^\infty e^{-a^2 v^2 t} \sin vu dv\right)$$

$$-\frac{\gamma z^2}{2a^2}+\frac{2\gamma}{2a^2\pi}\int_0^\infty \sin zu du \int_0^\infty v^2 e^{-a^2 v^2 t} \sin vu dv$$

$$+Az-\frac{2A}{\pi}\int_0^\infty \sin zu du \int_0^\infty v e^{-a^2 v^2 t} \sin vu dv$$

Die hier autretenden Doppelintegrale lassen sich auf das Kramp sche Innegral zurückführen. Thut man das, so erhält man

$$C=C_0\left(1-\frac{2}{\sqrt{\pi}}\int_0^{\frac{z}{2a\sqrt{t}}} e^{-\lambda^2}d\lambda\right)-\frac{\gamma z^2}{2a^2}+\frac{\gamma}{4a^3\sqrt{t}}\int_0^{\infty}\lambda^2 d\lambda\left(e^{-\frac{(z-\lambda)^2}{4a^2t}}-e^{-\frac{(z+\lambda)^2}{4a^2t}}\right)$$

$$+Az-\frac{Az}{2a\sqrt{\pi}\sqrt{t}}\int_0^{\infty}\lambda\, d\lambda\left(e^{-\frac{(z-\lambda)^2}{4a^2t}}-e^{-\frac{(z+\lambda)^2}{4a^2t}}\right)$$

oder indem man das zweite und dritte Glied partiell integrirt,

$$C=C_0\left(1-\frac{2}{\sqrt{\pi}}\int^{\frac{z}{2a\sqrt{t}}} e^{-\lambda^2}d\lambda\right)-\frac{\gamma z}{2a}+\frac{\gamma}{2a\sqrt{\pi}}\left((z^2+2at)\int_0^{+\frac{z}{2a\sqrt{t}}} e^{-\lambda^2}d\lambda\right.$$

$$\left.+2a\sqrt{t}\,.\,z\,.\,e^{-\frac{z^2}{4a^2t}}\right)-Az+\frac{Az}{\sqrt{\pi}}\left(\int_{-\frac{z}{2a\sqrt{t}}}^{\infty} e^{-\lambda^2}d\lambda+\int_{\frac{z}{2a\sqrt{t}}}^{\infty} e^{-\lambda^2}d\lambda\right)$$

Nun ist

$$\int_{-\frac{z}{2a\sqrt{t}}}^{\infty} e^{-\lambda^2}d\lambda+\int_{\frac{z}{2a\sqrt{t}}}^{\infty} e^{-\lambda^2}d\lambda=-\int_{\frac{z}{2a\sqrt{t}}}^{-\infty} e^{-\lambda^2}d\lambda+\int_{\frac{z}{2a\sqrt{t}}}^{\infty} e^{-\lambda^2}d\lambda=\int_{-\infty}^{\infty} e^{-\lambda^2}d\lambda=\sqrt{\pi}$$

so haben sich die mit A behafteten Glieder auf. Man hat somit

$$C=C_0\left(1-\frac{2}{\sqrt{\pi}}\int_0^{\frac{z}{2a\sqrt{t}}} e^{-\lambda^2}d\lambda\right)-\frac{\gamma z^2}{2\delta^2}+\frac{\gamma}{2a^2\sqrt{\pi}}\left(2(z^2+2a^2t)\int_0^{\frac{z}{2a\sqrt{t}}} e^{-\lambda^2}d\lambda\right.$$

$$\left.+2a\sqrt{t}\,.\,z\,e^{-\frac{z^2}{4a^2t}}\right)$$

Die Discussion dieses etwas complicirten Ausdrucks ist nicht schwer. Wenn nun t endllich, und z sehr gross ist, so dass $\frac{z}{2a\sqrt{t}}$ sehr gross ist, dann hat man

$$C = -\frac{\gamma z^2}{2a^2} + \frac{\gamma}{2a^2\sqrt{\pi}}(z^2 + 2a^2 t)\sqrt{\pi}$$

$$C = +\gamma t.$$

d. h. selbst in der Unendlichkeit müsste das Wasser herabfliessen. Im Fall der Aufsaugung und der horizontalen Leitung ist γ negativ zu setzen; es ist dann

$$C = -\gamma t.$$

das Wasser hat sich also noch gar nicht so weit fortgepflanzt. Die Schichte $C = 0$ muss sich in der endlichen Zeit um Endliches von der Fläche der Wasserzufuhr entfernt haben. Ist hingegen t sehr gross, und z endlich, so folgt, da hier $\frac{z}{2a\sqrt{t}}$ unendlich klein ist

$$C = C_0 - \frac{\gamma z}{2a} + \frac{\gamma}{a\sqrt{\pi}} \cdot z \cdot \sqrt{t}. \qquad \text{(X)}$$

C nimmt mit wachsendem z zu, falls $\frac{\gamma}{a^2} < \frac{\gamma\sqrt{t}}{\sqrt{\pi}}$ ist. Im Fall das Wasser aufgesogen, oder horizontal geleitet wird, nimmt C mit z ab, und kann in einer gewissen Entfernung von der Fläche der Wasserzufuhr verschwinden, welche durch

$$z = \frac{2a\sqrt{t}}{\sqrt{\pi}}$$

definirt ist. Indessen ist $\frac{z}{2a\sqrt{t}} = \frac{1}{\sqrt{\pi}}$ nicht mehr unendlich klein; darum hat die Gleichung (X) keine Giltigkeit mehr für einen solchen Werth von z, wo bei sehr grossem t die Schichte $C = 0$ sich bildet.

Um die Bewegung des Wassers etwas allgemeiner zu verfolgen, wollen wir die Gleichung (X_a) transformiren durch die Einführung einer neuen Variabel, welche durch

$$u = \frac{z}{2a\sqrt{t}}$$

definirt ist. Indem wir zur Abkürzung setzen

$$V=\frac{2}{\sqrt{\pi}}\int_u^\infty e^{-\lambda^2}d\lambda.$$

können wir die Gleichung (X_a) auch so schreiben

$$C=C_0V+2\gamma t\left[\frac{1}{2}+\frac{ue^{-u^2}}{\sqrt{\pi}}-V\left(u^2+\frac{1}{2}\right)\right]$$

die Bewegung der Schichte $C=\text{const}$ ist dann durch zwei Functionen von u bestimmt, und lässt sich unschwer verfolgen. Die Function

$$\Omega=\frac{1}{2}+\frac{ue^{-u^2}}{\sqrt{\pi}}-V\left(u^2+\frac{1}{2}\right)\Big]$$

bleibt für jedes positive u immer positiv und endlich und kann nur für $u=0$ verschwinden, sonst für keinen positiven Werth, und wird $=\frac{1}{2}$ für $u=\infty$. Da aber ue^{-u^2} und $V\left(u^2+\frac{1}{2}\right)$ ein Maximum haben, so wird Ω ungefähr bei $u=1.1$ ein Minimum, und bei $u=1.7$ ein Maximum; da ferner $C-C_0\,V$ mis wachsendem u nur stetig zunimmt, so sieht man ein, dass u von gewissem Werthe von t Werth von t ab. doppelwerthig wird, um dann bei einem gewissen Werth von t wieder einwerthig zu werden. Im Fall der Durchsickerung ist nun

$$2\gamma t=\frac{C-C_0V}{\Omega}$$

Es ist zunächst für $t=0$

$$C=C_0V=\frac{2C_0}{\sqrt{\pi}}\int_u^\infty e^{-\lambda^2}d\lambda.$$

da Ω nie unendlich gross werden kann. Nennt man die Wurzel dierer Gleichung u', welche positive und reell ist, wenn $C<C_0$ ist, so hat man, da t immer positiv sein muss

$$C_0V<C.$$

d. h. für jeden Werth von t muss

$$u > u'$$

u muss daher von diesem Werthe u' aus, welcher um so kleiner ist, je mehr sich $\frac{C_0}{C_0}$ der Einheit nährt, mit wachsender Zeit wachsen. Da aber u bei einem gewissen Werth von t doppelwerthig wird, so bildet sich die Schichte C=const in zwei Stellen entsprechend den beiden Werthen von u. Da diese beiden Schichten beim weiteren Verlauf der Zeit wieder in eine Schichte zusammenfallen, so nimmt die Distanz der beiden Schichten fortwährend ab, indem sie immer tiefer herabsinken, bis nach dem Verlauf der Zeit

$$t = \frac{C}{\gamma}$$

u unendlich gross wird, *d. h.* die Schichte C=const. bewegt sich in diesen endlichen Zeit in's Unendliche, und demgemäss strömte das Wasser mit unendlich grosser Geschwindigkeit niederwärts. Im Fall $\gamma < 0$ ist, *d. h.* wenn das Wasser aufgesogen oder horizontal geleitet wird, hat man, da t positiv sein muss

$$2\gamma t = \frac{C_0 V - C}{\Omega}$$

Es ist für $t = 0$

$$C = VC_0$$

wieder. Nennt man die Wurzel dieser Gleichung u', welche um so grösser ist, je kleiner $\frac{C}{C_0}$ ist, so ergiebt sich, dass beim weiterem Verlauf der Zeit

$$u < u'$$

sein muss. u kann daher nie unendlich gross werden, es nimmt nur von u' aus beständig mit wachsendem t ab, und convergiert gegen Null, da für $u = 0$, $t = \infty$ wird *d. h.* z ist eine endliche Grösse für $t = \infty$; die Verbreitung des Wassers verticalaufwärts oder horzontal hat eine Grenze.

Diese also geschilderten Erschinungen lassen sich nun in der Natur *nicht* finden. Wohl lehrt die Erfahrung, dass u beim Durchsickern unter gewissen Umständen mit der Zeit zunimmt, und beim Aufsaugen abnimmt; sie lehrt aber auch, dass die Geschwindigkeit des durchsickernden Wassers mit der Tiefe schnell abnimmt, dass u bei der horizontalen Leitung unter gewissen Umständen mit der Zeit zunimmt, statt abzunehmen. Es ist dies ein Zeichen dafür, dass die Reibung der Wassertheilchens an den Wänden der capillaren Hahlräume eine maassgebende Rolle spielt, dass $\varkappa^2 C$ nicht als unendlich klein vernachlässigt werden darf.

Wir wollen denn die Differentialgleichung (IX) integriren. Zu dem Ende setzen wir wieder

$$C = Z + e^{-\varkappa^2 t} \varphi$$

und nehmen an, dass Z die Gleichung

$$a^2 \frac{\partial^2 Z}{\partial z^2} + \gamma - \varkappa^2 Z = 0 \qquad (X_b)$$

erfülle und φ die Gleichung.

$$\frac{\partial \varphi}{\partial t} = a^2 \frac{\partial^2 \varphi}{\partial z^2}$$

so wird die Gleichung (IX) erfüllt. Das vollständige Integral der Gleichung (XI) ist

$$Z = C_1 e^{-\frac{\varkappa}{a} z} + C_2 e^{\frac{\varkappa}{a} z} + \frac{\gamma}{\varkappa^2}$$

Mithin haben wir jetzt

$$C = \frac{\gamma}{\varkappa^2} + C_1 e^{-\frac{\varkappa}{a} z} + C_2 e^{\frac{\varkappa}{a} z} + e^{-\varkappa^2 t} \varphi.$$

wo C_1 C_2 zwei willkürliche Constanten sind.

Es soll φ jetzt so bestimmt werden, dass sie die Gleichung befriedigt, und den Bedingungen

$$\begin{aligned} C &= C_0 \quad \text{für} \quad z = 0 \\ C &= 0 \quad \text{für} \quad t = 0 \end{aligned} \qquad (XI)$$

Genüge leistet. Da C in der Unendlichkeit nicht unendlich gross werden darf, und daher $C_2=0$ gesetzt werden muss, so wird allen Bedingungen gegnügt, wenn wir setzen

$$C_1=C_0-\frac{\gamma}{\varkappa^2}$$

und.

$$C=\frac{\gamma}{\varkappa^2}+C_1e^{-\frac{\varkappa}{a}}-\frac{2e^{-\varkappa^2t}}{\pi}\int_0^\infty \sin uz\,du\int_0^\infty\left(\frac{\gamma}{\varkappa^2}+C\,e^{-\frac{\varkappa}{a}v}\right)e^{-a^2v^2t}\sin vu\,dv.$$

oder indem wir das Doppelintegral mittelst der Formel

$$\int_0^\infty e^{-ax^2}\cos bx\,dx=\frac{1}{2}\sqrt{\frac{\pi}{a}}\;e^{-\frac{b^2}{4a^2}}$$

reduciren, und $C_1=C_0-\frac{\gamma}{\varkappa^2}$ setzen

$$C=\frac{\gamma}{\varkappa^2}\left(1-\frac{2e^{-\varkappa^2t}}{\sqrt{\pi}}\int_0^{\frac{z}{2a\sqrt{t}}}e^{-\lambda^2}d\lambda\right)+C_1e^{-\frac{\varkappa}{a}z}$$

$$-\frac{C_1}{2a\sqrt{\pi}\sqrt{t}}\int_0^\infty e^{-\frac{\varkappa}{a}\lambda}\left(e^{-\frac{(z-\lambda)^2}{4a^2t}}-e^{-\frac{(z+\lambda)^2}{4a^2t}}\right)d\lambda$$

Das letzte Integral lässt sich weiter auf die Form

$$2a\sqrt{t}e^{\varkappa^2t}\left(e^{-\frac{x}{a}z}\int_{\varkappa\sqrt{t}-\frac{z}{2a\sqrt{t}}}^{\infty}e^{-\lambda^2}d\lambda-e^{\frac{x}{a}z}\int_{\varkappa\sqrt{t}+\frac{z}{2a\sqrt{t}}}^{\infty}e^{-\lambda^2}d\lambda\right)$$

bringen. Man erhält somit

$$C=\frac{\gamma}{\varkappa^2}\left(1-\frac{2e^{-\varkappa^2t}}{\sqrt{\pi}}\int_0^{\frac{z}{2a\sqrt{t}}}e^{-\lambda^2}d\lambda\right)+C_1e^{-\frac{\varkappa}{a}z}$$

$$-\frac{C_1}{\sqrt{\pi}}\left(e^{-\frac{\varkappa}{a}z}\int_{\varkappa\sqrt{t}-\frac{z}{2a\sqrt{t}}}^{\infty}e^{-\lambda^2}d\lambda-e^{\frac{\varkappa}{a}z}\int_{\varkappa\sqrt{t}+\frac{z}{2a\sqrt{t}}}^{\infty}e^{-\lambda^2}d\lambda\right) \qquad \text{(XII)}$$

Für t=o wird in der That

$$C=C_0 e^{-\frac{\varkappa}{a}z}-Ce_1^{-\frac{\varkappa}{a}z}=0$$

und für $z=0$

$$C=\frac{\gamma}{\varkappa^2}+C_1=\frac{\gamma}{\varkappa^2}+\left(C_0-\frac{\gamma}{\varkappa^2}\right)=C_0$$

Die Discussion des also gefundenen Ausdrucks für C ist keine leichte in Folge der Unmöglichkeit, z und t getrennt darzustellen. Es folgt zunächst für unendliches z und endliches t, da $\frac{z}{2a\sqrt{t}}$ unendlich gross ist,

$$C=\frac{\gamma}{\varkappa^2}\left(1-e^{-\varkappa^2 t}\right)$$

Die Wassermenge in der Unendlichkeit ist anfangs Null. und wächst mit der Zeit asymptotisch zu der constanten und endlichen Menge $\frac{\gamma}{\varkappa^2}$. Im Fall das Wasser aufgesogen oder horizontal geleitet wird, ist

$$C=-\frac{\gamma}{\varkappa^2}\left(1-e^{-\varkappa^2 t}\right)$$

In diesen Fällen kann sich das Wasser nur durch eine endliche Strecke während der endlichen Zeit fortgepflanzt haben. Wird t unendlich gross, so hat man für endlich es z

$$C=\frac{\gamma}{\varkappa^2}+C_0 e^{-\frac{\varkappa}{a}z}$$

Die Wasserbewegung ist dann in der Endlichkeit stationär. und die Wassermenge nimmt von C_0 aus mit zunehmendem z asymptotisch zu $\frac{\gamma}{\varkappa^2}$ ab. Anderes aber, wenn das Wasser aufgesogen oder horizontal geleitet wird. In diesen Fällen ist

$$C=-\frac{\gamma}{\varkappa^2}+\left(C_0+\frac{\gamma}{\varkappa^2}\right)e^{-\frac{\varkappa}{a}z}$$

Es giebt sonach eine Distanz von der Fläche der Wasserzufuhr, wo kein Wasser mehr fliesst. Diese Distanz ist bestimmt durch

$$e^{-\frac{\varkappa}{a}z} = \frac{\frac{\gamma}{\varkappa^2}}{\left(C_0 + \frac{\gamma}{\varkappa^2}\right)} \; d.\,h. \quad z = \frac{a}{\varkappa}\log\left(\frac{C_0 + \frac{E}{\varkappa^2}}{\frac{E}{\varkappa^2}}\right)$$

und ist um so grösser, je kleiner $\frac{E}{x^2}$ ist, *d. h.* wie aus der Bedeutung der Constante E unmittelbar erhellt, je feinkörniger der Boden ist, je weniger derselbe Wasser absorbiert. Diese Stelle des verschlwindenden Wasserflusses ist bei der horizontalen Leitung weiter von der Fläche der Wasserzufuhr enternt, als bei der Aufsaugung.; da a bei dem ersteren Fall grösser ist, als bei dem letzteren Fall.

C ist die Wassermenge, welche in Zeit Eins durch Fläche Eins fliesst. Schreibt man die Gleichung für C so

$$C = C_0 e^{-\frac{\varkappa}{a}z} + \frac{\gamma}{\varkappa^2}\left(1 - e^{-\frac{\varkappa}{a}z}\right)$$

so sièht man, dass das Wasser durch einen Querschnitt $z = \text{const.}$ um so mehr durchsickert. je grösser $\gamma = \eta g - E$ st. *d. h.* je durchlässiger und je weniger porös der Boden ist. Fast das Gegentheil findet aber bei der Aufsaugung statt. Es ist in diesem Fall

$$C = C_0 e^{-\frac{\varkappa}{a}z} - \frac{\gamma}{\varkappa^2}\left(1 - e^{-\frac{\varkappa}{a}z}\right)$$

C ist dann desto grösser, je kleiner $\frac{\gamma}{\varkappa^2}$ ist, *d. h.* je feinkörniger, und daher undurchlässiger und je weniger porös der Boden ist. Es sind Resultate, welche die Erfahrung wenigstens qualitativ bestätigt hat.

Wir wollen jetzt annehmen, dass t klein sei und auch z, so dass $\frac{z}{2a\sqrt{t}}$ und $\varkappa\sqrt{t}$ kleine Brüche sind. Unter diesem Umstand kann man angenährt setzen

$$\int_{\varkappa\sqrt{t}-\frac{z}{2a\sqrt{t}}}^{\infty} e^{-\lambda^2} d\lambda = \frac{\sqrt{\pi}}{2} - \varkappa\sqrt{t} + \frac{z}{2a\sqrt{t}}$$

$$\int_{\varkappa\sqrt{t}+\frac{z}{2a\sqrt{t}}}^{\infty} e^{-\lambda^2} d\lambda = \frac{\sqrt{\pi}}{2} - \varkappa\sqrt{t} - \frac{z}{2a\sqrt{t}}$$

$$\int_0^{\frac{z}{2a\sqrt{t}}} e^{-\lambda^2} d\lambda. = \frac{z}{2a\sqrt{t}} \qquad e^{-\varkappa^2 t} = 1 - \varkappa^2 t.$$

Substitution dieser angenährten Ausdrücke in (XII) ergiebt nach einer leichten Umformung.

$$C = \frac{\gamma}{\varkappa^2}\left(1 - \frac{(1-\varkappa^2 t)z.}{a\sqrt{\pi}\sqrt{t}}\right) + \frac{C_1}{2}\left(e^{\frac{\varkappa}{a}z} + e^{-\frac{\varkappa}{a}z}\right)$$

$$-\frac{C_1\varkappa\sqrt{t}}{\sqrt{\pi}}\left(e^{\frac{\varkappa}{a}z} - e^{-\frac{\varkappa}{a}z}\right) - \frac{C_1}{\sqrt{\pi}}\,\frac{z}{2a\sqrt{t}}\left(e^{-\frac{\varkappa}{a}z} + e^{\frac{\varkappa}{a}z}\right)$$

Indem wir annährungsweise in diese Gleichung

$$e^{\frac{\varkappa}{a}z} + e^{-\frac{\varkappa}{a}z} = 2 + \left(\frac{\varkappa}{a}\right)^2 z^2$$

$$e^{\frac{\varkappa}{a}z} - e^{-\frac{\varkappa}{a}z} = \frac{2\varkappa}{a}z$$

einsetzen und rechts und links mit t dividiren und dann das Glied, in dem $\frac{\varkappa^2}{a^3}\left(\frac{z}{\sqrt{t}}\right)^3$ als Factor auftritt, vernachlässigen, so erhalten mir mit Bücksicht auf die Bedeutung von C_1

$$-2\frac{(C_0 - C)}{C\,t}\left(\frac{a}{\varkappa}\right)^2 = \left(\frac{z}{\sqrt{t}}\right)^2 - 2\frac{z}{\sqrt{t}}\cdot\frac{a}{\sqrt{\pi}}\left(2 - \frac{\gamma}{C_1\varkappa^2} + \frac{C_0}{\varkappa^2 C_1 t}\right)$$

Hieraus folgt

$$\frac{z}{\sqrt{t}} = \frac{a}{\sqrt{\pi}}\left(2 - \frac{\gamma}{C_1\varkappa^2} + \frac{C_0}{\varkappa C_1 t}\right) \pm \sqrt{\frac{a^2}{\pi}\left(2 - \frac{\gamma}{C\,\varkappa^2} + \frac{C_0}{\varkappa^2 C_1 t}\right)^2 - 2\left(\frac{a}{\varkappa}\right)^2 \frac{(C_0 - C}{C_1 t.}}$$

Das negative Vorzeichen des Badicals ist hier zn nehmen, da für jeden Werth von t für $z=0$, $C=C_0$ sein muss und nmgekehrt. Es lässt sich der Werth von $\frac{z}{\sqrt{t}}$ in der Nähe der Fläche der Wasserzufuhr für eine Wasserschichte $C=\text{const}$ mittelst dieser Gleichung verfolgen. Es wird beim verschwindenden t

$$\left[\frac{z}{\sqrt{t}}\right]=\infty-\infty=a\sqrt{\pi}\,\frac{(C_0-C)}{C_0}$$

Der Anfangswerth von $\frac{z}{\sqrt{t}}$ ist offenbar klein, da C in der Nähe der Fläche der Wasserzufuhr eine gute Strecke himdurch sich wenig von C_0 unterscheiden möchte. Da $\frac{z}{\sqrt{t}}$ doch endlich ist bei dem verschwindenden t, so muss $\frac{dz}{dt}$ für $t=0$ dann unendlich gross sein, was in der That der Fall ist. Der Ausdrtck für $\frac{z}{\sqrt{t}}$ convergiert aber mit wachsendem t gegen Null; es muss daher $\left[\frac{z}{\sqrt{t}}\right]$ $t=0$ einen relativ grossen Werth haben, von dem aus $\frac{z}{\sqrt{t}}$ mit t abnimmt.

Es folgt hieraus, dass $\frac{z}{\sqrt{t}}$ für jede Schchte in der Nähe der Fläche der Wasserzufhr klein ist, dass aber die Geschwindigkeit, mit der diese Schichte sich bewegt, sehr grose sein muss, und zwar so, dass sie für die Durchsickerung grösser ist, als bei der horizontalen Leitung, und bei dieser wieder grösser, als bei der Aufsaugung; eine Schlussfolgerung, die in der That durch die Erfahrung bestätigt wird.

Wir denken uns jetzt t so gross, dass $e^{-\varkappa^2 t}$ als verschwindend klein betrachtet werden kann, und um so mehr das Integral

$$\int_{\varkappa\sqrt{t}+\frac{z}{2a\sqrt{t}}}^{\infty} e^{-\lambda^2} d\lambda$$

da

$$\lim_{t=\infty}\left[e^{+x^2 t}\int_{\varkappa\sqrt{t}+\frac{z}{2a\sqrt{t}}}^{\infty} e^{-\lambda^2} dz\right]=0$$

ist

t soll aber dabei eine solche Grösse haben, dass, wenn z gross ist, $\left(\varkappa\sqrt{t}-\frac{z}{2a\sqrt{t}}\right)$ als unendlich klein betrachtet werden kann. Unter diesem Umstand haben wir

$$C=\frac{\gamma}{\varkappa^2}+C_1 e^{-\frac{\varkappa}{a}z}-\frac{C_1 e^{-\frac{\varkappa}{a}z}}{\sqrt{\pi}}\left(\frac{\sqrt{\pi}}{2}-\varkappa\sqrt{t}+\frac{z}{2a\sqrt{t}}\right)$$

was aber auch so geschrieben werden kann

$$\log\frac{2\left(C-\frac{\gamma}{\varkappa^2}\right)}{C_1}=-\frac{\varkappa}{a}z+\log\left[1+\frac{2}{\sqrt{\pi}}\left(\varkappa\sqrt{t}-\frac{z}{2a\sqrt{t}}\right)\right]$$

Da aber $\varkappa\sqrt{t}-\frac{z}{2a\sqrt{t}}$ sehr klein sein soll, so kann man diese Gleichung auch so schreiben

$$K=-\frac{\varkappa}{a}z+\frac{2}{\sqrt{\pi}}\left(\varkappa\sqrt{t}-\frac{z}{2a\sqrt{t}}\right)$$

wo zur abkürzung

$$\log\frac{\left(2\left(C-\frac{\gamma}{\varkappa^2}\right)\right)}{C_1}=K$$

gesetzt ist. Man findet hieraus

$$\frac{z}{\sqrt{t}}=\frac{\frac{2a}{\sqrt{\pi}}-\frac{K}{\sqrt{t}}}{1+\frac{1}{\sqrt{\pi}\varkappa\sqrt{t}}} \qquad \text{(XIII)}$$

Der Werth von $\frac{z}{\sqrt{t}}$ strebt also mit wachsendem t gegen $\frac{2a}{\sqrt{\pi}}$ zu; derselbe ist bei der Durchsiekerung grösser, als bei der Aufsaugung. $\frac{z}{\sqrt{t}}$ nimmt dabei mit t zu, wenn K positiv ist; *d. h.* wenn $\frac{2\left(C-\frac{\gamma}{\varkappa^2}\right)}{C_1}$ ein unechter Bruch ist. $\frac{z}{\sqrt{t}}$ nimmt aber mit t ab, wenn $\frac{2\left(C-\frac{\gamma}{\varkappa^2}\right)}{C_1}$ ein echter Bruch und $K < \frac{2}{\pi}$ ist, denn es ist

$$\frac{d\left(\frac{z}{\sqrt{t}}\right)}{d\sqrt{t}} = \frac{\frac{2a}{\varkappa\pi}+\frac{aK}{\varkappa}}{\left(\sqrt{t}+\frac{1}{x\sqrt{\pi}}\right)^2} = \frac{\frac{a}{x}\left(\frac{2}{\pi}+K\right)}{\left(\sqrt{t}+\frac{1}{\varkappa\sqrt{\pi}}\right)^2} \qquad \text{(XIII}_a\text{)}$$

Wir betrachten näher

$$1-\frac{2}{C_1}\left(C-\frac{\gamma}{\varkappa^2}\right) = \frac{C_0+\frac{\gamma}{\varkappa^2}-2C}{\left(C_0-\frac{\gamma}{\varkappa}\right)}$$

K wird somit negativ beim Durchsickern für $C_0+\frac{\gamma}{\varkappa^2} > 2C$ aber positiv für $C_0+\frac{\gamma}{\varkappa^2} < 2C$. Da wir wohl annehmen dürfen, dass $\frac{\gamma}{\varkappa^2}$ beim Durchsickern klein und C dagegen überall ziemlich gross ist, wie der unmittelbare Augenschen es wahrscheinlich macht, so können wir wohl weiter annehmen, dass bei der Durchsickerung wenigstens durch eine gewisse Stecke hindurch

$$C_0+\frac{\gamma}{\varkappa^2} < 2C$$

sei, wenn kein Druck sonst auf die Schichte $z=0$ einwirkt und so C_0 erhöht. Es folgt dann, dass $\frac{z}{\sqrt{t}}$ *bei der Durchsickerung weingstens durch gewisse Strecke mit der Zeit wachsen muss, wenn C_0 nicht besonders gross ist.* Wenn aber C_0 so gross ist, dass $C_0+\frac{\gamma}{\varkappa^2} \geqq 2C$ ist, dann wird $\frac{\varkappa}{\sqrt{t}}$ auch bei der Durchsickerung mit t abnehmen. Bei der Aufsaugung ist

$$1-\frac{2\left(C+\frac{E}{\varkappa^2}\right)}{C_t}=\frac{C_0-\frac{E}{\varkappa^2}-2C}{\left(C_0+\frac{E}{\varkappa^2}\right)}$$

$\frac{\gamma}{\varkappa^2}$ ist hier klein, C aber wohl sehr klein, also dass wir annehmen können, dass hier

$$C_0 > \frac{\gamma}{\varkappa^2}+2C$$

und dass $\frac{2\left(C+\frac{\gamma}{\varkappa^2}\right)}{\left(C_0+\frac{\gamma}{\varkappa^2}\right)}$ ein kleiner Bruch sei und K darum einen negativen grossen Werth habe. Hieraus folgt dann, *dass $\frac{z}{\sqrt{t}}$ bei der Aufsaugung mit der Zeit abnehmen muss.*

Bei der horizontalen Leitung ist wieder

$$\frac{1-2\left(C+\frac{E}{\varkappa^2}\right)}{C_0+\frac{E}{\varkappa^2}}=\frac{C^0-\frac{E}{\varkappa^2}-2C}{C_0+\frac{E}{\varkappa^2}}$$

Hier ist $\frac{E}{\varkappa^2}$ klein, und C hingegen nicht klein und entschieden grösser, als bei der Aufsaugung. Man darf daher wohl annehmen, dass bei der horizontalen Leitung wenigstens durch gewisse Strecke hindurch

$$C_0 - \frac{E}{x^2} < 2C$$

sei. Hieraus folgt, dass $\frac{z}{\sqrt{t}}$ *bei der horszintalen Zeitung wenigstens durch gewisse Strecke hindurch mit der Zeit zunehmen muss.*

Es folgt ferner aus dem Ausdruck

$$\frac{z}{\sqrt{t}} = a \frac{\left(\frac{1}{\sqrt{\pi}} - \frac{K}{\varkappa\sqrt{t}}\right)}{\left(1 + \frac{1}{\varkappa\sqrt{\pi}\sqrt{t}}\right)}$$

dass $\frac{z}{\sqrt{t}}$ *bei der Durchsickerung grösser sein muss, als bei der Horizontalen Zeitung, und bei dieser grösser als bei der Aufsaugung.*

Die Geschwindigkeit, mit der die Schichte $C = const$ *sich bewegt, nimmt in allen drei Fällen mit der Zeit nur ab., denn es ist*

$$\frac{dz}{dt} = \frac{1}{2\sqrt{t}} \frac{\left(\frac{2a}{\sqrt{\pi}} + \frac{1}{\varkappa\sqrt{\pi t}}\left(\frac{4a}{\sqrt{\pi}} - \frac{\varkappa}{a} \cdot \frac{E}{\sqrt{t}}\right)\right)}{\left(1 + \frac{1}{\varkappa\sqrt{\pi}\sqrt{t}}\right)^2}$$

was offenbar positiv bleibt, und mit wachsenden $\sqrt{t}$ in's Unendliche abnimmt., was für einen Werth K auch haben mag. Überschreitet t einen gewissen Werth, so dass $\varkappa\sqrt{t} - \frac{z}{2a\sqrt{t}}$ gross wird, was allenfalls eintreten muss, da z nie eine Grösse von der Ordnung t sein kann und höchstens von der Ordnung $\sqrt{t}$ bleibt, so gilt die Gleichung (XIII) nicht mehr, und die Grösse $\frac{z}{\sqrt{t}}$ gehorcht nicht dem oben ausgesprochen Gesetz. Die Zeit, von der ab die Gleichung (XIII) ungiltig wird, tritt dabei, um so früher ein, je grösser a ist. Es folgt hier aus, dass diese Zeit bei der Durchsickerung früher enitreten muss, als bei der horizontalen Leitung, und bei dieser wiederum früher, als bei der Aufsaugung.

Für $x\sqrt{t}-\frac{z}{2\varkappa\sqrt{t}}>1$ ist das Jntegral $\frac{2}{\sqrt{\pi}}\int\limits_{\varkappa\sqrt{t}-\frac{z}{2a\sqrt{t}}}^{\infty} e^{-\lambda^2}d\lambda.$

schon ein kleiner Bruch. Man kann daher die Gleichung

$$\log\left(\frac{C-\frac{\gamma}{\varkappa^2}}{C_1}\right)=-\frac{\varkappa}{a}\,2+\log\left(1-\frac{1}{\sqrt{\pi}}\int\limits_{\varkappa\sqrt{t}-\frac{z}{2a\sqrt{t}}}^{\infty} e^{-\lambda^2}d\lambda\right)$$

in erster Annährung schreiben,

$$\log\left(\frac{C_0-\frac{\gamma}{\varkappa^2}}{C-\frac{\gamma}{\varkappa^2}}\right)=\frac{\varkappa}{a}z+\frac{1}{\sqrt{\pi}}\int\limits_{\varkappa\sqrt{t}-\frac{z}{2a\sqrt{t}}}^{\infty} e^{-\lambda^2}\,d\gamma \qquad (\mathrm{XII}_a)$$

Nun hat Schlömilch für das Kramp' sche Integral von grossem Argument eine rasch convergierende Reihe entwickelt.† Indem wir von dieser Reihe Gebrauch mechen, und nur das erste Glied behalten, so erhalten wir in erster Annährung

$$\int\limits_{\varkappa\sqrt{t}-\frac{z}{2a\sqrt{t}}}^{\infty} e^{-\lambda^2}d\lambda=\frac{e^{-\left(x\sqrt{t}-\frac{2}{2a\sqrt{t}}\right)^2}}{2\left(x\sqrt{t}-\frac{z}{2a\sqrt{t}}\right)}$$

Indem wir diesen Ausdurck in (XII_a) einführen, und rechts und links mit $\sqrt{t}$ dividiren, kommt

$$\frac{\log\left(\frac{C_0-\frac{\gamma}{x^2}}{C-\frac{\gamma}{x^2}}\right)}{\sqrt{t}}=\frac{x}{a}\frac{z}{\sqrt{t}}+\frac{1}{2\sqrt{\pi}}\frac{e^{-\varkappa\sqrt{t}-\frac{z}{2a\sqrt{t}}}}{\left(\varkappa t-\frac{z}{2a}\right)}$$

Da man $\left(\varkappa\sqrt{t}-\frac{z}{2a\sqrt{t}}\right)$ mit t und daher auch

† Schlömilch: Compendium der höheren Analysis Band II pag. 266. Zweite Auflage).

$\varkappa t - \frac{z}{2a}$ in's Unendliche wächst, so sieht man, dass $\frac{z}{\sqrt{t}}$ in's Unendliche abnehmen muss, da $\log\left(\frac{C_0 - \frac{\gamma}{x^2}}{C - \frac{\gamma}{x^2}}\right)$ hier durchaus und endlich positiv ist, so lange $C - \frac{\gamma}{x^2}$ nicht verschwindend klein ist. Es folgt hieraus, *dass* $\frac{z}{\sqrt{t}}$ *gleichwohl ob das Wasser durchsickert, oder aufgesogen, oder horizontal geleitet wird, mit in's Unendliche wachsendem t in's Unendliche abnimmt, dass daher z eine endliche Grösse für* $t = \infty$ *ist* d. h. mit anderen Worten, *dass so wohl die Durchsickerung Aufsaugung, wie die horizontale Zeitung im Boden eine Grenze hat,* in so ferne, als es sich um die Bewegung einer Schichte $C = \text{const.}$ handelt, nicht aber um die Schichte

$$C - \frac{\gamma}{\varkappa^2} = 0$$

Noch ein Paar einfache Fälle seien hier behandelt. Wir wollen C für den Fall ermitteln, wo der Boden in seiner ganzen Ausdehnung zur Zeit $t = 0$ gesättigt ist, und in der Ebene $z = 0$ constant trocken gehalten wird, so dass

$$C = C_0 \quad \text{für} \quad t = 0$$
$$C = 0 \quad \text{für} \quad z = 0$$

Diesen Bedingungen genügt man, indem man setzt

$$C = \frac{\gamma}{x}\left(1 - \frac{2e^{-x^2 t}}{\sqrt{\pi}} \int_0^{\frac{z}{2a\sqrt{t}}} e^{-\lambda^2} d\lambda\right) + \frac{2C_0}{\sqrt{\pi}} e^{-\varkappa^2 t} \int_0^{\frac{z}{2a\sqrt{t}}} e^{-\lambda^2} d\lambda\Big)$$

$$- \frac{\gamma}{\varkappa^2} e^{-\frac{\varkappa}{a} z} + \frac{\gamma}{\sqrt{\pi}\,\varkappa^2}\left(e^{-\frac{\varkappa}{a} z} \int_{\varkappa\sqrt{t} - \frac{z}{2a\sqrt{t}}}^{\infty} e^{-\lambda^2} d\lambda - e^{\frac{\varkappa}{a} z} \int_{\varkappa\sqrt{t} + \frac{z}{2a\sqrt{t}}}^{\infty} e^{-\lambda^2} d\lambda\right)$$

Es ist für $t=0$

$$C=C_0-\frac{\varkappa}{\varkappa^2}e^{-\frac{\varkappa}{a}z}+\frac{\gamma}{\varkappa^2}e^{-\frac{\varkappa}{a}z}=C_0$$

und für $z=0$

$$C=\frac{\gamma}{\varkappa^2}-\frac{\gamma}{\varkappa^2}=0$$

wie es verlangt wurde. Es wird für grosses z bei endlichem t

$$C=C_0\ e^{-\varkappa^2 t}+\frac{\gamma}{\varkappa^2}\left(1-e^{-\varkappa^2 t}\right)$$

Das Wasser sickert also, und die Wassermenge in jeder Schichte sinkt von C_0 auf $\frac{\gamma}{\varkappa^2}$ herab. Für grosses t bei endllichem z wird

$$C=\frac{\gamma}{\varkappa^2}\left(1-e^{-\frac{\varkappa}{a}z}\right)$$

Die Durchsikerung wird also stationär, und die Wassermenge nimmt nach oben zu von o gegen $\frac{\gamma}{\varkappa^2}$ zu.

Ist die obere Grenzebene des Bodens die unendliche austrocknende Ebene, oder steht diese vertical, so hat man γ negativ zu setzen. Man erhält für endliches t bei unendlichem z

$$C=C_0\ e^{-\varkappa^2 t}-\frac{\gamma}{\varkappa^2}\left(1-e^{-\varkappa^2 t}\right)$$

C kann hier nach einer gewissen Zeit verschwinden, welche durch

$$e^{-\varkappa^2 t}=\frac{\frac{\gamma}{\varkappa^2}}{C_0+\frac{\gamma}{\varkappa^2}}$$

bestimmt ist. In der endlichen Zeit muss der Wasserfluss vertical aufwärts, oder horizontal nach der austrocknendem Ebene aufhören. Demgemäss ist für $t=\infty$ bei endlichem z.

$$C = -\frac{\gamma}{\varkappa^2}\left(1 - e^{-\frac{\varkappa}{a}z}\right)$$

Der Wasserfluss nach der austrocknenden Ebene hat aufgehört, weil das Wasser in verticaler Richtung abwärts in die Unendlichkeit sickert, und in horizontalet Richtung kein anderes Wasser giebt, als was an den Wänden der Capillarraume unbeweglich haften bleibt.

Wir wollen jetzt den Fall behandeln, wo der Boden, an der Ebene $z=0$ gesättigt gehalten wird, und in einer dazu parallelen Ebene $z=l$ Verdampfung des Wassers stattfindet. Es soll dann C so bestimmt werden, dass sie der Differentialgleichung (IX) genügt, und

$$\begin{aligned} C &= C_0 \quad \text{für} \quad z=0 \\ C &= 0 \quad \text{für} \quad t=0 \end{aligned} \qquad (a)$$

wird, und für $z=l$ die Gleichung

$$KC + \frac{\partial C}{\partial z} = 0 \qquad (b)$$

befriedigt, wo $\frac{\gamma(F-f)}{a^2} = K$ gesetzt worden ist. Eine particuläre Lösung der Gleichung (IX) ist

$$\frac{\gamma}{\varkappa^2} + Ce_1^{-\frac{\varkappa}{a}z} + C_2 e^{\frac{\varkappa}{a}z} + A\, e^{-\varkappa^2 t - a^2\lambda^2 t} \sin \lambda z.$$

wo A C_1 C_2 willkürliche Constanten sind. Die erste der Bedingungen (a) giebt zunächst,

$$\frac{\gamma}{\varkappa^2} - C_1 + C_2 = 0 \qquad (c)$$

Die Bedingung (b) ergiebt

$$K\left(\frac{\gamma}{\varkappa^2} + C_1 e^{-\frac{\varkappa}{a}l} + C_2 e^{\frac{\varkappa}{a}l}\right) - \frac{\varkappa}{a} C_1 e^{-\frac{\varkappa}{a}l} + \frac{\varkappa}{a} C_2 e^{\frac{\varkappa}{a}l}$$

$$+ A(K \sin\lambda l + \lambda \cos \lambda l) e^{-\varkappa^2 t - a^2\lambda^2 t} = 0 \qquad (d)$$

was befriedigt wird, wenn wir setzen

$$K\left(\frac{\gamma}{\varkappa^2}+Ce_1^{-\frac{\varkappa}{a}l}+C_2e^{\frac{\varkappa}{a}l}\right)-\frac{\varkappa}{a}\left(C_1e^{-\frac{\varkappa}{a}l}+C_2e^{-\frac{\varkappa}{a}l}\right)=0$$

$$K\sin\lambda l+\lambda\cos\lambda l=0 \qquad (d)$$

Die erste dieser Gleichungen und die Gleichung (c) bestimmen C_1 und C_2 eindeutig

$$C_1=\frac{\left(C_0-\frac{\gamma}{\varkappa^2}\right)e^{\frac{\varkappa}{a}l}\left(1+\frac{\varkappa}{aK}\right)+\frac{\gamma}{\varkappa^2}}{e^{l\frac{\varkappa}{a}}\left(1+\frac{\varkappa}{aK}\right)-e^{-\frac{\varkappa}{a}l}\left(1-\frac{\varkappa}{aK}\right)}$$

$$C_2=-\frac{\left[\frac{\gamma}{\varkappa}+e^{-\frac{\varkappa}{a}l}\left(C_0-\frac{\gamma}{\varkappa^2}\right)\left(1-\frac{\varkappa}{aK}\right)\right]}{e^{\frac{\varkappa}{a}l}\left(1+\frac{\varkappa}{aK}\right)-e^{-\frac{\varkappa}{a}l}\left(1-\frac{\varkappa}{aK}\right)}$$

Die transcendente Gleichung (d) ist dieselbe, welche bei der Theorie der Wärmeverbreitung in einer im diathermanen Medium befindlichen Kugel vorkommt, und hat bekanntlich unendlich viele positive reelle Wurzeln. Es seien diese

$$\lambda_1 \quad \lambda_2 \quad \lambda_3 \ldots\ldots \lambda_m \ldots\ldots\ldots$$

Da die Gleichung für c linear und homogen ist, so genügt auch die Function

$$C=\frac{\gamma}{\varkappa^2}C_1e^{-\frac{\varkappa}{a}z}+C_2e^{-\frac{\varkappa}{a}z}+\sum_1^\infty A_m e^{-\varkappa^2t-a^2\lambda^2_m t}\sin(\lambda_m t)$$

der Gleichung (IX) und befriedigt so wohl die erste der Bedingungen (a), wie (b). Die zweite der Bedingungen (a) lässt sich erfüllen, indem man setzt

$$-A_m=\frac{4\lambda_m}{2\lambda_m l-\sin\lambda_m l}\int_0^l\left(\frac{\gamma}{\varkappa^2}+C_1e^{-\frac{\varkappa}{a}z}+C_2e^{\frac{\varkappa}{a}z}\right)\sin\lambda_m z\,dz$$

da bekanntlich

$$\int_0^l \sin(\lambda_m z).\sin(\lambda_n z)dz = 0 \quad \text{für } m \lessgtr n$$

$$\int_0^l \sin(\lambda_n z)\ \sin(\lambda_n z)dz = \frac{2\lambda_n l - \sin 2\lambda_n l}{4\lambda_n} \quad \text{für } m = n.$$

ist.

Indem wir demnach zur Abkürzung setzen

$$A_m = \frac{4\lambda_n}{2\lambda_n - \sin(2\lambda_n l)} \left[\frac{\lambda_m}{\left(\frac{\varkappa}{a}\right)^2 + \lambda^2_m} \left(C_0 - \frac{\gamma}{\varkappa^2}\right) + \frac{\gamma}{\lambda_n \varkappa^2} \ (1 - \cos \mu l) \right.$$

$$- \frac{\varkappa}{a\left(\left(\frac{\varkappa}{a}\right)^2 + \lambda^2_m\right)} \sin(\lambda_n l) \left(\frac{2\left(C_0 - \frac{\gamma}{\varkappa^2}\right) + \frac{\gamma}{\varkappa^2}\left(e^{\frac{\varkappa}{a}l} + e^{-\frac{\varkappa}{a}l}\right)}{e^{\frac{\varkappa}{a}l}\left(1 + \frac{x}{aK}\right) - e^{-\frac{\varkappa}{a}l}\left(1 - \frac{\varkappa}{aK}\right)} \right)$$

$$\left. - \frac{\varkappa}{\left(\left(\frac{\varkappa}{a}\right)^2 + \lambda^2_m\right)} \cos(\lambda_n l) \left(\frac{2\left(C_0 - \frac{\gamma}{x}\right) - \frac{\gamma}{x}\left(e^{\frac{\varkappa}{a}l} - e^{-\frac{\varkappa}{a}l}\right)}{e^{\frac{\varkappa}{a}l}\left(1 + \frac{\varkappa}{aK}\right) - e^{-\frac{\varkappa}{a}l}\left(1 - \frac{\varkappa}{aK}\right)} \right) \right]$$

haben wir

$$C = \frac{\gamma}{\varkappa^2}\left(1 - \frac{\left(e^{\frac{\varkappa}{a}z} - e^{\frac{\varkappa}{a}z}\right)}{e^{\frac{\varkappa}{a}l}\left(1 - \frac{\varkappa}{aK}\right) - e^{-\frac{\varkappa}{a}l}\left(1 - \frac{\varkappa}{aK}\right)}\right)$$

$$+ \left(C_0 - \frac{\gamma}{\varkappa^2}\right)\left(\frac{\left(1 + \frac{\varkappa}{aK}\right)e^{\frac{\varkappa}{a}(l-z)} - \left(1 - \frac{\varkappa}{aK}\right)e^{-\frac{\varkappa}{a}(l-z)}}{e^{\frac{\varkappa}{a}}\left(1 - \frac{\varkappa}{aK}\right) - e^{-\frac{\varkappa}{a}l}\left(1 - \frac{\varkappa}{aK}\right)} \right)$$

$$- \sum_1^\infty A_m e^{-\varkappa^2 t - a^2 \lambda^2_m t} \sin \lambda_m z.$$

als die gesuchte Function, welche allen gestellten Bedingungen Genüge leistet. Wir begnügen uns diese Gleichung nur in dem

Fall näher zu discutiren, wo t so gross geworden ist, dass die unendliche Reihe verschwindend klein ist, also dass die Wasserbewegung eine stationöre geworden und durch

$$C=\frac{\gamma}{\varkappa^2}\left(1-\frac{\left(e^{\frac{\varkappa}{a}z}-e^{-\frac{\varkappa}{a}z}\right)}{e^{\frac{\varkappa}{a}l}\left(1-\frac{\varkappa}{aK}\right)-e^{-\frac{\varkappa}{a}l}\left(1-\frac{\varkappa}{aK}\right)}\right]$$

$$+\left(C_0-\frac{\gamma}{\varkappa^2}\right)\left(\frac{\left(1+\frac{\varkappa}{aK}\right)e^{\frac{\varkappa}{a}(l-z)}-\left(1-\frac{\varkappa}{aK}\right)e^{-\frac{\varkappa}{a}(l-z)}}{e^{\frac{\varkappa}{a}l}\left(1+\frac{\varkappa}{aK}\right)-e^{-\frac{\varkappa}{a}l}\left(1-\frac{x}{aK}\right)}\right)$$

bestimmt ist. Die Wassermenge, welche bei der Ebene $z=l$ durchsickert, ist hiernach

$$C=\frac{\varkappa}{aK}\,\frac{\left[2C_0+\frac{\gamma}{\varkappa}\left(e^{\frac{\varkappa}{a}l}+e^{-\frac{\varkappa}{a}l}-z\right)\right]}{e^{\frac{\varkappa}{a}l}\left(1+\frac{\varkappa}{aK}\right)-e^{-\frac{\varkappa}{a}l}\left(1-\frac{\varkappa}{aK}\right)}$$

Wenn nun l sehr klein ist, so ist

$$C=C_0$$

demnach bewegt sich durch eine unendlich dünne Schichte überall dieselbe Wassermenge völlig unabhängig von der Verdampfung, die auf einer Grenzebene stattfindet. Ist hingegen l sehr gross, so hat man

$$C=\frac{\gamma}{\varkappa(aK+\varkappa)}=\frac{\gamma a}{\varkappa(\eta(F-f)+a\varkappa)}$$

Die Wassermenge, welche in der Zeit Eins aus der Ebene $z=l$ heraustritt, nimmt demnach mit der Grösse der Verdampfung ab; sie ist dabei um so grösser, je grösser γ ist; *d.* h. je grobkörniger, und je weniger porös der Boden ist. Wird $K=\infty$, findet die Verdampfung an der Ebene $z=l$ sehr rasch statt, so wird $C=0$, was doch selbstverständlich ist.

Wenn die verdampfende Ebene, über der Ebene $C=C_0$ liegt, so hat man $\frac{\gamma}{\varkappa^2}<0$ zu setzen. Für sehr grosses l hat man

$$C=-\frac{\gamma}{\varkappa(aK+\varkappa)}$$

Das Wasser steigt gar nicht zur Ebene der Verdampfung empor. Die Schichte $C=0$ liegt darum in der Endlichkeit; ihre Höhe ist bestimmt durch

$$0=-\frac{\gamma}{\varkappa^2}+\left(C_0+\frac{\gamma}{\varkappa^2}\right)e^{-\frac{\varkappa}{a}z}$$

also durchaus unabhängig von der Verdampfung. Anderes aber, wenn die Verdampfung sehr stark stattfindet. d. h. wenn $K=\infty$ ist. In diesem Fall hat man

$$C=-\frac{\gamma}{\varkappa^2}\left(1+\frac{\left(e^{\frac{\varkappa}{a}z}-e^{-\frac{\varkappa}{a}}\right)}{\left(e^{\frac{\varkappa}{a}l}-e^{-\frac{\varkappa}{a}l}\right)}\right)$$

$$+\left(C+\frac{\gamma}{\varkappa^2}\right)\left(\frac{e^{\frac{\varkappa}{a}(l-z)}-e^{-\frac{\varkappa}{a}(l-z)}}{e^{\frac{\varkappa}{a}l}-e^{-\frac{\varkappa}{a}l}}\right)$$

was verschwindet, wenn $z=l$ wird d. h. die Schichte $C=0$ steigt immer höher, je grösser die Verdampfung ist, also, dass das Wasser im Boden höher aufgesogen wird, wenn es an einer freien Fläche verdampft, als wenn dies nicht der Fall ist.

Man sieht somit, dass die problematische Grenzbedingung (XIII) Ausdrücke geliefert hat, welche wenigstens qualitativ mit der Erfahrung nicht in Widersprnch gerathen.

Das Mittel, die Folgerungen der theorstich abgeleiteten Formeln für Fälle, wo das Wasser im Boden durchsickert, oder aufgesogen oder horizontal fortgeleitet wird, näher experimentell zu prüfen, besteht einzig und allein in der Messung der Distanz derjenigen Schichte, wo der Boden beginnt, eine dunklere Färbung anzunehmen, von der Ebene der Wasserzufuhr. Da es nachweisbar ist, dass der für eine unendliche Ebene der Wasrerzufuhr aufgestellte Ausdruck für C giltig bleibt, wenn der Boden durch eine für Wasser undurchdringliche cylindrische Fläche von unendlicher Launge unschlossen wird, so kann der Boden iu Bezug auf die drei Arten Wasserbewgung in einer Glasrohre unbedenklich in Untersuchung genommen und der für C auf gestellte Ausdruck naher gepsrüft werdeni wenn Sorge dafür getroffen wird, dass die Wasserzufuhr constant ver sich geht. Es ist aber eine schwierige Frage, welchen Werth man C für diese Grenzschichte der Andunklung beizulegen hat. $C=0$ für diese Schichte anzunehmen ginge schon desshalb nicht, weil die Füllung der capillaren Hohlräume in der Grenzschichte, wie der Augenschein es unmittelbar lehrt, mit der Distanz von der Ebene der Wasserzufuhr entschieden abnimmt, und aus demselben Grund darf man auch nicht für diese Grenzschichte durch die ganze Strecke hindurch, die sie wandert, $C=\text{const}$ annehmen. Es bleibt dann nichts übrig als anzunehmen, dass C für die Grenzschichte der Andenklung in hinreichender Entfernung von der Ebene der Wasserzufuhr sich so langsam mit der Entfernung ändere, dass man sie eine lange Strecke hin als constant ansehen könne. Da ferner für die Grenzschichte bei der Durchsickerung entschieden grösseren Werth haben muss, als bei der horizontalen Leitung, und bei dieser auch grösser, als bei der Aufsaugung, so müssen, wenn des abgeleitete Ausdruck für C anderes einigermaassen richtig die Wasserbewegung in Boden darstellt, folgende Gesetze durch die Erfahrung bestätigt werden.

1) Die Grösse $\frac{z}{\sqrt{t}}$ ist anfangs klein, gleichwohl ob das Wasser durchsickert, oder horizontal geleitet, oder aufgesogen wird, wenn die Wasserzufuhr nur nicht unter Druckerhöhung geschieht. Dieselbe nimmt dann mit der *Zeit* ab, um dann wieder zuzunehmen.

2) Wenn die Wasserzufuhr eine gewisse Grösse nicht überschreitet, so muss $\frac{z}{\sqrt{t}}$ durch gewisse Strecke hindurch bei der Durchsickerung, und bei der horizontalen Leitung mit der *Zeit* wachsen, bei der Aufsaugeng aber mit der *Zeit* abnehmen. Überschreit der Wasserzufuhr eine gewisse Grösse, so kann $\frac{z}{\sqrt{t}}$ bei allen drei Arten Wasserbewegung mit der *Zei* nur abnehmen.

3) Nach Verfluss einer grossen *Zeit* nimmt $\frac{z}{\sqrt{t}}$ bei allen drei Arten Wasserhewegung mit der *Zeit* nur ab.

4) Unter übrigens gleichen Umständen ist der Werth des $\frac{z}{\sqrt{t}}$ bei der Durchsickerung grösser, als bei der horizontalen Leitung, und bei dieser grösser, als bei der Aufsaugung.

Ich habe ans den *Zahlen*, welche Liebenberg für Steighöhe des Wassers in verschiedenen Böden gefunden hat, $\frac{z}{\sqrt{t}}$ für die Aufsaugung berechnet, indem ich als *Zeiteinheit* die Stunde und Millimeter als Längeneinheit wählte.

AUFSAUGUNG DES WASSERS
NACH LIEBENBERG.

	Grober Tert. Sand.		Melmlehm.		Humoser Lösslehm.	
Zeit t	z	$\frac{z}{\sqrt{t}}$	z	$\frac{z}{\sqrt{t}}$	z	$\frac{z}{\sqrt{t}}$
$^1/_2$ St.	185	261.63	70	98.995	170	240.42
$1^1/_2$ St.	230	187.78	110	89.813	225	183.71
$4^1/_2$ St.	400	188.56	215	101.35	330	155.56
1 Tag	760	155.13	415	84.711	550	112.27
2	930	134.01	525	75.828	625	90.271
3	1015	119.62	600	70.744	700	82.496
4	1060	108.18	655	66.850	740	75.525
5	1100	109.55	710	64.814	780	71.203
6	1120	93.334	750	62.500	790	65.834
7	1140	87.955	780	60.178	810	62.494
8	1160	83.716	825	59.539	820	59.178
9	1170	79.609	855	58.135	840	57.154
10	1175	75.845	890	57.449	850	54.867
11	1178	72.502	915	56.314	860	52.930
12	1180	69.531	930	54.800	870	51.265
13	1181	66.860	955	54.065	880	49.829
14	1182	65.986	975	53.190	890	48.553
15	1183	62.350	995	52.683	900	47.434
16	1184	60.142	1015	51.558	905	45.971
17	1185	58.733	1030	51.008	910	45.065
18	1186	57.110	1040	50.037	915	44.023
19	1187	55.506	1045	48.937	920	43.083
20	1188	54.236	1055	48.154	925	42.220
21	1189	52.961	1070	47.661	930	41.330
22	1190	51.788	1080	47.000	935	40.690
23	1191	51.043	1090	46.394	940	40.009
24	1192	49.667	1095	45.625	945	39.375

AUFSAUGUNG DES WASSERS
NACH LIEBENBERG.

Basalt.		Röth.		Sandmoor.		Thon.	
z	$\frac{z}{\sqrt{t}}$	z	$\frac{z}{\sqrt{t}}$	z	$\frac{z}{\sqrt{t}}$	z	$\frac{z}{\sqrt{t}}$
95	134.35	60	84.852	110	115.56	3	4.243
130	106.96	90	73.484	165	134.74	6	3.266
195	91.922	150	70.710	210	98.994	10	4.714
310	63.278	265	54.093	310	63.278	35	7.144
350	54.921	330	47.663	350	50.552	50	7.222
370	43.604	380	44.783	380	44.783	60	7.071
390	39.803	410	41.845	400	40.824	70	7.144
410	37.427	435	39.710	410	37.427	80	7.303
430	35.834	460	38.334	425	35.417	90	7.500
440	33.947	475	36.647	435	33.561	100	7.715
455	32.837	495	35.724	440	31.754	110	7.939
470	31.979	510	34.700	445	30.278	120	8.163
480	30.984	520	33.565	450	29.047	130	8.391
492	30.280	530	32.620	455	28.004	140	8.617
505	29.757	540	31.819	460	27.106	150	8.839
520	29.439	550	31.137	465	26.325	160	9.058
530	28.914	560	30.551	470	25.641	170	9.274
535	28.197	565	29.778	470	24.772	180	9.487
545	27.684	570	28.955	475	24.128	185	9.397
560	27.732	575	28.475	482	23.870	190	9.409
560	26.943	580	27.906	482	23.191	195	9.382
570	26.693	590	27.629	484	22.666	200	9.366
580	26.474	595	27.158	485	22.137	205	9.357
585	26.058	600	26.726	490	21.826	210	9.354
590	25.676	605	26.329	493	21.455	215	9.356
600	25.538	610	25.963	497	21.154	220	9.364
615	25.625	610	25.417	500	20.786	225	9.374

AUFSAUGUNG DES WASSERS
NACH LIEBENBERG.

	Grober Tert. Sand.		Melmlehm.		Humoser Lösslehm.	
Zeit t	z	$\frac{z}{\sqrt{t}}$	z	$\frac{z}{\sqrt{t}}$	z	$\frac{z}{\sqrt{t}}$
25	1193	48.703	1100	44.906	960	39.191
26	1194	47.798	1105	44.235	965	38.631
27	1195	46.944	1110	43.604	968	38.027
28	1196	46.137	1115	43.013	975	37.611
29	1197	45.372	1120	42.454	980	37.062
30	1198	44.647	1125	41.926	982	36.597
31	1200	43.994	1130	41.425	985	36.112
32			1133	40.884	990	35.724
33			1140	40.509	995	35.356
34			1145	40.083	1000	35.007
35			1148	39.610	1000	34.503
36			1152	39.173	1010	34.345
37			1155	38.758	1020	34.229
38					1030	34.107

AUFSAUGUNG DES WASSERS

NACH LIEBENBERG.

Basalt.		Röth.		Sandmoor.		Thon.	
z	$\frac{z}{\sqrt{t}}$	z	$\frac{z}{\sqrt{t}}$	z	$\frac{z}{\sqrt{t}}$	z	$\frac{z}{\sqrt{t}}$
620	25.311	615	25.107	500	20.412	230	9.390
625	25.020	620	24.820	502	20.096	235	9.414
630	24.749	635	24.945	503	19.760	240	9.428
635	24.496	630	24.303	504	19.443	245	9.451
640	24.259	633	23.994	505	19.142	250	9.476
645	24.038	636	23.702	506	18.858	255	9.503
650	23.830	640	23.464	507	18.588	260	9.532
655	23.635	643	23.202	508	18.331	265	7.562
660	23.452	646	22.955	509	18.087	270	9.594
665	23.279	650	22.754	510	17.854	275	9.626
670	23.117	654	22.565	511	17.631	278	9.592
675	22.952	658	22.376			280	9.521
680	22.819	662	22.215			282	9.463
685	22.683	665	22.020			285	9.437

Wie man sieht, bestätigt sich das Gesetz, dass $\frac{z}{\sqrt{t}}$ für Aufsaugnng mit wachsender Zeit stetig abnimmt. Weil das Zeitintervall der Beobachtung ein zu weit von einander abstehndes war, können jedoch die meisten Böden nicht gut den theoretisch verlangten Verlauf der Grösse $\frac{z}{\sqrt{t}}$ zeigen, ausser dem Thon, bei dem $\frac{z}{\sqrt{t}}$ anfangs klein ist, und dann zu einem Maximum aufsteigt, um zuletzt sichtbar wieder abzunehmen, ganz so, wie die Theorie es verlangt. Es geht ferner aus den obenstehenden Zahlen die theoretisch erwartete Thatsache hervor, dass die Grösse $\frac{z}{\sqrt{t}}$ um so kleiner ist, je feinkörniger der Boden ist, dass hingegen das Aufsteigen um so länger dauert, ja feinkörniger der Boden ist.

Liebenberg hat auch die Durchsickerung des Wassers in Böden untersucht. Die von ihm mitgetheilten Daten sind aber nicht recht für unseren Zweck brauchbar. Denn Liebenberg hielte die Wasserzufuhr nicht constant; er liess das Wasser 2 Zoll hoch auf dem Boden stehen, und es durch denselben einschlucken. In diesem Versuch ist die Grösse C_0 nicht eine Constante, sondern eine Function der Zeit und es ist nicht schwierig, die Differentialgleichung (IX) für diesen Fall zu integriren. Es ist aber nicht nöthig. Die Durchsickerung des Wassers bei diesem Liebenberg'schen Versuche geht nämlich unter Druckerhöhung vor sich. Denkt man sich die Zeit, während deren das Wasser auf dem Boden steht, in kleine Intervalle getheilt während deren C_0 als constant betrachtet werden und der Ausdruck (XII) daher angewendet werden kann.

Die Grösse $\frac{2\left(C-\frac{\gamma}{\varkappa^2}\right)}{C_0-\frac{\gamma}{\varkappa^2}}$ kann dann nur ein echter Bruch

sein.: $\frac{z}{\sqrt{t}}$ kann folglich nur mit der Zeit abnehmen. Die Bewegaug des Wassers muss diesen Charakter noch beim weiteren Verlauf der Zeit tragen, weil es sicht nicht in dem Masse schnell durch den Boden fortpflanzen kann, wie anfangs, wo der Druck. das Wasser in den Boden getrieben hatte. Die Liebenberg' sche Beobachtung bestätigt es in der That

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DURCKSICKERUNG DES WASSERS
NACH LIEBENBERG.

t		$^1/_4$ St.	$^1/_2$ St.	$1\ /_2$ St.	4 St.	24 St.	48 St.	72 St.
Grober Diluvialsand	z	380	450	530	545	555	565	575
	$\frac{z}{\sqrt{t}}$	760	643.76	437.76	272.5	113.29	81.551	67.765
Mittelfeiner Diluvialsand	z	130	140	182	200	290	320	350
	$\frac{z}{\sqrt{t}}$	260	200.28	150.32	10.0	59.196	46.190	41.248
Feiner Diluvialsand	z	140	150	210	220	260	——	——
	$\frac{z}{\sqrt{t}}$	280	214.58	173.45	110.	53.071	——	——
Grober Tert. Sand	z	120	130	165	175	195	210	215
	$\frac{z}{\sqrt{t}}$	240	185.98	136.28	87.5	39.803	30.312	25.338
Lehmmergel	z	90	115	130	143	170	180	185
	$\frac{z}{\sqrt{t}}$	180	164.51	107.37	71.5	34.701	25.981	21.802
Feiner Tert. Sand	z	80	115	130	140	160	172	182
	$\frac{z}{\sqrt{t}}$	160	164.51	107.37	70	32.660	24.827	21.448
Porphyrboden stark verwittert	z	85	120	130	135	152	160	162
	$\frac{z}{\sqrt{t}}$	170	171.67	107.37	70	31.026	23.095	19.092
Lehm	z	100	125	130	140	169	178	180
	$\frac{z}{\sqrt{t}}$	200	178.82	107.37	67.5	34.497	25.693	21.213
Muschelkalk	z	95	110	118	125	150	155	160
	$\frac{z}{\sqrt{t}}$	190	157.36	97.463	62.5	30.618	22.373	18.856
Lössmergel	z	30	60	105	115	140	150	155
	$\frac{z}{\sqrt{t}}$	60	34.171	86,728	57.5	28.577	21.651	18.167
Melmmergel	z	60	80	100	128	140	147	152
	$\frac{z}{\sqrt{t}}$	120	114.44	82,596	64.	28.577	21.218	17.913
Aulehm (Untergrund)	z	40	80	115	130	135	140	145
	$\frac{z}{\sqrt{t}}$	80	114.44	94.986	65	27.556	20.203	17.088
Lösslehm	z	30	60	105	110	128	138	141
	$\frac{z}{\sqrt{t}}$	60	34.171	86.728	55	26.127	19.919	16.617

DURCHSICKERUNG DES WASSERS
NACH LIEBENBERG.

t		$^1/_4$ St.	$^1/$ St.	$1^1/_2$ St.	4 St.	24 St.	48 St.	72 St.
Humoser Lösslehm	z	70	75	80	100	128	140	140
	$\frac{z}{\sqrt{t}}$	140	107.29	66.077	50	26.127	20.208	16.499
Porphyrboden	z	55	80	100	120	125	128	130
	$\frac{z}{\sqrt{t}}$	110	114.44	82.596	60	25.515	18.475	15.321
Melmlehm	z	70	85	100	110	120	125	130
	$\frac{z}{\sqrt{t}}$	140	121.60	82.596	55.	24.494	18.042	15.321
Aulehm (Krume)	z	35	70	100	112	118	122	130
	$\frac{z}{\sqrt{t}}$	70	100.14	82.596	61	24.086	17.609	15.321
Granit	z	65	80	90	100	113	118	122
	$\frac{z}{\sqrt{t}}$	130	114.44	74.336	50	23.066	17.032	14.378
Basalt	z	75	85	95	105	110	115	122
	$\frac{z}{\sqrt{t}}$	150	121.66	78.466	52.5	22.453	16.599	14.378
Röth	z	45	65	80	95	100	105	115
	$\frac{z}{\sqrt{t}}$	90	92.986	66.077	475	20.412	15.156	13.553
Thon	z	15	18	20	40	72	80	90
	$\frac{z}{\sqrt{t}}$	30	25.751	16.519	20	14.697	11.547	10.607

Einer meiner Studenten auf dem hiesigen Institute, Herr O. Inagaki hat auf meine Veranlassung hin einige Böden in Bezug auf die drei Arten Wasserbewegung in Untersuchung genommen und seine Resultate sind im Folgenden zusammengestellt.

TUFFBODEN VON KOMABA

(*Aufsaugung*)

t (*St.*)	z (*mm*)	$\frac{z}{\sqrt{t}}$
0.25	75	150.000
0.50	95	134.350
1.00	125	125.000
1.50	153	124.924
2.50	191	120.799
3.50	223	119.199
4.50	251	118.322
5.50	274	116.834
6.50	296	116.101
7.50	317	115.752
24.50	518	104.652
25.50	530	104.956
26.50	539	104.705
28.50	555	103.961
30.50	569	103.030
48.50	570.5	96.278
50.50	680	95.689
52.50	691	95.367
54.50	701	94.955
72.50	770	90.432
75.50	781	89.883
78.50	791	89.277
96.50	844	85.917
99 50	853	85.514
101.50	858.5	85.213

TUFFBODEN VON KOMABA

(*Aufsaugung*)

Korngrösse $>1^{mm}$ $<2^{mm}$			Korngrösse $<1^{mm}$		Korngrösse $<1^{mm}$ in einer kleinen Röhre festgefüllt.	
t (*St.*)	z (*mm*)	$\frac{z}{\sqrt{t}}$	z (*mm*)	$\frac{z}{\sqrt{t}}$	z (*mm*)	$\frac{z}{\sqrt{t}}$
0.083	75	260.329	50	173.552	52	180.494
0.250	90	180.000	76	152.000	85	170.000
0.583	104	136.207	115	150.613	132	172.878
1.083	116	114.466	153	147.020	170	163.356
17.083	211	51.050	488	118.069	433	104.762
18.083	215	50.550	499	117.345	443.5	104.294
19.083	217	49.675	511	116.976	454.0	103.928
20.083	219	48.898	521	116.258	463.0	103.316
22.083	225	47.889	540	114.912	480.5	102.250
24.083	231	47.071	560	114.112	498.0	101.478
42.083	268	41.312	——	——	612.5	94.417

TUFFBODEN VON KOMABA. [Horizontale Leitung] fest eingestampft. ohne Druck.			TUFFBODEN VON KOMABA. (Aufsaugung) fest eingestampft ohne Druck.		
t (*St.*)	z (*mm*)	$\frac{z}{\sqrt{t}}$	t (*St.*)	z (*mm*)	$\frac{z}{\sqrt{t}}$
0.5	33.0	46.669	0.167	29	70.964
1.0	51.5	51.500	0.417	55	85.171
1.5	67.5	55.113	0.667	75	91.833
2.0	82.3	58.193	1.167	105	97.197
3.0	108.5	62.642	1.667	133	103.011
4.0	132.0	66.000	2.667	181	104.709
5.0	153.0	68.424	3.667	203	106.008
6.0	172.0	70.219	4.667	231	106.928
7.0	190.5	72.002	5.667	254	106.698
23.0	416.0	86.742	6.667	276	106.892
24.0	427.0	87.161	7.667	297	107.261
25.0	437.0	87.400	24.667	498	100.270
26.0	447.5	87.762	25.667	510	100.666
28.0	468.0	88.444	26.667	519	100.503
30.0	488.0	89.096	28.667	535	99.922
48.0	635.0	91.654	30.667	549	98.776
50.0	648.5	91.712	48.667	650.5	93.246
52.0	662.5	91.872	50.667	660.0	92.722
54.0	676.5	93.126	52.667	671.0	92.460
72.0	789.5	93.043	54.667	681.0	92.105
75.0	806.0	93.069	72.667	750.0	87.982
78.0	823.0	93.186	75.667	761.0	87.484
96.0	920.0	93.466	78.667	771.0	86.928
99.0	936.5	94.122	96.667	824	83.808
101.0	947.0	94.230	99.667	833	83.439
			101.667	838.5	83.160
			192.667	1019.0	73.413

TUFFBODEN VON KOMABA [Aufsaugung.] losegefüllt. ohne Druck.			TUFFBODEN VON KOMABA (Horizontale Leitung) losegefüllt ohne Druck.		
t (*St.*)	z (*mm*)	$\frac{z}{\sqrt{t}}$	t (*St*)	(z *mm*)	$\frac{z}{\sqrt{t}}$
0.167	65	159.058	0.5	42	59.397
0.417	110	170.343	1.0	72	72.000
0.667	135	165.299	1.5	101.5	82.874
1.167	173	160.144	2.0	128.0	90.510
1.667	205	158.776	3.0	175.0	101.036
2.667	256	156.757	4.0	216.5	108.250
3.667	287	149.874	5.0	256.0	114.487
4.667	318	147.200	6.0	292.0	119.208
5.667	340	142.824	7.0	326.0	123.216
6.667	362	140.198			
7.667	379	136.876			
24.667	553	111.344			
25.667	560	110.535			
26.667	566.5	109.702			
28.667	578.5	108.047			
30.667	589.5	106.451			
48.667	664.0	95.181			
50.667	671.0	94.267			
52.667	677.0	93.287			
54.667	684.0	92.511			
72.667	729.0	85.518			
75.667	735.0	84.495			
78.667	741.0	83.545			
96.667	774.5	78.774			
99.667	780.5	78.180			
101.667	784.0	77.755			
192.667	900.0	64.840			
266.667	972.0	59.522			

TUFFBODEN VON KOMABA
Horizontale Leitung ohne Drnck.

t (*St*)	z (*mm*)	$\frac{z}{\sqrt{t}}$	
1.500	48.0	39.192	lose gefüllt.
4.167	107.0	52.417	
21.167	288.5	62.707	
28.667	355.5	66.397	
49.667	494.5	70.167	
70.667	603.5	71.791	
71.667	609.0	71.938	
73.167	618.5	72.307	
74.167	624.5	72.515	
75.167	630.0	72.665	
75.667	633.0	72.770	
97.667	729.0	73.765	
98.667	734.0	73.894	
118.167	810.5	74.560	
120.167	819.0	74.712	
122.167	828.0	74.912	
123.167	832.0	74.968	
0.5	10.0	14.142	festeingestampft.
1.0	16.0	16.000	
23.0	185.0	37.697	
24.0	191.5	39.090	
43.5	277.0	41.999	
45.5	286.0	42.399	
47.5	297.0	43.093	
48.5	302.5	43.436	
93.0	528.0	54.751	
95.0	538.5	55.249	
118.5	643.5	59.114	
143.0	740.5	61.924	
164.0	816.0	63.719	

HORIZONTALE LEITUNG UNTER DRUCKERHÖHUNG.

	Undergrundlehm von Komaba.		Clay aus der Provinz Shinano.		Clay aus Gumma-Ken Kreis Nitta.		Lehm aus dem Waizen-feld in Kōtsuke.		Clay-bodem aus der Provinz Echizen.	
t	z	$\frac{z}{\sqrt{t}}$	z	$\frac{z}{\sqrt{t}}$	z	$\frac{z}{\sqrt{t}}$	z	$\frac{z}{\sqrt{t}}$	z	$\frac{z}{\sqrt{t}}$
0.167	28.0	69.379	40.0	99.113	80.0	198.226	35.0	86.724	76.0	188.311
0.333	39.5	68.416	55.5	96.129	92.5	160.215	47.0	81.406	89.0	154.153
0.500	47.5	67.175	68.0	96.166	103.5	146.371	56.0	79.196	101.5	143.543
0.667	55.0	68.930	79.5	97.367	113.0	138.396	63.0	77.159	111.0	135.946
0.833	62.0	67.918	85.5	93.660	123.5	135.287	71.0	77.777	120.5	132.001
1.000	69.0	69.000	93.0	93.000	133.0	133.000	77.0	77.000	130.0	130.000
1.167	76.0	70.361	101.5	93.969	142.0	131.464	85.0	78.693	139.0	128.687
1.333	82.0	71.014	109.5	94.830	148.5	128.605	90.0	77.942	148.0	128.172
1.500	88.0	71.852	116.5	95.122	152.0	124.107	97.0	79.200	154.5	126.149
1.667	94.0	72.811	121.5	94.112	157.0	121.610	101.5	78.621	160.0	123.934
1.833	100.0	73.855	127.0	93.796	160.5	118.537	106.0	78.286	166.0	122.599
2.000	105.0	74.246	132.5	93.692	165.0	116.673	111.0	78.489	172.0	121.622
2.333	114.0	74.631	143.5	93.943	178.0	113.255	118.5	77.576	183.0	119.802
2.667	122.0	74.709	154.0	94.305	181.5	111.145	126.5	77.465	194.0	118.799
3.000	129.0	74.478	160.0	92.376	187.0	107.964	135.0	77.942	202.5	116.913
3.333	135.0	73.943	168.5	92.291	195.5	107.080	142.3	77.941	211.0	115.569
3.667	141.5	73.896	177.5	92.696	202.5	105.752	150.0	78.335	218.0	113.846
4.000	147.5	73.750	185.5	92.750	208.5	104.250	157.0	78.500	225.5	112.750
4.333	153.0	73.499	193.0	92.714	216.5	104.003	163.0	78.303	236.0	113.371
4.667	158.0	73.130	200.0	92.582	223.5	103.460	169.5	78.463	240.5	111.329
5.000	163.0	72.896	207.0	92.573	228.0	101.965	175.5	78.486	247.0	110.462
5.333	168.0	72.746	214.0	92.665	233.0	100.892	182.0	78.808	253.5	109.769
5.667	173.0	72.674	218.5	91.788	238.0	99.980	188.0	78.976	259.5	109.011
6.000	177.5	72.464	223.5	91.243	241.5	98.592	194.0	79.200	265.0	108.186
6.333	182.5	72.518	230.5	91.592	245.5	97.552	201.0	79.809	270.0	107.287
6.667	187.0	72.425	235.0	91.015	251.0	97.212	205.0	79.396	275.5	106.700
7.333	196.0	72.378	246.3	90.952	259.5	95.827	216.5	79.948	289.0	106.720
8.000	203.0	71.771	256.5	90.686	266.5	94.222	226.0	79.903	298.0	105.359
8.667	210.2	71.401	263.0	89.336	274.0	93.073	235.3	79.927	307.5	104.452
9.333	217.0	71.030	272.0	89.033	281.0	91.979	243.5	79.704	314.5	102.944
10.000	224.5	70.993	282.5	89.334	287.5	90.915	252.5	79.847	322.7	102.046
10.667	230.0	70.422	291.5	89.252	293.0	89.711	260.0	79.607	331.5	101.499
11.333	236.5	70.332	300.5	89.365	299.0	88.919	267.0	79.402	340.0	101.111
12.000	243.0	70.148	308.5	89.056	304.0	87.757	273.5	78.953	348.0	101.459
12.667	249.3	70.046	317.0	89.068	308.5	86.680	281.0	78.953	354.5	99.605
13.333	255.0	69.835	322.5	88.320	313.3	85.801	287.5	78.735	361.0	98.864
14.000	261.0	69.755	329.0	87.929	317.0	84.722	293.5	78.441	367.0	98.085
14.667	266.0	69.456	336.0	87.734	321.0	83.817	300.0	78.334	373.5	97.526
15.667	273.0	68.971	346.5	87.541	327.0	82.614	307.3	77.637	383.0	96.762

HORIZONTALE LEITUNG UNTER DRUCKERHOHUNG.

	Undergrundlehm von Komaba.		Clay aus der Provinz Shinano.		Clay aus Gumma-Ken Kreis Nitta.		Lehm aus dem Waizenfeld in Kōtsuke.		Clay-bodem aus der Provinz Echizen.	
t	z	$\frac{z}{\sqrt{t}}$	z	$\frac{z}{\sqrt{t}}$	z	$\frac{z}{\sqrt{t}}$	z	$\frac{z}{\sqrt{t}}$	z	$\frac{z}{\sqrt{t}}$
16.667	280.0	68.585	357.0	87.446	333.2	81.617	315.3	77.231	392.0	96.020
17.667	287.0	68.360	365.0	86.938	339.5	80.865	323.5	77.053	401.0	95.512
18.667	293.7	67.977	372.5	86.216	345.5	79.967	330.5	76.494	408.5	94.547
19.667	300.0	67.647	381.0	85.913	351.5	79.261	338.0	76.217	416.0	93.804
20.667	306.0	67.310	389.0	85.568	357.5	78.639	345.0	75.889	423.5	93.156
21.667	311.5	66.922	397.5	85.398	363.5	78.093	352.0	75.622	431.2	92.638
22.667	316.5	66.478	404.0	84.856	369.5	77.610	358.0	75.194	438.5	92.103
23.667	322.5	66.291	412.0	84.689	375.0	77.083	364.0	74.839	445.5	91.575
24.667	327.0	65.840	420.5	84.666	380.0	76.511	370.0	74.498	452.7	91.149
25.667	332.5	65.630	428.5	84.579	385.0	75.993	375.5	74.118	460.0	90.797
26.667	338.0	65.453	434.5	84.140	391.0	75.716	381.5	73.877	467.0	90.434
48.667	430.5	61.710	558.0	79.986	488.0	69.952	482.0	69.092	595.5	85.362
50.667	438.5	61.604	567.0	79.656	497.0	69.821	490.0	68.839	606.0	85.135
52.667	447.0	61.594	578.7	79.741	508.0	69.999	499.0	68.759	618.0	85.157
54.667	456.5	61.742	590.0	79.797	519.5	70.262	508.0	68.707	630.0	85.207
71.667	517.0	61.070	672.0	79.380	592.0	69.929	573.3	67.720	717.0	84.695
73.667	523.5	60.993	680.0	79.226	601.5	70.081	581.0	67.692	726.0	84.586
75.667	531.0	61.044	689.0	79.208	608.5	69.954	589.0	67.713	736.0	84.612
77.667	537.5	60.996	699.0	79.316	615.5	69.841	596.0	67.629	742.5	84.252
97.667	599.0	60.611	778.0	78.724	683.5	69.161	659.0	66.682	834.5	84.441
144.667	723.0	60.111	936.5	77.861	821.0	68.259	782.0	65.016	1008.5	83.848
168.667	779.0	59.982	999.0	76.922	888.5	68.414	835.5	64.333	—	—
192.667	830.0	59.796	—	—	949.5	68.406	881.5	63.507	—	—
216.667	881.0	59.852	—	—	1006.0	68.344	927.0	62.977	—	—

TUFFBADEN VON KOMABA.
HORIZONTALE LEITUNG UNTER DRUCKERHÖHUNG.

t (*St*)	z (*mm*)	$\frac{z}{\sqrt{t}}$
0.167	53 5	130.917
0.333	64.0	110.907
0.500	72.5	102.530
0.667	79.5	97.343
0.833	84.0	92.036
1.000	88.5	88.500
1.167	92.0	85.163
1.333	96.0	83.149
1.500	98.5	80.425
1.667	102.0	79.001
1.833	105.0	77.554
2.000	108.0	76.367
2.333	113.5	74.308
2.667	119.0	72.868
3.000	124.0	71.591
3.333	128.5	70.383
3.667	133.0	69.454
4.000	137.5	68.750
4.333	141.5	67.977
4.667	145.0	67.119
5.000	148.5	66.411
5.333	152.0	65.818
5.667	156.0	65.531
6.000	160.0	65.320
6.333	163.0	64.809
6.667	166.5	64.483
7.333	172.5	63.700
8.000	177.0	62.579
8.667	182.5	61.999
9.333	187.0	61.211
10.000	192.5	60.874
10.667	197.0	60.318
11.333	201.5	59.855
12.000	206.5	59.611
12.667	210.0	59.004
13.333	214.2	58.662
14.000	218.0	58.263
14.667	221.0	57.706
15.667	226.3	57.173
16.667	232.0	56.828
17.667	236.0	56.212
18.667	341.0	55.780

TUFFBADEN VON KOMABA.
HORIZONTALE LEITUNG UNTER DRUCKERHÖHUNG.

t (*St*)	z (*mm*)	$\frac{z}{\sqrt{t}}$
19.667	246.0	55.471
20.667	250.5	55.102
21.667	255.0	54.782
22.667	259.5	54.505
23.667	263.5	54.164
24.667	267.5	53.860
25.667	272.0	53.688
26.667	276.0	53.447
48.667	347.0	49.741
50.667	353.5	49.662
52.667	360.0	49.606
54.667	367.5	49.704
71.667	414.0	48.904
73.667	419.0	48.818
75.667	424.5	48.801
77.667	429.0	48.679
97.667	476.0	48.165
144.667	569.0	47.307
168.667	613.0	47.200
192.667	651.0	46.900
216.667	689.5	46.842

QUARZSAND.
(Horizontale Leitung.)
Unter Druckerhöhung.

t (*St*)	z (*mm*)	$\frac{z}{\sqrt{t}}$
0.167	330	807.524
0.333	430	745.154
0.500	510	721.249
0.667	580	710.350
0.833	640	701.099
1.000	700	700.000
1.167	750	694.385
1.333	805	697.158
1.500	855	698.104
1.667	900	697.130
1.833	930	686.857

(Tabelle I) TUFFBODEN VON KOMABA.

Horizontalleitung nach O. Inagaki.

Ohne Druck.

t Stunde.	z Millimeter.	$\frac{z}{\sqrt{t}}$	$\frac{z}{\sqrt{t}}$ Nach (A)	Differenz.
0.25	31.75	63.500		
0.75	62.25	71.880		
1.5	94.50	77.158		
2.5	129.25	81.740		
3.5	156.75	52.865		
4.5	179.75	84.735		
10.	265.0*	83.801	83.801	0
17.	361.75	87.757	86.924	−0.833
19.5	389.5	88.205	87.629	−0.576
20.5	400.25	88.400	87.860	−0.540
21.5	410.5	88.530	88.099	−0.431
22.5	420.5	88.651	88.314	−0.317
24.5	440.25	88.943	88.713	−0.230
32.5	510.75	89.592	89.915	+0.323
40.	574.25○*	90.707	90.707	0
44.	604.25	90.885	91.048	+0.163
46.	618.75	91.237	91.204	−0.033
48.	633.50△	91.447	91.379	−0.088
59.	685.75	91.648	91.853	+0.205
64	766.25	92.032	92.255	+0.223
66	747.63°	92.236	92.345	+0.109
68.	758.88	91.988	92.432	+0.443
70.5	772.75	92.049	92.530	+0.481
78.	826.75△*	93.616	93.616	0

(Tabelle I) TUFFBODEN VON KOMABA.

Horizontalleitung nach O. Inagaki.

Ohne Druck.

$\frac{z}{\sqrt{t}}$ Nach (B)	Differenz.	$\frac{z}{\sqrt{t}}$ Nach (C)	Differenz.	$\frac{z}{\sqrt{t}}$ Nach (D)
80.290	−3.511	84.257	−0.456	83.796
84.903	−2.854	87.173	−0.584	88.727
.....	.....	87.835	−0.370	89.520
.....	.....	88.062	−0.338	89.842
.....	.....	88.278	−0.258	90.090
86.964	−1.687	88.475	−0.055	90.315
87.545	−1.398	88.843	+0.100	90.500
89.327	−0.265	89.969	+0.377	91.846
90.499	−0.208	90.707	0	92.374
91.000	−0.115	91.025	+0.140	92.609
91.231	−0.006	91.170	−0.060	92.710
91.447	0	91.330	−0.117	92.803
92.190	+0.542	91.774	+0.126	93.107
92.790	+0.758	92.155	+0.123	93.334
92.921	+0.685	92.236	0	93.382
.....	.....	.....	.....	93.427
93.196	+1.147	.....	.....	93.471
93.616	0	92.703	−0.913	93.617

(Tabelle I) TUFFBODEN VON KOMABA.

Horizontalleitung nach O. Inagaki.

Ohne Druck.

Differenz.	$\frac{z}{\sqrt{t}}$ Nach (E)		
			$[A]\ \frac{z}{\sqrt{t}} = \frac{98.449 - \frac{14.258}{\sqrt{t}}}{1 + \frac{0.38259}{\sqrt{t}}}$
−0.005	82.351	−1.444	$[B]\ \frac{z}{\sqrt{t}} = \frac{101.959 - \frac{37.801}{\sqrt{t}}}{1 + \frac{0.38259}{\sqrt{t}}}$
+0.967	87.380	−[illegible].377	
+1.315	88.235	+0.030	
+1.442	88.515	[illegible].115	$[C]\ \frac{z}{\sqrt{t}} = \frac{97.938 - \frac{11.022}{\sqrt{t}}}{1 + \frac{0.38259}{\sqrt{t}}}$
+1.560	88.768	+0.238	
+1.664	88.996	+0.345	
+1.557	89.393	+[illegible]	$[D]\ \frac{z}{\sqrt{t}} = 47.445 + \sqrt{(47.445)^2 - \frac{9296.1}{t}}$
+2.354	90.477	+0.385	
+1.667	91.030	+[illegible].373	
+1.724	91.324	+0.439	$[E]\ \frac{z}{\sqrt{t}} = 46.819 + \sqrt{(46.819)^2 - \frac{9296.1}{t}}$
+1.473	91.419	−0.182	
+1.356	91.965	+0.518	
+1.660	91.830	+0.182	
+1.302	92.061	+0.029	
+1.146	92.120	−0.115	
+1.439	92.155	+0.167	
+1.422	92.209	−0.140	
+0.001	92.347	−1.269	

TUFFBODEN VON KOMABA (TABELLE II)

DURCHSICKERUNG OHNE DRUCK.

t Stunden	z Millimeter	$\frac{z}{\sqrt{t}}$	$\frac{z}{\sqrt{t}}$ berechnet	Differenz.
0.033	28.0	153.44		
0.117	42.0	122.79		
0.200	56.0	125.51		
0.283	68.0	127.86		
0.367	78.0	128.23		
0.450	87.0	129.69		
0.617	103.0	130.81		
0.783	117.5	120.56		
0.950	131.5	134.92		
1.117	144.0	136.25		
1.367	161.0	137.70		
1.617	175.5	138.01		
1.950	194.5	139.28		
2.283	213.0	140.97		
2.617	230.0	142.18		
2.950	244.0	142.06		
3.450	265.0	142.67		
3.950	287.0	144.41		
4.450	305.5	144.82	134.92	−9.90
4.950	324.0	145.63	134.44	−8.19
5.450	341.5	146.28	139.64	−6.64
5.950	357.5	147.56	141.55	−5.01
6.450	374.0	147.26	143.28	−3.98
6.950	389.5	147.75	144.81	−2.98
7.450	404.0	148.01	146.28	−1.73
7.950	418.0	148.26	147.45	−0.81
8.450	*432.0	148.61	148.61	0
23.950	806.0	164.69	164.75	+0.06
24.950	*823.5	164.86	164.86	0
25.950	835.0	163.92	.....	
26.950	846.0	162.97	.....	
27.950	857.0	162.11	.....	
28.950	867.0	161.14	.....	
29.950	876.0	160.16	.....	
30.950	886.0	159.25	.....	

$$\frac{z}{\sqrt{t}} = \frac{189.75 - \frac{76.583}{\sqrt{t}}}{1 + \frac{0.2896}{\sqrt{t}}}$$

(Tabelle IV) TUFFBODEN VON KOMABA.

(Aufsaugung.) Durchmesser der Glasröhre=0.61 Cm.

eingepresst.

t Stunde.	x Millimeter.	$\sqrt[3]{t}$	$\sqrt[3]{t}$ Berechnet.	Differenz.	
1	53	53.000			
2	88	62.224			
3	109	62.932			
4	135	67.500			
5	148	66.187			
6	164	66.951			
22	415	88.479	104.990	+16.511	
23	416	86.740			$\sqrt[3]{t} = \dfrac{27.731 + \frac{402.59}{\sqrt{t}}}{1 + \frac{0.383}{\sqrt{t}}}$
24	417	85.120			
25	424	84.801			
26	430	84.330			
27	436	83.909			
28	437	82.585			
29	440	81.705			
47	493	71.912			
48	494	71.303			
49	495	70.714			
50	501	70.851			
51	512	71.693			
52	514	71.279			
53	515	70.741			
54	517	70.354			
71	550	65.272			
72	552	65.053			
73	554	64.841			
74	558	64.865			
75	560	64.664			
76	563	64.580			

(Tabelle IV) TUFFBODEN VON KOMABA.

(Aufsaugung.) Durchmesser der Glasröhre = 0.61 Cm.

eingepresst.

t Stunde	z Millimeter	$\frac{z}{\sqrt{t}}$	$\frac{z}{\sqrt{t}}$ Berechnet	Differenz
77	564	64.274		
78	566	65.580		
95	604	61.970		
96	605	61.748		
97	607	61.631		
98	608	61.416		
99	609	61.207	65.671	+4.464
119	681	62.427	62.444	+0.016
120	683	62.349	62.306	—0.043
121	684	62.182	62.166	—0.016
122	685	62.017	62.034	+0.017
123	686	61.604	61.840	+0.236
124	688	61.785	61.760	—0.025
125	689*	61.625	61.633	+0.008
126	690	61.469	61.482	+0.013
143	711	59.457	59.493	+0.036
144	712	59.333	59.385	+0.052
145	713	59211	59.280	+0.069
146	715*	59.174	59.174	0
147	720	59.384	.....	
148	740	60.808	.....	
149	751	61.580	.....	
150	763	62.299	.....	

Herr Inagaki hat die Druckerhöhung bei der horizontalen Leitung and Durchsickerung dadurch vermieden, dass er das Wasser nicht unmittelbar in die mit dem Boden gefüllte Röhre einfliessen, sondern er zuerst durch eine dicke Schichte feinen Quarzsandes aufsaugen liess, and dieselbe mit dem in Untersuchung befindlichen Boden in Berührung brachte.

Wie man sieht, bestätigen sich die theoretischen Schlussfolgerungen auf eine Weise, die wenig zu wünschen übrig lässt. Fast ohne Ausnahme ist die Grösse $\frac{z}{\sqrt{t}}$ bei allen drei Arten Wasserbewegung zuerst entschieden klein, und steigt dann mehr oder minder langsam auf. Sie wächst bei der Aufsaugung zu einem Maximum, um dann beständig abzunehmen. Anderes aber bei der horizontalen Leitung und Durchsickerung; die Grösse $\frac{z}{\sqrt{t}}$ nimmt dann stetig zu, wenn die Wasserzufuhr nicht unter Druckerhöhung stattfindet;—unter Druckerhöhung steigt $\frac{z}{\sqrt{t}}$ zu eniem Maximunr auf, und nimmt von da stetig ab. Selbst der grobkörnige Ouarzsand gehorcht unverkennbar diesem Gesetz, ungeachtet der geringen Anzahl der Beobachtungen, die man hatte machen können.

Der Werth der Grösse $\frac{z}{\sqrt{t}}$ wird dabei durch das Einstampfen des Bodens d. h. durch die Verringerung des Querschnittes der capillaren Hohlräume auffällig deprimirt und ist im Allgemeinen um so kleiner, je feinkörniger der Boden ist. Die Grösse $\frac{z}{\sqrt{t}}$ ist ferner unter übrigens gleichen Umständen kleiner für die Aufsaugung, als für die horizontale Leitung, und für diese wieder kleiner, als für die Durchsickerung—alles ganz so wie wir theoretisch gefolgert haben.

Nun verlangt die Theorie, dass $\frac{z}{\sqrt{t}}$ auch bei der horizontalen

Leitung und der Durchsickerung ohne Druckerhöhung nach dem Verlauf grösserer Zeit wieder anfange, abzunehmen. Bei der Durchsickerung im Tuffboden von Komaba, nach Herrn Inagaki Versuch nimmt $\frac{z}{\sqrt{t}}$ in der That gegen das Ende der Beobachtungsreihe wieder ab.—es ist aber höchst bedenklich, anzunehmen, dass das Maximum der $\frac{z}{\sqrt{t}}$ bei der Durchsickerung schon bei dieser verhältnissmässig kleinen Distanz von der Fläche der Wasserzufuhr bereits erreicht sei. Bei der horizontalen Leitung ohne Druck konnte eine Abnahme der Grösse $\frac{z}{\sqrt{t}}$ nicht constatirt werden, wahrscheinlich, weil die Länge der zur Untersuchung gebrauchten Röhre dazu zu kurz gewesen war.

Um den Verlauf der Grösse $\frac{z}{\sqrt{t}}$ für die drei Arten Wasserbewegung im Boden etwas genauer zu verfolgen, habe ich zwei Böden in Untersuchung genommen.—der eine war der magere stark eisenhaltige Tuffboden von Komaba und der andere ein sowohl durch Fruchtbarkeit als durch die Gleichmässigkeit der Korngrösse ausgezeichnter lehmiger Sandboden aus der Provinz Mito.

(Tabelle III) TUFFBODEN VON KOMABA.

(Aufsaugung.) Dnrchmesser der Glasröhre = 1.61 Cm

losegefüllt

t Stunde	z Millimeter	$\frac{z}{\sqrt{t}}$	$\frac{z}{\sqrt{t}}$ berechnet nach (A)	Differenz
1	55	55.000		
2	96	67.881		
3	115	66.396		
4	139	68.500		
5	151	67.529		
6	169	68.994		
22	416	88.671		
23	417	86.950		
24	418	85.324		
25	430	86.001		
26	436	81.643		
27	438	82.368		
28	444	83.908		
29	447	83.006	77.775	−5.221
47	504	73.516	71.702	−1.814
48	507	73.179	71.519	−1.660
49	510	72.857	71.246	−1.611
50	511	72.265	71.041	−1.041
51	512	71.694	70.814	−0.880
52	514	71.279	70.606	−0.673
53	516	70.878	70.404	−0.474
54	518	70.490	70.207	−0.383
71	574	68.121	67.513	−0.608
72	575	67.764	67.389	−0.375
73	577	67.534	67.288	−0.256

(Tabelle III) TUFFBODEN VON KOMABA.

(Aufsaugung.) Durchmesser der Glasröhre = 1.61 Cm.

losegefüllt

$\frac{z}{\sqrt{t}}$ berechnet nach (B)	Differenz	
97.882	+9.211	
80.990	+7.474	
73.928	+5.807	[A] $\frac{z}{\sqrt{t}} = \frac{48.213 + \frac{188.51}{\sqrt{t}}}{1 + \frac{0.383}{\sqrt{t}}}$

(Tabelle III) TUFFBODEN VON KOMABA.

(Aufsaugung.) Durchmesser der Glasröhre = 1.61 Cm.

losegefüllt

t Stunde	z Millimeter	$\frac{z}{\sqrt{t}}$	$\frac{z}{\sqrt{t_0}}$ berechnet nach (B)	Differenz
74	580	67.423	67.138	−0.285
75	583	67.316	67.018	−0.298
76	584	66.988	66.922	−0.066
77	586*	66.781	66.781	0
78	588	66.578	66.664	+0.086
95	634	65.049	65.483	+0.434
96	637	65.013	64.935	−0.065
97	639*	64.880	64.853	−0.027
98	641	64.750	64.750	0
119	731	67.010		
120	732	66.822		
121	734	66.757		
122	736	66.635		
123	738	66.543		
124	739	66.364		
125	740△	66.187		
126	741	66.013		
143	770	64.390		
144	771	64.249		
145	773	64.193		
146	775	64.140		
147	781	64.415		
148	782	64.281		
149	784	64.227		
150	785△	64.094		

(Tabelle III) TUFFBODEN VON KOMABA.

(Aufsaugung.) Durchmesser der Glasröhre = 1.61 Cm

losegefüllt

$\frac{z}{\sqrt{t}}$ berechnet nach (B)	Differenz	
		[B] $\frac{z}{\sqrt{t}} = \frac{41.407 + \frac{302.35}{\sqrt{t}}}{1 + \frac{0.383}{\sqrt{t}}}$
70.238	+5.189	
69.268	+4.518	
66.780	−0.230	
66.675	−0.147	
66.576	−0.179	
66.475	−0.160	
66.379	−0.164	
66.278	−0.086	
66.187	0	
66.085	+0.072	
64.623	+0.233	
64.543	+0.294	
64.460	+0.267	
64.365	+0.225	
64.313	−0.102	
64.236	−0.045	
64.164	−0.063	
64.094	0	

(Tabelle V) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.

(Aufsaugung) Durchmesser der Röhre = 1.43. Cm

losegefüllt

t Stunde	z mm	$\frac{z}{\sqrt{t}}$	$\frac{z}{\sqrt{t}}$ berechnet	Differenz
1	64.0	64.000		
2	99	70.003		
3	124	71.591		
4	143	71.500		
5	160	71.553		
6	174	71.035		
7	186	72.569		
8	192	67.881		
25	331	66.200		
26	335	65.698		
27	342	65.819		
28	348	65.766		
29	354	65.736		
30	358	65.361		
31	365	65.556		
32	378	66.821		
49	439	62.714	74.070	+11.356
50	441	62.366		
51	444	62.171		
52	448	62.127		
53	452	62.087		
54	455	61.918		
55	460	62.027		
56	464	62.005		
73	513	60.043		
74	516	59.985		
75	519	59.929		
76	523	59.991		
77	527	60.058		
78	529	59.898		
79	532	59.855		
80	534	59.704		
97	571	57.977		
98	573	57.880		
99	576	57.890		
100	578	57.800	62.742	+4.942
101	580	57.712		
102	582	57.626		
146	660	57.747		
147	661	54.518		

(Tabefle V) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.

(Aufsaugung) Durchmesser der Röhre = 1.45. Cm losegefüllt

t Stunde	z mm	$\frac{z}{\sqrt{t}}$		
148	662	54.416		
149	665	54.478		
150	666	54.378		
151	668	54.361		
152	670	54.344		
153	672	54.327		
170	693	53.150		
171	699	53.072		
172	696	53.070		
173	697	52.992		
174	698	52.939		
175	699	52.840		
176	701	52.840		
177	703	52.840	53.685	+0.845
194	720	51.693	52.448	+0.755
195	721	51.641		
196	723	51.644		
197	724	51.583		
198	725	51.524		
199	726	51.465	52.112	+0.647
200	728	51.478	52 050	+0.572
201	729	51.420	51.983	+0.573
218	746	50.593	50.947	+0.354
219	747	50.478	50.894	+0.416
220	748	50.429	50.835	+0.406
221	749	50.383	50.776	+0.393
222	750	50.336	50.722	+0.386
223	751	50.291	50.667	+0.376
224	752	50.246	50.614	+0.368
225	754	50.267	50.559	+0.292
242	770	49.497	49.676	+0.179
243	771	49.459	49.627	+0.168
244	772	49.423	49.582	+0.159
245	773	49.385	49.531	+0.156
246	774	49.348	49.481	+0.133
247	775	49.297	49.427	+0.202
248	776	49.276	49.393	+0.117
249	777	49.240	49.343	+0.103
266	791	48.501	48.581	+0.080
267	792	48.470	48.538	+0.068

$$\frac{z}{\sqrt{t}} = \frac{25.534 + \frac{308.15}{\sqrt{t}}}{1 + \frac{0.255}{\sqrt{t}}}$$

(Tabelle V) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.

(Aufsaugung) Durchmesser der Röhre = 1,43, Cm

losegefüllt

t Stunde	z mm	$\frac{z}{\sqrt{t}}$	$\frac{z}{\sqrt{t}}$ berechnet	Differenz
268	793	48.439	48.494	+0.055
269	794	48.410	48.454	+0.044
270	795	48.383	48.413	+0.030
271	796	48.364	48.369	+0.005
314	828	46.727	46.771	+0.044
315	829	46.709	46.736	+0.027
316	830	46.692	46.707	+0.015
317	831	46.673	46.686	+0.013
318	832	46.656	46.638	—0.018
319	833	46.639	46.605	—0.034
320	834	46.623	46.571	—0.052
321	835	46.606	46.555	—0.041
338	847	46.070	46.013	—0.057
339	848	46.057	45.987	—0.170
340	849	46.044	45.956	—0.088
341	850	46.030	45.925	—0.105
342	851	46.017	45.895	—0.222
343	852	46.003	45.865	—0.138
344	853	45.991	45.840	—0.151
345	854	45.978	45.809	—0.169
362	864	45.411	45.333	—0.077
363	865	45.412	45.312	—0.100
364	866	45.391	45.277	—0.114
365	867	45.381	45.253	—0.128
366	868	45.371	45.244	—0.127
367	669	45.362	45.198	—0.174
368	869.5	45.326	45.174	—0.152
369	870.0	45.291	45.144	—0.147
410	894.△	44.152	44.152	0
411	894.5	44.122	44.129	+0.007
412	895.	44.093	44.110	+0.017
413	896.	44.090	44.088	—0.002
414	896.5	44.061	44.071	+0.010
415	897	44.032	44.043	+0.011
416	898	44.028	44.019	—0.009
417	899	44.024	43.998	—0.026
434	908	43.586	43.639	+0.053
435	908	43.536	43.622	+0.086
436	910	43.581	43.591	+0.010
439	911	43.579	43.574	—0.005

(Tabelle V) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.

(Aufsaugung) Durchmesser der Röhre = 1.43. Cm

losegefüllt

t Stunde	z mm	$\frac{z}{\sqrt{t}}$	$\frac{z}{\sqrt{t}}$ berechnet	Differenz
438	911.5	△43.553	43.553	0
439	912	43.527	43.532	—0.005
482	931	42.406	42.723	+0.317
483	931.5	42.385	42.704	+0.319
484	932	42.365	42.686	+0.321
485	933	42.365	42.668	+0.303
486	934	42.367	42.649	+0.282
487	934.5	42.347	42.637	+0.290
488	935	42.325	42.619	+0.294
489	936	42.328	42.601	+0.273
501	943	41.922	42.316	+0.384
507	943.5	41.903	42.299	+0.396
508	944	41.883	42.282	+0.399
509	944.5	41.864	42.265	+0.401
510	945	41.846	42.248	+0.402
511	946	41.849	42.232	+0.386
512	947	41.852	42.215	+0.463
513	947.5	41.833	42.199	+0.366
530	953	41.395	42.029	+0.624
531	953.5	41.378	41.916	+0.538
532	954	41.362	41.903	+0.541
533	955	41.366	41.890	+0.524
534	956	41.370	41.875	+0.505
535	956.5	41.352	41.860	+0.508
536	957	41.336	41.844	+0.508
537	957.5	41.319	41.828	+0.509
554	964	40.957	41.578	+0.621
555	965	40.962	41.565	+0.634
556	965.5	40.946	41.552	+0.606
557	966	40.931	41.536	+0.605
558	967	40.936	41.521	+0.585
559	968	40.941	41.509	+0.568
560	968.5	40.927	41.494	+0.567
561	969	40.911	41.479	+0.567

(Tabelle VI) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.

(Aufsaugung) Durchmesser der Röhre = 0.77 Cm.

eingepresst.

t Stunde	z mm	$\frac{z}{\sqrt{t}}$
1	64	64.000
2	98	69.296
3	124	71.591
4	144	72.000
5	162	72.448
6	175	71.443
7	183	69.167
8	194	68.588
25	332	66.400
26	347	68.053
27	352	67.742
28	358	67.655
29	365	67.778
30	370	67.552
31	375	67.352
32	386	68.235
49	448	64.000
50	451	63.781
51	455	63.712
52	459	63.652
53	463	63.597
54	465	63.279
55	469	63.240
56	473	63.208
73	523	61.212
74	527	61.263
75	529	61.084
76	532	61.024
77	536	61.083
78	539	61.029
79	541	60.868
80	543	60.710
97	579	58.789
98	581	58.689
99	584	59.403
101	587	58.409
102	589	58.319
146	655	54.207
147	658	54.271
148	661	54.334

$$\frac{z}{\sqrt{t}} = \frac{23.422 + \frac{406.44}{\sqrt{t}}}{1 + \frac{0.435}{\sqrt{t}}}$$

(Tabelle VI) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.

(Aufsaugung) Durchmesser der Röhre=0.77 Cm.

eingepresst.

t Stunde	z mm	$\frac{z}{\sqrt{t}}$	$\frac{z}{\sqrt{}}$=berechnet	Differenz
149	662	54.232		
150	664	54.215		
151	666	54.168		
152	667	54.102		
153	668	54.004	54.368	+0.364
170	687	52.690	52.830	+0.140
171	689	52.689	52.747	+0.058
172	690	52.615	52.665	+0.050
173	691	52.536	52.584	+0.048
174	693	52.536	52.502	−0.034
175	694	52.462	52.422	−0.040
176	695	52.387	52.342	−0.045
177	697	52.389	52.264	−0.125
194	712	51.119	51.012	−0.107
195	713	51.059	50.944	−0.115
196	714	51.000	50.872	−0.128
197	715	50.942	50.804	−0.138
198	716	50.884	50.739	−0.145
199	717	50.826	50.673	−0.147
200	718	57.770	50.603	−0.167
201	719	50.714	50.538	−0.176
218	734	49.713	49.489	−0.224
219	735	49.667	49.435	−0.232
220	736	49.621	49.379	−0.242
221	737	49.576	49.318	−0.258
222	738	49.531	49.263	−0.268
223	740	49.554	49.207	−0.347
224	741	49.511	49.145	−0.366
225	742	49.467	49.095	−0.372
242	755	48.533	48.199	−0.334
243	756	48.498	48.153	−0.345
244	757	48.463	48.105	−0.358
245	758	48.429	48.054	−0.375
246	759	48.381	48.006	−0.385
247	760	48.343	47.947	−0.396
248	761	48.324	47.910	−0.414
249	762	48.289	47.860	−0.429
266	771	47.273	47.085	−0.188
267	772	47.246	57.045	−0.201
268	773	47.218	47.001	−0.127

(Tahelle VI) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.

(Aufsaugung) Durchmesser der Röhre = 0.77 Cm.

eingepresst.

t Stunde	z mm	$\frac{z}{\sqrt{t}}$	$\frac{z}{\sqrt{t}}$ berechnet	Differenz
269	774	47.191	46.958	—0.233
270	775	47.165	46.915	—0.250
271	776	47.139	46.874	—0.265
314	806	47.485	45.250	—0.235
315	807	45.469	45.216	—0.253
316	808	45.454	45.180	—0.274
317	809	45.438	45.148	—0.290
318	810	45.422	45.114	—0.308
319	811	45.408	45.092	—0.316
320	812	45.393	45.049	—0.344
321	813	45.377	45.016	—0.361
338	825	44.874	44.475	—0.399
339	826	44.862	44.448	—0.414
340	827	44.851	44.417	—0.434
341	827.5	44.812	44.389	—0.423
342	828	44.773	44.358	—0.415
343	829	44.761	44.326	—0.375
344	829.5	44.724	44.295	—0.429
345	830	44.686	44.269	—0.417
362	840	44.150	43.783	—0.367
363	841	44.152	43.762	—0.390
364	842	44.133	43.729	—0.404
365	843	44.125	43.700	—0.425
366	843.5	44.090	43.686	—0.304
367	844	44.057	43.648	—0.309
368	844.5	44.023	43.616	—0.307
369	845	43.990	43.693	—0.297
410	866	42.769	42.579	—0.190
411	867	42.766	42.556	—0.210
412	868	42.763	42.545	—0.218
413	869	42.761	42.513	—0.248
414	869,5	42.734	42.488	—0.246
415	870	42.707	42.470	—0.237
416	871	42.704	42.446	—0.258
417	871.5	42.678	42.423	—0.255
434	879	42.194	42.054	—0.140
435	880	42.193	42.032	—0.161
436	881	42.193	42.004	—0.189
437	882	42.192	41.991	—0.202
438	883	42.191	41.979	—0.212

(Tabelle VI) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.

(Aufsaugung) Durchmesser der Röhre=0.77 Cm.

eingepresst.

t Stunde	z mm	$\frac{z}{\sqrt{t}}$	$\frac{z}{\sqrt{t}}$ berechnet	
439	883.5	42.017	41.949	−0.122
482	902	41.086	41.117	+0.031
483	902.5	41.066	41.103	+0.037
484	903	41.046	41.084	+0.038
485	904	41.049	41.061	+0.012
486	905	41.052	41.052	+0.002
487	905.5*	41.033	41.033	0
488	906*	41.013	41.013	0
489	907	41.017	40.995	−0.022
506	914	40.633	40.709	+0.076
507	914.5	40.614	40.687	+0.073
508	915	40.597	40.671	+0.074
509	915.5	40.579	40.653	+0.074
510	916	40.562	40.636	+0.074
511	916.5	40.543	40.627	+0.084
512	917	40.527	40.607	+0.080
513	918	40.530	40.587	+0.057
530	926	40.223	40.315	+0.092
531	926.5	40.206	40.299	+0.093
532	927	40.191	40.283	+0.092
533	927.5	40.174	40.270	+0.096
534	928	40.159	40.254	+0.095
535	928.5	40.142	40.237	+0.095
536	929	40.127	40.223	+0.096
537	929.5	40.111	40.206	+0.095
554	935	39.725	39.952	+0.227
555	935.5	39.709	39.937	+0.228
556	936	39.695	39.925	+0.230
557	937	39.702	39.910	+0.208
558	937.5	39.687	39.892	+0.205
559	938	39.673	39.879	+0.206
560	938.5	39.659	39.864	+0.205
561	939	39.645	39.843	+0.203

Der Verlauf der Grösse $\frac{z}{\sqrt{t}}$ ist wieder ein solcher, wie die Theorie es verlangt, wenn gleich das Minimum in der Nähe der Fläche der Wasserzufuhr nicht zu constatieren ist. Das innigere Gefüge der Bodentheilchen drückt wieder den Werth von $\frac{z}{\sqrt{t}}$ herab und es steigt zu einem Maximum auf, um dann langsam und stetig abzunehmen. Für den Tuffboden von Komaba wächst es bei der 119sten Stunde wieder um einige Einheiten. Da aber dieses in den beiden Röhren gleichzeitig geschieht, so kann dieses entweder durch die zufällig in derselben Höhe der beiden Röhren herrschende Lockrheit der Füllung veranlasst sein, oder durch eine starke Tenperaturerniederigung der Decembernacht, welche zwischen der 99sten und 119sten Stunde lag, indem das aufgesogene Wasser theilweise fror und so den Boden auflckerte. Indess.—es mag dem sein, wie es wolle,—wir werden jedenfalls in diesem zum zweiten Male wiederkehren den Wachsen des $\frac{z}{\sqrt{t}}$ für den Komababoden nwr den Effect einer zufällig einspielenden Ursache erblicken dürfen.

Es lässt sich hiernach vermuthen, dass die Bedingung unter der die Gleichung

$$\frac{z}{\sqrt{t}} = \frac{a - \frac{b}{\sqrt{t}}}{1 + \frac{c.}{\sqrt{t}}}$$

abgeleitet wurde, wohl angenährt für die Grenzschichte der Verdunkelung erfüllt sei, dass diese Gleichung durch passende Werthe der Constanten *a, b, c,* wenn auch innerhalb gewisser Zeitraüme die Beobachtung wiedergeben könne

Ich habe diese Constanten für die horizontale Leitung im Tuffboden von Komaba mittelst der von Hrrn Inagaki beobachteten Daten (Tabelle I) berechnet und so gefunden

$$a=98.449 \qquad b=14.258$$
$$c.=0.38259$$

indem ich ganz willkürlich die drei mit * bezeichneten Daher benutzte. Die mit diesen Constanten berechneten Werthe des $\frac{z}{\sqrt{t}}$ sind unter der Rubrik $\left(\frac{z}{\sqrt{t}}\right.$ berechnet$\left.\right)$ eingetragen.

Wie man sieht, stellt die in Rede stehende Gelichung ziemlich leidlich die Beobachtung dar, denn die Differenz ist und bleibt unter dem Komma. Indessen wächst die Differenz negativ für kleinere t, und positiv für grössere t, er ist dies eine Fingerzeige dafür, dass diese Gleichung für eine Zeitdifferenz $78-10=68$ Stunden eigentlich nicht mehr gilt, dass b nicht constant geblieben war. Wenn wir die zeitlich nicht allzu weit abstehenden etwa mit Δ bezeichneten Daten herausgreifen und darum für C den oben bestimmten Werth setzen, so erhalten wir

$$a=101.95 \qquad b=37.801$$

a ist also ungefähr dieselbe geblieben, während b sich bedeutend verändert hat. Wie aus der Tabelle I ersichtlich, is; die Übereinstimmung zwischen Beobachtung und Berechnung eine grössere geworden, wogegen die Abweichung so wohl für kleniere, als für grösere t. allerdings bedeutender geworden ist. Indessen; die auffallend grosse Differenz für $t=78$ legt die Vermuthung nah, dass die Gleichung nicht mehr recht für eine solche Zeit gilt. Wenn wir daher zur Bestimmung der Constanten a, b, die mit o bezeichneten Daten wählen, so erhalten wir

$$a=97.938 \qquad b=11.022$$

a ist also wieder fast dieselbe geblieben, und b hat sich auch um ein Paar Einheiten verringert. Die Übereinstimmung ist denn grösser geworden, und selbst für die Zeiten, für die mittelst der letzthin bestimmten Constanten berechneten

Werthe der $\frac{z}{\sqrt{t}}$ Abweichungen von mehereren Einheiten zeigen, sind dieselben jetzt nur Brüche geworden.

Die Grösseninterval le, innerhalb deren $\frac{z}{\sqrt{t}}$ sich bewegt, sind aber zu klein, als dass man hätte mit Fug die Erage verneinen können, ob man ebenso gut die Beobachtung durch eine willkürlich angenommene, langsam zunehmende Funktion wiedergeben könne. Eine solche Funktion ist

$$\frac{z}{\sqrt{t}} = a + \sqrt{a^2 - \frac{b}{t}}$$

ein Ausdruck, der mit dem theoretisch abgeleiteten die Eigenschaft gemein hat, mit wachsendem t gegen eine Grenze zu convergieren.

Benutzt man zur Bestimmung der zwei Constuaten die mit * bezeichneten Daten, so findet man

$$a = 47.445 \qquad b = 9296.1$$

Die mit diesen Constanten berechneten Werthe sind unter der Rubrik $\left(\frac{z}{\sqrt{t}}\right.$ berechnet nach $D\left.\right)$ eingetragen. Wie man sieht, stellt der angenommene Ausdruck für $\frac{z}{\sqrt{t}}$ die Beobachtung entscheiden schlechter dar, als der theoretisch abgeleitete, denn die Differenzen sind alle positiv, und gross. und fast constant, als wenn man a etwas abcorrigieren müsste, um eine bessere Übereinstimmung zu erzielen. Wenn wir nun $a = 47.445 + s$ setzen, und smittelst der Methode der kleinsten Quadrate bestimmen, so ergiebt sich in erster Annährung

$$a = 46.819.$$

Die mittelst dieser Constante berechneten Werthe sind unter der Rubrik ($\frac{z}{\sqrt{t}}$ berechnet nach E) eingetragen. Wenn gleich die Übereinstimmung zwischen Beobachtung und Berechnung grösser geworden ist, so herrscht das positive Vor-

zeichen der Differenz in der Mitte vor, und die Differenz selbst wird für die extremen Werth von t so gross, dass wir wohl, berechtigt sind, daraus zu schliessen, dass das Intervall, innerhalb dessen der in Rede stehende Ausdruck die Beobachtung wiedergiebt, viel enger ist, als der theoretisch abgeleitete Ausdruck, dass daher der angenommene Ausdruck wieder schlechter die Beobachtung darstellt, als der theoretisch abgeleitete Ausdruck, von dem wir wenigsten wissen, dass er nur für mässig grosses t gelten würde.

Ich habe a, b, c auch für den Versuch der Herrn Inagaki in Bezug auf die Durchsickerung in Komababoden berechnet, wobei ich c zunächst für verschwindend klein ansah und a und b bestimmte, und dann c mithelst eines anderen Werthes des $\frac{z}{\sqrt{t}}$ berechnete, um dann a und b rückwärts mittelst der beiden mit * bezeichneten Daten zu bestimmen So erhielte ich

$$a=189.75 \qquad b=-76.583 \qquad c=0.2896.$$

Die mit diesen Constanten berechneten Werthe des $\frac{z}{\sqrt{t}}$ sind unter der Rubrik $\left(\frac{z}{\sqrt{t}} \text{ berechnet}\right)$ Tabelle (II) eingetragen. Da aber Herr Inagaki unglücklicherweise seine Beobachtungen gerade in den Stunden 8—23 hatte aussetzen müssen, so können wir hier nichts, als auf die regelmässige Zunahme der Differenzen mit kleiner werdendem t hinzuweisen und zu vermuthen, dass eine leidlich gute Übereinstimmung zwidchen Beobachtung und Berechnung sich zwischen der 8ten und 23sten Stunde gezeigt haben müsste.

Ich habe die Constanten in Bezug auf die Aufsaugung in Komababoden berechnet, indem ich von vorn herein $C=0.383$ setzte, und a und b mittelst der mit* bezeichneten Daten (Tabelle III) bestimmte, und fand für die lose Füllung

$$a=48.213 \qquad b=188.51$$

Wie man sieht, stellt der in Rede stehende Ansdruck mit diesem Werthe der Constanten die Beobachtung durch 20 Stunden leidlich dar. Für $t > 119$ giebt der Ausdruck $\frac{z}{\sqrt{t}}$ natürlich zu klein. Berechnet man a und b mittelst der mit Δ bezeichneten Date unter Beibehaltung des Werthes für c, so findet man.

$$a = 41{,}407 \qquad b = 302.35$$

Mit diesen Constanten stellt der Ausdruck die Beobachtung für $t > 119$ auch leidlich dar. Für die compaktere Füllung lassen sich die Constanten, mittelst der mit * bezeichneten Daten (Tabelle IV) zu

$$a = 27.731 \qquad b = 402.59$$

bestimmen, und zwar unter Bei behaltung des Werthes für c, was eigentlich durch nichts gerechtfertigt ist, wenn c mit $\frac{1}{\varkappa\sqrt{\pi}}$ identisch wäre. Trotzdem sieht man, dass der fragliche Ausdruck mit diesen Constanten ziemlich genau die Beobachtung für $t > 119$ wiedergiebt Die Constante a erscheint dabei, was besonders zu bemerken ist, gegen das a für die lose Füllung stark deprimirt, wie die Theorie von a verlangen würde, wenn a mit $\frac{2a}{\sqrt{\pi}}$ hätte identificirt werden können.

Die Constanten für die Aufsaugung im Mitoboden (Tabelle V und VI) sind auf dieselbe wenig genaue Weise, wie die Constanten für die Durchsickerung in Komababoden ermittelt worden, Ihre Werthe sind

$$\left.\begin{array}{ll} a = 25.534 & b = 388.15 \\ c = 0.255 & \end{array}\right\} \text{ für die lose Füllung}$$

$$\left.\begin{array}{ll} a = 23.422 & b = 406.44 \\ c = 0.435 & \end{array}\right\} \text{ für die compakte Füllung.}$$

Die zur Bestimmung dieser Constanten benutzten Daten sind mit * bezeichnet. Die für die Constanten der compakten Füllung benutzten Daten sind absichtlich zeitlich so dicht

an einander gewählt, um zu sehen, welchen Effect die Wahl ,eines kleinen Werthintervalles der Daten auf die Constanten ausüben würde. Zuerst bemerken wir, dass die festere Füllung des Bodens wieder eine Depression der Constanten herbeigeführt hat,-ohne sonderlich b zu beeinflüssen. Die Genauigkeit, mit der der in Rede stehende Ausdruck die Aufsaugung des Wassers im Mito-Boden darstellt, ist wider alles Erwarten trotz der wenig genauen Methode, die Constanten zu bestimmen, trotz dem dazu Daten herausgegriffen worden sind, welche zeitlich, und der Grösse nach so wenig von einander abstehen. Dass ich bei der Wahl der Beobachtungsdaten nur zufäilig so glücklich gewesen war, lässt sich wohl kaum annehmen.

Dass die Differenzen mit wachsenden t positiv zunehmen, war auch theoretisch zu erwarten, da $\frac{z}{\sqrt{t}}$ doch mit wachsendem t stärker abnehmen muss, als der in Rede stehende Ausdruck es giebt, der doch nur gegen die constante Grenze a convergiert. Das Verhalten der Differenzen bei abnehmendem t ist bemerkenswerth ; sie steigen zuerst negativ zu einem Maximum auf, und nachden sie dann gegen Null wieder abgenommen haben, wachsen sie positiv. Auch dieses Verhalten der Differenzen war theoretisch vorauszusehen, da $\frac{z}{\sqrt{t}}$ ja mit abnehmendem t nur zu einem Maximum wächst, während der bedingungsweise giltige Ausdruck dafür in's Unendliche zunehmen kann.

Nach dieser Erörterungen glaube ich zu dem Schluss berechtigt zu sein, dass der in Rede stehende Ausdruck mit ziemlicher Genauigkeit alle drei Arten Wasserbewegung in einem Boden innerhalb gewisser Distanzen von der Fläche der Wasserzufnhr darzustellen vermag.

Man könnte sonach das Vermögen eines Bodens, Wasser fortzupflanzen, durch die Bestimmung der Constante a numerisch charakterisiren, wenn a nur mit $\frac{2a}{\sqrt{\pi}}$ identificirt wer-

den dürfte. Es ist dieses wahrscheinlich angenährt gestattet, wie das Verhalten dieser Constante gegen die Compaction der Bodentheilchen darthut, wie der Umstand dass a ziemlich unverändert bleibt, welche von den Beobachtungsdaten auch dazu benutzt werden mögen, wenn t nur nicht zu gross oder zu klein und das Zeitintervall nicht all zu klein gewählt wird. Es ist aber eine nur rohe Annährung in der Bestimmung der Constante a, in so fern, als c durchaus nicht mit $\frac{1}{\varkappa\sqrt{\pi}}$ identificiert werden kann. Der Ausdruck

$$\frac{z}{\sqrt{t}} = \frac{a + \frac{b}{\sqrt{t}}}{1 + \frac{c}{\sqrt{t}}}$$

ist nämlich unter der Bedingung abgeleitet worden, dass $\varkappa\sqrt{t} - \frac{z}{2a\sqrt{t}}$ unendlich klein oder wenigstens ein kleiner, Bruch sei. Wenn wir nun c mit $\frac{1}{\varkappa\sqrt{\pi}}$ identificiren und $\varkappa$ daraus berechnen, so ergiebt sich für $\varkappa$ ein so grosser Werth, dass $\varkappa\sqrt{t} - \frac{z}{2a\sqrt{t}}$ nur für kleine Werthe von t auf kleine Brüche herabsinkt. Für den Tuffboden von Komaba ist z. B. c=0.383. Identificirt man dieses c mit $\frac{1}{\varkappa\sqrt{\pi}}$, so erhält man

$$\varkappa = 1.47312\left[\frac{1}{\sqrt{\text{Stunde}}}\right]$$

oder

$$\varkappa = 0.024552\left[\frac{1}{\sqrt{\text{Secunde}}}\right]$$

mithin

$$\varkappa = 0.00060278\left[\frac{1}{\text{Secunde}}\right]$$

Es ist entschieden zu gross für den Reibungscoefficienten einer Flüssigkeit, wie Wasser, wenn gleich es nicht in Abrede-

gestellt werden kann, dass die Reibung einer tropfbaren Flüssigkeit an einem so unregelmässig gestalteten Körper, wie ein Bodentheilchen wahrscheintich eine ausseroraentlich grosse sein möchte.

Der in Rede stehende Ausdruck hat demnach genau genommen fast nur den Werth eines empirischen, der mit leidlicher Genauigkeit der Beobachtung angepasst werden kann und verdient in so fern den Vorzug vor jedem empirisch angenommen Ausdruck, als er aus einer theoretisch aufgestellten Formel abgeleitet wurde, welche wenigstens qualitativ die betreffende Erscheinung fast in allen Instanzen wiedergiebt.

Wie sehen somit, dass die Giltigkeit des Ausdrucks für $\frac{z}{\sqrt{t}}$ durch so ziemlich grosses Zeitintervall nur auf die Kosten der physikalischen Bedeutung der Constanten geschehen ist, dass seine Giltigkeit in Wahrheit auf ein bei Weitem kleineres Zeitintervall beschränkt ist. Nun soll $\varkappa\sqrt{t} - \frac{z}{2a\sqrt{t}}$ unendlich klein sein. Wenn wir annehmen, dass diese Differenz so klein sei, dass sie trotz der Multiplication mit $\frac{2a}{\sqrt{t}}$ nicht aufhört, ein kleiner Bruch zu sein, so wird jene Bedingung erfüllt wenn $2a\varkappa - \frac{z}{t}$ einem kleinen Bruch gleich ist. Nun verändert sich $\frac{z}{t}$ für grosses t durch geraume Zeit hindurch im allgemeinen so langsam, dass man durch ein ziemlich grosses Zeitintervall $\frac{z}{t}$ als eine Constante ansehen kann. Greift man einen Werth für $\frac{z}{t}$ bei grossem t heraus und setzt ihn geradezu $= 2a\varkappa$. und bestimmt mittelst zweier Daten a und b., so erhält man eine Gleichung, bei der die Erfüllung der Bedingung gesichert ist, under der sie abgeleitet worden ist.

So erhalten wir, indem wir für die Aufsaugung in Mito-Boden bei loser Füllung rund

$$2a\varkappa = 3$$

setzen, weil in der Nähe von $t=410$ $\frac{z}{t}$ etwas grösser ist, als 2. nämlich $=2.1814$, und a, b mittelst der Werthe von $\frac{z}{\sqrt{t}}$ für $t=438$ und $t=410$

$$a=20.396 \qquad b=782.64$$
$$c=6.799$$

a hat sich also nur etwas verringert, während b einen mehr als zweifachen Werth erhalten hat. Man findet aus dem Werthe für a und c

$$\varkappa=0.982983\left[\frac{1}{\sqrt{\text{Stunde}}}\right]$$

oder

$$\varkappa=0.0013863\left[\frac{1}{\sqrt{\text{Secunde}}}\right]$$

$$\varkappa^2=0.0000018138\left[\frac{1}{\text{Secunde}}\right]$$

Dieses ist von einer Grössenordnung, wie wir bei dem Reibungscoefficienten einer Flüssigkeit wie Wasser hätten gewärtig sein können. Indem wir $\frac{z}{\sqrt{t}}$ mittelst der obenstehenden Werthe für a, b, c berechnen, finden wir

t	z	$\frac{z}{\sqrt{t}}$ berechnet	Differenz	$\varkappa\sqrt{t}-\frac{z}{2at\sqrt{t}}$
219	747	50.215	−0.679	−0.1610
225	754	49.932	−0.335	−0.1365
245	773	49.077	−0.308	−0.0587
266	791	48.581	+0.081	+0.0186
314	828	46.659	+0.112	+0.1797
345	854	45.777	−0.201	+0.2526
362	864	45.228	−0.105	+0.3248
410	894	44.152	0	+0.4589
438	911,5	43.553	0	+0.5309
482	931	42.792	+0.386	+0.6381
506	943	42.378	+0.456	+0.6944
530	953	41.991	+0.596	+0.7489
561	969	41.519	+0.608	+0.8170

Wie man sieht, ist die Differenz zwischen Beobachtung und Berechnung für grössere und kleinere Werthe von t durchgängig etwas grösser geworden, als wenn man die Constanten ohne jede Rücksicht auf jene Bedingung bestimmt hätte, aber entschieden kleiner, als man hätte eigentlich erwarten können, da es doch durchaus willkürlich ist gerade für $t=410$, $2a\varkappa=3$ zu setzen. Dabei nimmt die Differenz in demselben Sinne zu, wie $\varkappa\sqrt{t}-\frac{z}{2a\sqrt{t}}$ wächst und das Minimum derselben entspricht der Stelle, wo $\frac{z}{t}$ viel genauer $=3$ ist, wie denn $\frac{796}{266}=2.8393$ ist. Ich glaube hieraus schliessen zu dürfen, dass der Ausdruck auch bei einem Werth von c, der theoretisch zu erwarten war, die Bewegung der Grenzschichte der Verdunkelung durch ziemlich grosses Zeitintervall darzustellen vermag und wie die Vertheilung der Differenzen zwischen Beobachtung und Berechnung der Grösse und dem Vorzeichen nach beschaffen sind, dieselben geradezu für eine Fingerzeige halten zu können, dass die für C gefundene Funktion die Wasserbewegung in einem Boden im Grossen und Ganzen richtig darstellt.

Wenn es nur ein Kriterium geben würde, dafür, dass die Bedingung $\varkappa\sqrt{t}-\frac{z}{2a\sqrt{t}}=0$ erfüllt sei, so hätte man es leicht a für jeden Boden zubestimmen, und so seine Fähigkeit, Wasser fortzupflanzen, numerisch zu charakterisieren. Ein solches Kriterium lässt sich nicht finden, wohl aber ein wenn auch nicht allzu scharfes und auch nicht unbedingtes Kriterium dafür, dass $\varkappa\sqrt{t}-\frac{z}{2a\sqrt{t}}$ ein nicht allzu grosser Bruch sei. Es seien t und t' zwei mässig grosse Zeiten und z und z' die entsprechenden Distanzen der Grenzschichte der Verdunkelung von der Fläche der Wasserzufuhr. Es ist dann

$$\frac{z}{\sqrt{t}}=\frac{a+\frac{b}{\sqrt{t}}}{1+\frac{c}{\sqrt{t}}} \qquad \frac{z'}{\sqrt{t'}}=\frac{a+\frac{b}{\sqrt{t'}}}{1+\frac{c}{\sqrt{t'}}}$$

oder, was dasselbe ist

$$z=\frac{a\sqrt{t}+b}{1+\frac{c}{\sqrt{t}}} \qquad z'=\frac{a\sqrt{t'}+b}{1+\frac{c}{\sqrt{t'}}}$$

Indem man diese beiden Ausdrücke von einander abzieht, erhält man

$$z'-z+c\left(\frac{z}{\sqrt{t'}}-\frac{z}{\sqrt{t}}\right)=a(\sqrt{t'}-\sqrt{t}) \qquad \text{(A)}$$

Nun ist

$$\frac{\sqrt{t'}}{z'}=\frac{a\sqrt{t'}+b}{\sqrt{t'}+c} \qquad \frac{z}{\sqrt{t}}=\frac{a\sqrt{t}+b}{\sqrt{t}+c}$$

Die Substitution dieser Ausdrucke in (A) ergiebt nach eine, leichten Umformung

$$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}=a+\frac{c\,(b-ac)}{(c+\sqrt{t})\,(c+\sqrt{t'})}$$

Hiraus folgt, indem wir berücksichtigen

$$a=\frac{2a}{\sqrt{\pi}} \qquad b=\frac{a}{\varkappa}\log\frac{\left(C_0+\frac{\varkappa^2}{\gamma}\right)}{2\left(C+\frac{\gamma}{\varkappa^2}\right)} \qquad c=\frac{1}{\varkappa\sqrt{\pi}}$$

$$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}=a\left[1+\frac{\left(\frac{\pi K}{2}-1\right)}{(1+\varkappa\sqrt{\pi}.\sqrt{t})\,(1+\varkappa\sqrt{\pi}.\sqrt{t'})}\right] \qquad \text{(B)}$$

wo $\log\frac{\left(C_0+\frac{\gamma}{\varkappa^2}\right)}{2\left(C+\frac{\gamma}{\varkappa^2}\right)}=K$ gesetzt ist.

In Fall der Aufsaugung kann K ein echter Bruch sein und ist $>\frac{2}{\sqrt{\pi}}$, da $\frac{z}{\sqrt{t}}$ hier mit t abnimmt, dann ist $\frac{K\pi}{2}-1$ ein echter Bruch und zwar vermuthlich ein kleiner echter Bruch, da die Geschwindigkeit, mit der $\frac{z}{\sqrt{t}}$ abnimmt, die von $\left(\frac{\pi K}{2}=1\right)$ in erster Instanz abhangt, schon bei mässig grossem t eine recht kleine ist, (die Gleichung XIIIa). Wenn also K ein echter Bruch ist, und überdies $\varkappa$ ziemlich gross ist, was vermuthlich der Fall ist, so kann das zweite Glied der rechten Seite in (B) selbst bei mässig grossem t nur eine unbedeutende Grösse gegen a selbst sein. Das Kriterium, für die Stelle, wo $\varkappa\sqrt{t}-\frac{z}{2a\sqrt{t}}$ nur ein kleiner Bruch ist, wo daher jene unter dieser Bedingung abgeleitete Gleichung am besten angewendet werden kann, würde darin bestehen, dass $\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$ *nahezu constant bleibt, wie gross oder klein man auch* $\sqrt{t'}-\sqrt{t}$ *wählen mag, wenn man* $\sqrt{t'}-\sqrt{t}$ *nur nicht so gross wählt, dass b sich um Erhebliches ändert.* Bei der Durchsickerung und bei der herizontalen Leitung kann K negativ sein, wenn die Wasserzufuhr nicht unter Druckerhöhung vor sich geht. Da in diesem Fall $\frac{2\left(C-\frac{\gamma}{\varkappa^2}\right)}{C-\frac{\gamma}{\varkappa^2}}>1$

ist, und dabei, weil C gross ist, einen Werth haben kann, der sich von 1 wenig entfernt. Wenn gleich das zweite Glied rechter Seite in (B) mit dem in diesem Fall grossen a multiplicirt, ist und einen gegen a selbst noch ziemlich bedentenden Werth haben kann, so wird das oben ausgerprachene striterium ungefäht auch für diese Fälle gelten, wenn $\varkappa$ nicht allzu klein ist. Findet die Durchsickterung und horzontale Leitung unter Druckerhöhung statt, so ist sowohl $\frac{2\left(C-\frac{\gamma}{\varkappa^2}\right)}{Co-\frac{\gamma}{\varkappa^2}}$ als $\frac{2\left(C+\frac{E}{\varkappa^2}\right)}{Co+\frac{E}{\varkappa^2}}$ ein echter Bruch, und $<\frac{2}{\pi}$ oder $>\frac{2}{\pi}$, je nachdem $\frac{z}{\sqrt{t}}$ zunimmt, ader abnimmt. Man kann sich sonach in diesen Fällen $\frac{\pi}{2}K-1$ also einen echten Bruch, und mithin das zweite Glied rechter Seite in (B) als eine wenig bedeutende Grösse gegen a denken, wenn $\varkappa$ nicht allzu klein ist. Das oben aufgestellte Kriterium muss sich daher für diese Fälle auch ziemlich gut bewähren.

Um dieses experimentell zuprüfen, habe ich den Sandlehm von Mito auch in Bezug auf die Durchsickerung und die hosizontale Leitung untersucht und so wohl $\frac{z}{\sqrt{t}}$ wie $\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$ berechnet' wo bei $t'=t+1$ genommen ist und die Werthe des $\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$ für grössere Zeitdifferenzen eingeklammert sind (Tabelle VII, VIII, VIIII, X, XI) Die Daten für die Aufsaugung sind dieselben, wie in (Tabelle V).

(Tabelle VII) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.
(Aufsaugung.)
(losegefüllt)

t	z	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$	t	z	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$
1	64	64.000	149	665	57.980
2	99	84.545	150	666	24.509
3	124	78.641	151	668	49.020
4	143	70.921	152	670	49.261
5	160	71.986	153	672	49.382
6	174	65.605	170	693	[30.671]
7	186	61.131	171	694	26.110
8	192	35.900	172	696	52.356
25	331	[64.007]	173	697	26.316
26	335	40.395	174	698	26.316
27	342	72.016	175	699	26.385
28	348	62.959	176	701	53.050
29	354	64.181	177	703	53.191
30	358	43.478	194	720	[27.231]
31	365	77.263	195	721	27.933
32	378	14.590	196	723	55.866
49	439	[46.161]	197	724	28.011
50	441	28.130	198	725	28.196
51	444	42.553	199	726	28.196
52	448	57.390	200	728	56.497
53	452	57.976	201	729	28.329
54	455	73.865	218	746	[28.942]
55	460	59.094	219	747	29.586
56	464	59.613	220	748	29.586
73	513	[46.197]	221	749	29.674
74	516	51.457	222	750	29.762
75	519	51.724	223	751	29.850
76	523	69.565	224	752	29.940
77	527	69.929	225	754	59.880
78	529	35.211	242	770	[28.762]
79	532	53.069	243	771	31.056
80	534	35.651	244	772	31.250
97	571	39.796	245	773	31.250
98	573	39.526	246	774	31.348
99	576	59.514	247	775	31.446
100	578	39.920	248	776	31.446
101	580	40.090	249	777	31.546
102	582	40.323	266	790	[26.425]
146	660	[39.324]	267	792	32.680
147	661	24.155	268	793	32.680
148	662	24.331	269	794	32.787

(Tabelle VII) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.
(Aufsaugung)
(losegefülit)

t	z	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$	t	z	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$
270	795	32.787	483	931.5	21.929
271	796	32.893	484	932	22.026
314	828	[25.349]	485	933	44.052
315	829	35.461	486	934	44.052
316	830	35.461	487	934.5	22.026
317	831	35.587	488	935	22.174
318	832	35.587	489	936	44.348
319	833	35.714	506	943	[18.368]
320	834	35.587	507	943.5	22.422
321	835	35.714	508	944	22.523
338	847	[25.625]	509	944.5	22.625
339	848	36.765	510	945	22.523
340	849	36.899	511	946	45.249
341	850	36.899	512	947	45.249
342	851	37.037	513	947.5	22.625
343	852	36.900	530	953	[14.777]
344	853	37.175	531	953.5	23.042
345	854	37.037	532	954	23.042
362	864	[22.119]	533	955	46.083
363	865	38.022	534	956	36.297
364	866	38.168	535	956.5	23.932
365	867	38.168	536	957	23.149
366	868	38.314	537	957.5	23.149
367	869	38.314	554	964	[17.862]
368	869.5	19.157	555	965	47.169
369	870	19.157	556	965.5	23.474
410	894	[23.097]	557	966	23.697
411	894.5	20.325	558	967	47.169
412	895	20.243	559	968	47.169
413	896	40.650	560	968.5	23.697
414	896.5	20.325	561	969	23.697
415	897	20.405			
416	898	40.650			
417	899	40.816			
434	908	[20.925]			
435	908	0			
436	910	83.681			
437	911	42.815			
438	911.5	21.408			
439	912	21.408			
482	931	[18.948]			

(Tabelle VIII) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.
(Horizontale Leitung.)
losegefüllt; Druck vorhanden.

t	z (*mm*)	$\frac{z}{\sqrt{t}}$	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$	
0.5	56	79.201		
1	78	78.000	78.000	
1.5	106	68.746	96.581	
2	123	86.776	10.864	
2.5	135	85.381	81.392	
3	148	85.448	133.12	
3.5	162	86.594	86.778	
4	176	88.000	104.51	
4.5	186	87.680	95.808	
5	197	88.101	88.945	[98,623]
5.5	297	88.265	93.793	
6	217	88.589	93.722	
6.5	226	88.644	92.999	
7	235	88.822	91.696	
7.5	242	88.367	84.612	
8	252	89.096	93.100	
8.5	259	88.836	96.099	
9	267	89.000	87.412	
9.5	274	88.898	89.981	
10	281	88.861	86.260	[90.694]
10.5	288	88.879	88.552	
11	294	88.665	84.250	
11.5	299	88.170	72.895	
12	305	88.046	74.576	
12.5	312	88.247	90.089	
13	318	88.259	91.871	
13.5	323	87.908	79.250	
14	328	87.662	73.477	
14.5	333	87.450	74.850	
15	339	87.531	83.778	[81,621]
15.5	344	87.378	85.204	
16	351	87.750	94.489	
16.5	356	87.642	96.000	
17	361	86.994	81.234	
17.5	366	87.490	82.440	
18	372	87.680	92.049	
18.5	376	87.420	84.889	
19	382	87.635	85.985	
19.5	387	87.638	95.819	
20	392	87.656	88.339	[88,452]
20.5	396	87.460	80.501	

(Tabelle VIII) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.
(Horizontale Leitung.)
losegefüllt; Druck vorhanden.

t	z	$\frac{z}{\sqrt{t}}$	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$	
21	400	87.287	72.399	
21.5	405	87.561	82.494	
22	408	86.986	74.211	
22.5	412	86.858	65.666	
23	414	86.326	56.925	
23.5	417	86.022	46.892	
24	422	86.141	77.519	
24.5	428	86.072	107.74	
25	434	86.800	103.63	[79.561]
25.5	439	86.934	109.89	
26	444	87.076	101.04	
26.5	449	87.224	102.04	
27	453	87.181	113.92	
27.5	457	87.146	83.073	
28	461	87.120	83.946	
28.5	464	86.916	74.153	
29	468	86.907	74.707	
29.5	472	86.902	86.113	
30	475	86.722	76.070	[85.917]
30.5	479	86.732	76.671	
31	483	86.750	88.300	
31.5	487	86.780	89.687	
32	490	86.622	78.563	
32.5	494	86.654	78.652	
33	498	86.690	91.220	
33.5	501	86.571	80.460	
34	505	86.606	81.020	
34.5	508	86.487	81.585	
35	512	86.545	82.257	[84.320]
35.5	515	86.415	82.939	
36	518	86.333	71.514	
36.5	521	86.236	71.855	
37	524	86.145	72.464	
37.5	527	86.058	72.993	
38	530	85.973	73.529	
38.5	532	85.739	61.728	
39	536	85.828	74.442	
39.5	538	85.601	74.907	
40	543	85.856	87.957	[78.868]
40.5	548	86.109	126.42	
41	552	86.209	114.65	

(Tabelle VIII) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.
(Horizontale Leitung.)
losegefüllt; Druck vorhanden.

t	z	$\frac{z}{\sqrt{t}}$	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$	
41.5	555	86.153	89.745	
42	558	86.101	77.320	
42.5	562	86.208	90.792	
43	566	86.316	104.30	
43.5	569	86.272	91.744	
44	572	86.232	79.051	
44.5	576	86.346	92.839	
45	579	86.312	93.334	[93.823]
45.5	582	86.280	80.428	
46	585	86.254	81.081	
46.5	588	86.228	81.410	
47	591	86.207	81.743	
47.5	594	86.187	82.192	
48	596	86.062	68.965	
48.5	599	86.012	69.347	
49	602	86.000	83.566	
49.5	605	85.990	84.033	
50	607	85.844	70.422	[77,199]
50.5	609	85.757	56.498	
51	612	85.698	71.123	
51.5	615	85.698	85.836	
52	617	85.562	71.632	
52.5	623	85.983	115.27	
53	626	85.986	130 44	
53.5	628	85.860	72.887	
54	631	85.866	73.207	
54.5	633	85.743	73.421	
55	636	85.759	73.746	[84.010]
55.5	639	85.773	88.889	
56	642	85.791	89.553	
56.5	644	85.678	74.962	
57	646	85.564	59.969	
57.5	649	85.587	75.528	
58	651	85.481	75.987	
58.5	654	85.507	75.987	
59	657	85.532	91.603	
59.5	661	85.693	107.528	[78.835]
60	662	85.463	77.160	
60.5	664	85.367	46.511	
61	666	85.273	62.305	
61.5	669	85.308	78.125	

(Tabelle VIII) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.
(Horizontale Leitung.)
losegefüllt. Druck vorhanden.

t	z	$\frac{z}{\sqrt{t}}$	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$	
62	671	85.216	78.247	
62.5	673	85.128	62.993	
63	676	85.169	79.239	
63.5	678	85.083	79.365	
64	681	85.125	79.618	
64.5	683	85.043	80.000	
65	686	85.087	80.256	[75.877]
65.5	689	85.133	96.774	
66	692	85.180	97.243	
66.5	695	85.226	97.560	
67	698	85.275	97.719	
67.5	701	85.327	98.200	
68	702	85.132	65.898	
68.5	704	85.059	49.342	
69	707	85.113	82.781	
69.5	709	85.047	83.334	
70	711	84.981	66.556	[82,156]
70.5	715	85.157	100.503	
71	718	85.210	117.450	
71.5	721	85.267	101.009	
72	723	85.206	84.460	
72.5	726	85.265	84.746	
73	728	85.206	85.324	
73.5	730	85.149	68.494	
74	732	85.094	68.729	
74.5	735	85.155	85.763	
75	737	85.298	86.206	[88,554]
75.5	739	85.043	69.445	
76	741	84.998	69.323	
76.5	743	84.950	69.687	
77	745	84.902	70.176	
77.5	747	84.658	70.176	
78	749	84.807	70.299	
78.5	752	84.877	88.495	
79	754	84.832	88.810	
79.5	756	84.789	71.048	
80	758	84.748	71.302	[73.943]
80.5	761	84.816	89.285	
81	763	84.788	89.607	
81.5	765	84.738	71.944	
82	768	84.811	90.253	

(Tabelle VIII) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.

(Horizontale Leitung)

losegefüllt, Druck vorhanden.

t	z	$\frac{z}{\sqrt{t}}$	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$	
82.5	771	84.883	108.700	
83	773	84.848	90.744	
83.5	775	84.813	72.993	
84	777	84.777	73.126	
84.5	779	84.744	73.261	
85	782	84.822	91.912	[87.147]
85.5	784	84.789	92.251	
86	785	84.649	55.556	
86.5	788	84.727	74.075	
87	789	84.590	74.350	
87.5	792	84.668	74.767	
88	793	84.534	74.907	
88.5	793	84.295	18.762	
89.5	800	84.563	132.077	
90.5	805	84.621	94.877	[78.365]
91.5	808	84.470	57.143	
92.5	814	84.635	115.160	
93.5	818	84.594	77.071	
94.5	822	84.557	77.519	
95.5	826	84.524	78.125	[80.988]
96.5	830	84.493	78.431	
97.5	836	84.666	118.11	
98.5	840	84.637	79.051	
99.5	844	84.612	79.840	
100.5	847	84.489	66.000	[83.169]
101.5	850	84.370	60.241	
102.5	855	84.452	10.101	
103.5	858	84.337	60.851	
104.5	862	84.324	81.467	
105.5	865	84.215	31.475	[73.021]
106.5	868	84.111	61.983	
107.5	872	84.105	82.815	
108.5	875	84.004	62.240	
109.5	878	83.903	62.240	
110.5	881	83.811	63.025	[66.527]
111.5	884	83.716	63.158	
112.5	888	83.720	84.579	
113.5	891	83.633	63.829	
114.5	895	83.641	65.652	
115.5	898	83.558	64.239	[72.279]
116.5	902	83.579	88.687	

(Tabelle VIII) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.

(Horizontale Leitung)

losegefüllt. Druck vorhanden.

t	z	$\frac{z}{\sqrt{t}}$	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$	
117.5	905	83.489	62.761	
118.5	909	83.503	90.910	
119.5	913	83.520	81.632	
120.5	916	83.445	68.182	[98.524]
121 5	918	83.282	43.478	
122.5	921	83.213	66.667	
123.5	925	83.236	88.889	
124.5	929	83.261	88.889	
125.5	931	83.106	44.445	[66.371]
126.5	934	83.042	68.182	
127.5	936	82.893	44.445	
128.5	941	83.012	11.364	
129.5	943	82.867	45.455	
130.5	946	82.810	68.182	[67.873]
131.5	948	82.670	46.511	
132.5	951	82.617	68.182	
133.5	955	82.634	93.023	
134.5	957	82.518	46.511	
135.5	960	82.471	69.767	[64.816]
136.5	962	82.338	46.511	
137.5	966	82.382	93.023	
138.5	969	82.338	71.428	
139.5	972	82.296	69.767	
140.5	975	82.255	71.428	
141.5	978	82.217	71.428	
169.	1023	76.902	52.632	
169.5	1025	78.730		[70.422]
170.5	1027	78.652		
171.5	1030	78.648	76.924	[40.724]
172.5	1033	78.592	78.948	
173.5	1036	78.652	78.948	
174.5	1088	78.578	52.632	
175.5	1041	78.586	78.948	
176.5	1049	78.96	21.628	
193.	1083	77.956		
193.5	1086	78.071		
194.5	1088	78.014	55.556	
195.5	1091	78.028	83.334	
196.5	1094	78.044	83.334	[91.228]
197.5	1096	77.988	57.143	[56.013]
198.5	1098	77.934	83.334	

(Tabelle VIII) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.

(Horizontale Leitung)

losegefüllt. Druck vorhanden.

t	z	$\frac{z}{\sqrt{t}}$	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$	
199.5	1101	77.951	86.714	[77.585]
216.	1139	77.498		[66.318]
216.5	1142	77.590		
217.5	1144	77.571	58.823	
128.5	1145	77.460	29.412	
219.5	1147	77.418	58.823	
220.5	1149	77.378	60.607	
221.5	1152	77.493	88.235	
222.5	1154	77.364	58.823	[68.182]
263.	1237	76.273		[63.847]
263.5	1239	76.327		
164.5	1242	76.368	100.000	
265.5	1245	76.408	96.774	
266.5	1247	76.387	64.516	
267.5	1248	76.394	33.333	
268.5	1251	76.347	96.774	
269.5	1253	76.326	66.667	[80.403]
286.	1285	75.982		[64.646]
286.5	1286	75.977		
287.5	1288	75.962	66.667	
288.5	1290	75.949	88.965	
289.5	1291	75.877	33.333	
290.5	1292	75.864	35.714	
291.5	1294	75.790	66.667	
292.5	1295	75.720	33.333	[52.083]
309.	1325	75.377		[63.158]
309.5	1327	75.429		
310.5	1329	75.422	71.628	
311.5	1331	75.414	71.428	
312.1	1332	75.348	34.483	
313.5	1334	75.343	71.428	
314.5	1336	75.336	71.428	
315.	1337	75.330		[70.588]
332.	1367	75.024		[63.425]
333.	1368	74.967	37.027	
334	1370	74.964	71.437	
335	1372	74.960	74.024	
336	1373	74.903	37.037	
337	1375	74.901	74.075	
338	1377	74.898	71.428	
339	1378	74.782	37.037	[57.592]

(Tabelle VIII) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.

(Horizontale Leitung)

losegefüllt. Druck vorhanden.

t	z	$\frac{z}{\sqrt{t}}$	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$	
356	1404	74.411		[57.98]
357	1405	44.362	38.462	
358	1407	74.362	74.075	
359	1408	74.310	38.462	
360	1410	74.314	74.075	
361	1412	74.316	76.924	
362	1413	74.266	38.462	
363	1415	74.269	76.924	[58.782]
380	1441	73.921		[58.823]
381	1442	73.877	40.000	
382	1444	73.882	76.924	
383	1446	73.887	80.000	
384	1447	73.841	38.462	
385	1449	73.848	80.000	
386	1452	73.909	115.390	
387	1454	73.169	76.924	[59.524]
428	1512	73.097		[69.080]
429	4514	73.060	83.332	
430	1515	73.423	41.117	
431	1516	72.988	40.000	
432	1517	72.951	41.667	
433	1518	72.963	43.478	
434	1518	72.974	83.332	
435	1520	72 577	83.332	[72.626]
452	1522	72.543		[57.143]
453	1543	72.557	41.667	
454	1544	72.570	86.956	
455	1546	72.539	83.332	
459	1548	72.459	43.478	
457	1549	72.427	0	
458	1549	72.394	43.478	
459	1550	72.282	43.478	[48.781]
476	1551	72.252		[66.158]
477	1577	72.222	43.478	
878	1578	72.284	43.478	
478	1579	72.254	130.430	
479	1581	72.270	43.478	
480	1583	72.240	86.956	
481	1585		45.458	[56.250]
482	1586			

(Tabelle X.) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.

(Durchsickerung.)

		losegefüllt.	Druck vorhanden.	
t	z (mm)	$\frac{z}{\sqrt{t}}$	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$	
0.5	60	84.857		
1	75	75.000	75.000	
1.5	100	81.647	77.264	
2	112	79.198	28.960	
2.5	116	73.365	44.906	
3	125	72.003	40.893	
3.5	131	70.023	51.777	
4	137	68.500	44.793	
4.5	144	67.881	51.896	
5	152	67.975	63.532	[67.975]
5.5	161	68.652	75.928	
6	170	69.402	84.349	
6.5	179	70.209	88.105	
7	188	71.057	91.696	
7.5	195	71.205	84.612	
8	103	71.773	82.147	
8.5	211	72.372	84.793	
9	219	73.000	93.240	
9.5	226	73.325	95.980	
10	233	73.682	86,261	[87.056]
10.5	241	74.375	88.552	
11	248	74.774	97.212	
11.5	255	75,188	99.403	
12	261	75.344	88.135	
12.5	268	75.803	90.089	
13	274	75.994	91.871	
13.5	281	76.479	93.659	
14	288	76.972	95.517	
14.5	294	77.208	97.304	[94.284]
15	300	77.461	91.395	
15.5	306	77.725	92.950	
16	312	78.000	94.489	
16.5	318	78.287	96.000	
17	324	78.583	97.481	
17.5	330	78.884	98.928	
18	336	79.195	100.42	
18.5	341	79.283	93.377	
19	347	79.607	94.582	
19.5	353	79.937	104.53	
20	359	80.275	106.01	[98 465]
20.5	364	80.394	98.390	

(Tabelle X.) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.

(Durchsickerung.)

t	z (mm)	$\frac{z}{\sqrt{t}}$ losegefüllt.	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$ Druck vorhanden.	
21	370	80.740	99.547	
21.5	376	81.091	109.990	
22	381	81.231	102.04	
22.5	387	81.587	103.188	
23	391	81.530	94.877	
23.5	397	81.896	95.969	
24	403	82.264	116.27	
24.5	408	82.429	107.74	
25	413	82.600	99.010	[102.292]
25.5	414	91.984	59.941	
26	420	82.560	70.708	
26.5	426	82.754	122.45	
27	434	83.534	133.74	
27.5	439	83.712	134.99	
28	444	83.906	104.93	
28.5	448	83.919	95.339	
29	452	83.934	85.379	
29.5	457	84.083	96.877	
30	460	83.985	86.956	[98.492]
30.5	464	84.017	76.671	
31	468	84.056	88.300	
31.5	472	84.106	89.687	
32	476	84.147	89.786	
32.5	479	84.023	78.652	
33	482	83.905	68.415	
33.5	486	93.969	80.480	
34	490	84.035	92.594	
34.5	493	83.934	81.585	
35	496	83.840	70.505	[82.041]
35.5	500	83.898	82.939	
36	504	84.000	71.514	
36.5	508	84.083	95.786	
37	511	84.008	84.542	
37.5	514	83.934	72.993	
38	518	84.032	85.785	
38.5	521	83.967	86.427	
39	525	84.068	86 – –	
39.5	528	84.010	87.923	
40	532	84.116	87.941	[88.105]
40.5	535	84.066	88.495	
41	539	84.178	89.172	

(Tabelle X.) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.

(Durchsickerung.)

		losegefüllt.	Druck vorhanden.	
t	z (mm)	$\frac{z}{\sqrt{t}}$	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$	
41.5	542	84.135	89.745	
42	545	84.097	77.320	
42.5	547	83.907	64.851	
43	551	84.097	78.228	
43.5	555	84.149	104.850	
44	557	83.971	79.155	
44.5	560	83.947	66.313	
45	564	84.075	80.000	[83.399]
45.5	568	84.205	107.238	
46	570	84.041	80.971	
46.5	573	84.027	67.842	
47	577	84.164	95.368	
47.5	579	84.010	82.192	
48	583	84.149	80.874	
48.5	586	84.143	97.087	
49	590	84.285	97.495	
49.5	594	84.439	112.05	
50	596	84.289	84.388	[88.227]
50.5	599	84.271	70.622	
51	602	84.493	85.349	
51.5	605	84.306	85.336	
52	609	84.454	100.66	
52.5	611	34.326	86.455	
53	614	34.339	72.359	
53.5	617	84.318	87.464	
54	621	84.508	102.33	
54.5	623	84.390	88.105	
55	627	84.545	88.626	[89.803]
55.5	630	84.565	103.705	
56	634	84.723	104.32	
56.5	638	84.849	120.22	
57	641	84.902	102.86	
57.5	944	84.930	90.634	
58	647	84.955	90.910	
58.5	649	84.852	75.987	
59	654	85.143	107.20	
59.5	657	85.175	122.89	
60	660	85.204	92.451	[100.060]
60.5	663	85.237	73.891	
61	665	85.145	77.881	
61.5	668	85.181	78.125	
62	673	85.469	125.39	

(Tabelle X) LEHMIGER SANDBODEN AUS DES PROVINK MITO.

(Durchsickerung.)

losegefüllt. Drauk vorhanden.

t	z (mm)	$\frac{z}{\sqrt{t}}$	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$	
62.5	674	85.255	94.489	
63	678	85.420	78.900	
63.5	680	85,333	95.238	
64	683	85.375	79.744	
64.5	686	85.410	95.986	
65	689	85.459	95.541	[91.685]
65.5	691	85.381	80.645	
66	694	85 426	81.036	
66.5	697	85.471	97.560	
67	700	85.518	97.719	
67.5	702	85.445	81.833	
68	705	85.692	82.101	
68.5	708	85.542	98.685	
60	711	85.595	99.502	
69.5	713	85.724	83.334	
70	716	85.577	83.334	[88.728]
70.5	719	85.633	100.496	
71	722	85.686	100.84	
71.5	725	85.741	101.009	
72	727	85.676	84.460	
72.5	730	85.733	84.746	
73	732	85.614	85.179	
73.5	735	85.733	85.617	
74	738	85.793	102.92	
74.5	740	85.733	85.763	
75	743	85.785	86.207	[91.960]
75.5	746	85.856	104.167	
76	748	85.800	86.956	
76.5	751	85.864	87.108	
77	754	85.927	104.89	
77.5	756	85.876	87.720	
78	759	85.939	88.028	
78.5	762	86.006	106.194	
79	765	86.070	106.38	
79.5	767	86.066	88.810	
80	769	85.979	71.302	[91.548]
80.5	772	86.044	89.285	
81	774	86.000	89.766	
81.5	777	86.068	89.929	
82	779	86.026	90.253	
82.5	782	86.095	90.580	

(Tabelle XI) LEHMIGER SANDBODEN AUS DEK PROVINZ MITO.

(Durchsickerung)

Losegefüllt. Druck vorhanden.

t	z	$\frac{z}{\sqrt{t}}$	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$	
83	784	86.056	90.701	
83.5	787	86.125	91.241	
84	790	86.196	111.11	
84.5	793	86.266	109.89	
85	795	86.230	91.912	[94,408]
85.5	798	86.302	92.251	
86	800	86.256	125.00	
86.5	803	86.339	92.593	
87	805	86.306	92.937	
87.5	808	86.379	93.459	
88	811	86.453	112.35	
88.5	813	86.419	93.808	
89	815	86.389	75.188	
89.5	817	86.359	75.471	
90	820	86.435	94.698	[93,562]
90.5	823	86.513	114.07	
91	824	86.379	76.045	
91.5	826	86.351	57.143	
92	828	86.321	76.482	
92.5	831	86.403	95.969	
93.5	835	86.354	77.071	
94.5	840	86.409	96.899	
95.5	846	86.571	117.19	[91,035]
96.5	851	86.630	98.039	
97.5	855	86.590	78.741	
98.5	861	86.752	118.68	
99.5	866	86.818	99.800	
100.5	871	86.884	99.800	[94,010]
101.5	876	86.950	108.00	
102.5	880	86.920	80.646	
103.5	882	86.697	40.569	
104.5	883	86.377	16.950	
105.5	896	87.233	26.585	[101,419]
106.5	899	87.115	61.983	
107.5	905	87.287	123.96	
108.5	910	87.364	104.17	
109.5	914	87.345	84.388	
110.5	918	87.329	84.746	[91,474]
111.5	923	87.410	105.264	
112.5	927	87.290	84.367	

(Tabelle XI) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.

(Durchsickerung)

losegefüllt. Druck vorhanden.

t	z	$\frac{z}{\sqrt{t}}$	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$	
113.5	932	87.482	106.381	
114.5	936	87.474	85.652	
115.5	941	87.559	107.066	[97.780]
116.5	946	87.656	11.089	
117.5	950	87.640	83.682	
118.5	954	87.638	90.910	
119.5	959	87.728	102.040	
120.5	963	87.789	90.910	[95.651]
121.5	968	87.819	108.70	
122.5	973	87.910	111.11	
123.5	977	87.914	88.889	
124.5	983	88.099	133.33	
125.5	987	88.105	88.889	[106.194]
126.5	992	88.198	113.64	
127.5	997	88.294	111.11	
128.5	1002	88.393	113.64	
129.5	1005	88.316	68.182	
130.5	1010	88.412	113.64	[104.073]
131.5	1015	88.514	116.28	
132.5	1019	88.524	90.910	
133.5	1024	88.626	116.28	
134.5	1027	88.555	697.67	
135.5	1032	88.657	116.28	[101.852]
136.5	1037	88.759	116.28	
137.5	1047	88.777	93.023	
138.5	1044	88.712	71.428	
139.5	1048	88.730	93.023	
140.5	1053	88.836	119.05	[98.590]
141.5	1056	88.773	71.428	
142.5	1062	88.963	142.86	
143.5	1066	88.988	95.238	
144.5	1071	89.096	119.05	
145.5	1075	89.121	97.562	[105.212]
162	1155	90.724	—	[126.12]
162.5	1156	90.684	—	
163.5	1162	90.876	153.85	
164.5	1167	90.989	128.21	
165.5	1171	90.983	102.565	
166.5	1176	91.138	131.58	
167.5	1180	91.174	102.565	
168.5	1185	91.289	128.21	

(Tabelle XI) LEHMIGER SANDBODEN AUS DER PROVINZ MITO.

(Durchsickerung)

Losegefüllt. Druck vorhanden.

t	z	$\frac{z}{\sqrt{t}}$	$\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$	
169.5	1189	91.327	114.29	[116,84]
186	1265	92.757	.....	[146,43]
186.5	1268	92.850	.....	
187.5	1276	93.019	222.22	
188.5	1279	93.156	81.081	
189.5	1284	93.276	138.89	
190.5	1289	93.390	138.89	
191.5	1291	93.293	55.556	
192.5	1293	93.192	54.054	[118,14]
209	1375	95.111	.....	[140,89]
209.5	1377	95.135	.....	
210.5	1381	95.183	114.29	
211.5	1384	95.166	88.235	
212.5	1386	95.078	58.823	
213.5	1388	94.993	57.143	
214.5	1389	94.840	29.412	
215.5	1391	94.757	58.823	[71,750]

Bei der horizontalen Leitung war das eine Ende der Glasröhre mit einer dicken Schichte Quarzsand abgersperrt, welche von einer daneben stehender Zelle aus, in der das Wasserniveau constant erhalten war, mit Wasser fortwährend getränkt wurde, sodass das Wasser sich wohl ohne erhebliche Druckdifferenz in der Fläche der Wasserzufuhr durch den ganzen Querschnilt des untersuchten Bodens fortgepflanzt haben möchte. Bei der Durchsickerung wurde das Wasser auf dem untersuchten Boden mittelst eines Heberapparates constant 16 mm tief erhalten.

Wie man sieht, zeigt $\frac{z}{\sqrt{t}}$ wieder den theoretisch verlangten Verlauf. Es nimmt zuerst entschieden ab und dann wieder zu. Bei der horizontalen Leitung dauerte die Zunahme bis zur 8 *ten*. Stunde und dann beginnt $\frac{z}{\sqrt{t}}$ langsam aber stetig abzunehmen. Eine solche Abnahme konnte aber bei der Durchsickerung nicht constatiert werden, wenn die an dem anderen freien Ende der Röhre wieder auftretende Abnahme der $\frac{z}{\sqrt{t}}$ nicht als eine solche theoretisch verlangte Abnahme angesehen werden kann.

Was den Quotienten $\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$ anbelangt, so übt, da der Nenner $\sqrt{t+1}-\sqrt{t}$ bei grossen t ein kleiner Bruch ist, die Abrundung der abgelesenen z auf ganzes Millimeter einen so schweren Einfluss auf den Quotienten aus, dass eine sprungsweise Änderung desselben um 50% und noch mehr keine Seltenheit ist. Dennoch zeigt sich bei der Aufsaugung mit leidlicher Schärfe, dass der eingeklammerte Quotient im allgeminen von dem nicht eingeklammerten differirt, dass die beiden Quotienten aber zwischen der *197 sten* und *242 sten* Stunden mit Ausnahme von ein Paar uneingeklammerten Quotienten ziemlich gut mit einander coïncidiren, um dann bei wachsendem t immer weiter von einander abzuweichen.

Viel unregelmässiger verläuft der Quotient für die Durch

sickerung, und für die horizontale Leitung schon, weil die Grenzschichte der Verdunkelung bei diesen beiden Bewegungsarten weniger regelmässig gestaltet ist, als bei der Aufsaugung. Dennoch bemerkt man, dass die in Rede stehende Coincidenz der beiden Quotienten bei der Durchsickerung innerhalb der *20 sten* und *30 sten* Stunde, oder innerhalb der *55 sten* und *60 sten* Stunde, und bei der horizontalen Leitung innerhalb der *56 sten* und *65 sten* Stunde zu vermuthen ist.

Nun besteht eine gewisse theoretische Beziehung zwischen den Constanten α mitlin auch a für die drei Arten Wasserbewegung in einem und demselben Boden. Es sei a_1 diese Constante für die Durchsiekerung a_2 für die horizontale Leitung, und a_3 für die Aufsaugung. Man hat dann

$$a_1^2 = a^2 + b^2$$
$$a_2^2 = a^2$$
$$a_3^2 = a^2 - b^2$$

gemäss der Theorie, die wir entwickelt haben.

Hieraus folgt die Relation.

$$\frac{a_1^2 + a_3^2}{2} = a_2^2$$

Nun ist das arithmetische Mittel aller Werthe von $\frac{z' - z}{\sqrt{t'} - \sqrt{t}}$ für die Aufsaugung innerhalb der 197′ sten und 242′ sten Stunde

33.228

und wenn wir die beiden fast doppelt so grossen Werthe 57.497 unk 59.880 ausschliessen

29.089

Das arithmetisehe Mittel aller Werthe von $\frac{z' - z}{\sqrt{t'} - \sqrt{t}}$ für die Durchsickerung innerhalb der 20′ sten und 25′ sten Stunde ist,

104.091

Nimmt man das arithmetische Mittel aller Quotientin innerhalb der 20′ sten und 30′ sten Stunde, so kommt

101.911

ERRATA.

Pag. 111. *Zeile* 15 lies:

$$\frac{(104.091)^2 + (33.228)^2}{2} = 5969 \text{ rund.}$$

und *Zeile* 18

$$\frac{(103.947)^2 + (29.089)^2}{2} = 5826 \text{ rund.}$$

Scheidet man die beiden zu kleinen Werthe 59.941 und 70.708 aus, so folgt

$$103.947$$

Das arithmetische Mittel aller Quoteinten innerhalb der 55′ sten und 60′ sten Stunde ist,

$$102.060$$

also ungefähr dieselbe Zahl.

Das arithmetische Mittel aller Quotienten für die horizontale Leitung innerhalb der 56 sten und 65 sten Stunde ist

$$77.206$$

Es ist nun

$$(77.206)^2 = 5961 \text{ rund.}$$

$$\frac{(101.011)^2 + (33.228)^2}{2} = 5653 \text{ rund.}$$

oder

$$\frac{(103.09)^2 + (33.228)^2}{2} = 5866 \text{ rund.}$$

oder, wenn wir die Werthe 59.941 und 70.708 auscheiden, wie die Werthe 56.497 und 59.880

$$\frac{(103.947)^2 + (29.089)^2}{2} = 5933 \text{ rund.}$$

Die theoretisch geforderte Beziehung zwischen den Constanten a für die drei Bewegunsarten ist demnach annährend erfüllt.

Wenn wir bedenken, wie wenig Vertrauen der Werth der Quotienten $\frac{z' - z}{\sqrt{t'} - \sqrt{t}}$ verdient in Folge der Abrundung der z auf ganzes Millimeter, wie gering die Wahrscheinlichkeit dafür ist, dass die Füllung des Bodens dieselbe Compaction bei den drei Versuchen gehabt, so können wir nicht umhin, darüber überrascht zu sein, dass die beiden Zahlen nicht grössere Differenzen aufweisen. Vielleicht haben sich die durch die Abrundung begangenen Fehler, und die mit t veränderlichen zweiten Glieder des Quotienten $\frac{z' - z}{\sqrt{t'} - \sqrt{t}}$ zufällig ausgeglichen, und so diese

etwas überraschende Übereinstimmung herbei geführt. Es wird darum noch nöthig sein, an anderen Böden näher zuprüfen, ob jene theoretische Beziehung zwischen den Constanten für die drei Arten Wasserbewegung auch für sie annährend erfüllt ist.

Wenn die Folgerungen einer theoreisch abgeleiteten Formel wenigstens qualitativ überall bestätigt werden, und in einen speciellen Fall numerische Prüfung ertragen, wenn es gestattet ist, darauf hin auf die Richtigkeit der Theorie selbst zu schliessen, so glaube ich mich zu dem Schluss berechtigt, dass der theoretisch abgeleitete Ausdruck für die durch einen Boden for tgepflanzte Wassermenge (XII) sich der Wirklichkeit anpassen lässt, das daher die Grundannahmen, von denen ich bei der Ableitung der Differentialgleichung für die durch den Boden fortgepflanzte Wassermenge ausgegangen bin, sich nicht allzu weit von der Wirklichkeit entfernt haben.

Wohl liegt der Gedanke nahe, die drei Constanten a, b, c, mit den Werthen für $\frac{z}{\sqrt{t}}$ innerhalb der Zeiten, wo jene Coincidenz der beiden Quotienten sich zeigt, zu bestimmen, um zur genueren Zahl für a zu kommen, allein $\frac{z}{\sqrt{t}}$ bewegt sich so langsam, und die Ungenauigkeit der abgelesenen z so gross, dass ein genauerer Werth für a auf dienem Weg nicht zu erlangen ist.

Man könnte wieder den Weg einschlagen, die Grösse $2a\varkappa$ gleich zu setzen dem Mittelwerthe aller Quotienten $\frac{z}{t}$ innerhalb der Zeiten, für die das Kriterium sich erfüllt, und die übrig bleibenden zwei Constanten mittelst zweier moglichst weit abstehenden Daten bestimmen. Für die Aufsaugung kann man in der That auf diesem Wege einen Werth für a erhalten der nur weing nämlich in den Decimalstellen von dem Mittelwerthe aller Quotienten $\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$ differiert, und wohl den Anspruch

auf die grössere Genauigkeit erheben darf. Allein; dieser Weg giebt für a der Durchsickerung einen so grossen Werth und für a der horizontalen Leitung einen so kleinen Werth, dass die theoretisch geforderte Beziehung zwischen den Constanten der drei Arten Wasserbewegung nicht einmal in roher Annährung enfüllt wird, eine Thatsache, die beweist, dass die Grösse $\frac{2a}{\sqrt{t}}\left(\pi\sqrt{t}-\frac{z}{2a\sqrt{t}}\right)$ bei diesen Bewegungsarten nicht mehr mehrere Stunden hindurch als ein kleiner Bruch angesehen werden kann.

Wenn man sich aber zur Charakterisierung eines Bodens in Bezug auf sein Vermögen Wasser fortzupflanzen, mit den Ziffern höherer Stelle begnügen will, so würde eine solche Zahl, deren Dimension $\left[\frac{\text{Länge}}{\sqrt{\text{Zeit}}}\right]$ ist, dadurch zu ermitteln sein, dass man die Bewegung der Grenzschichte der Verdunklung von dem Zeitpunkt ab, wo die Bewgung mit fast constanter Geschwindgkeit vor sich geht, durch mässig grosse Zeit möglichst scharf verfolgt, und die Stelle ermittelt wo $\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$ ungefähr denselben Werth zeigt, gleich viel ob man $\sqrt{t'}-\sqrt{t}$ gross nimmt, oder klein. Der Mittelwerth aller, Quotienten $\frac{z'-z}{\sqrt{t'}-\sqrt{t}}$ innerhalb der so ausgezeichneten Zeiten würde ungefähr mit $\frac{2a}{\sqrt{\pi}}$ identificiert werden können.

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On the Nature of Japanese Farcy, an Enzootic Skin Disease of the Horses and Cattle of Japan.

BY

H. Tokishige, *Juigakushi.*

Under different synonyms, Japanese farcy (*hiso*), pseudofarcy (*kasei-hiso*), equine pox (*hōsō*), equine syphilis (*kasa*), inundation fever (*gōzui-netsu*), *yakume* (=duty), *dekime* (=eruption), *inochitori* (=fatal), &c., there is known a special kind of skin disease, which prevails among the horses and cattle of Japan, and which is, among infectious diseases of our animals, the most devastating. As the symptoms of this disease are more or less allied to those of *malleus farciminosus*, so it is popularly known as farcy (*hiso*), and, in fact, in the *Regulations for Contagious Diseases of Animals*, issued in 1886 and amended in the previous year, this disease is treated in the same way as genuine glanders and farcy.

To our farmers and empirics this disease has been known from old times, under the vulgar names of *kasa*, *hoso*, &c.; and it has been supposed to be identical with small pox or syphilis in mankind. They believe that horses, especially foals must, in the natural course of things, contract this disease ; but that, when once it is safely passed through, the animal becomes not only immune against further infection, but is stronger and more robust in constitution than before. Most farmers are well pleased when farcy is got over, saying,—"My pony has done his duty." Owing to this superstition, those horses which have had farcy are more highly esteemed than those which have not yet had it. This fact is sufficient to show how wide-spread this enzooty is.

Formerly the disease was known only in the north-eastern part of Japan, more especially in Sendai and the neighborhood. Later on, the disease gradually spread over a wider area towards the south-west, and at present it is found in nearly all the provinces of Japan. It prevails especially in low marshy districts

and after inundations, more in rainy years and seasons than in dry, more in cold seasons than in hot.

The ancient history of this disease is quite unknown. We find in Chinese literature a description of a skin disease, called *sō* [瘡] or *wo* [黄], which is apparently similar to our farcy, but the nature, as to be explained presently, seems to be different. Our veterinary literature of old times is mostly a translation of the Chinese ; hence nothing new is to be found in it. It seems, however, generally accepted that this disease is not of recent origin, but can be traced back to many hundred years ago, and was originally known only in the north-east. It is also reasonable to suppose that Japan was originally free from this disease. From whence was it imported ? We might naturally suppose that it came from China or Korea ; but the following facts go to disprove this presumption.

Peuch and others have mentioned, under different names—*farcin de rivière, farcin cordé, farcin d'Afrique, lymphangite farcinoïde, erysipèle chirurgical,* &c., &c.,—a skin disease of horse prevailing in Africa and the sourthern parts of Europe. According to the descriptions of these authors it is perhaps identical with our farcy. Chinese farcy, on the other hand, which was first observed by us in imported Chinese ponies, was always true farcy-glanders. Viewed from these facts and from the mode of propagation from the north to the south or to those provinces in which there was intercourse with Chinese and other foreigners from old times, it is reasonable to suppose that our farcy came not from China but from some other countries. Whether it came from Africa or from Europe*, and in what way, is a question which can not be decided.

The nature of this disease remained totally unknown until 1888. At that time experiments were conducted in Sendai by special commisioners, among whom were Drs. *Yokura, Miura, Ikeda,* and *Tokishige* ; they found characteristic bacilli identical with *Schütz-Loeffler's* bacillus. Later on a second kind of pathogenic germ, a kind of *Saccharomyces,* was found by the author in the horse as well as cattle patients affected with Japanese farcy. We are now pretty well justified in saying that Japanese farcy is mostly a saccharomycotic affection, though there may also be

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* *Date Masamune* imported Persian horses to the north-east of Japan.

some cases of true farcy. Some preliminary remarks on this subject have already been published in the *Journal of the Central Veterinary Association of Japan*, and its reference in the *Centralblatt für Bakteriologie und Parasitenkunde*†. We shall first treat of farcy in horses, and before we enter upon a definitive statement we will enumerate the chief cases, actually examined.

I. In Horses.

Case I.‡

In July 1886 we were supplied with farcy matter from the Military Veterinary Hospital. In the content of farcy boils we found many *diplococci*, and a number of *oblong corpuscles* faintly stained with gentiana violet. Later we ascertained that these corpuscles were pathogenic *saccharomyces*, which are found in most cases of Japanese farcy.

A sheep was inoculated subcutaneously with farcy matter. Shortly after the inoculation, a strong local inflammatory swelling and suppuration were observed ; these symptoms, however, soon subsided and disappeared. There was *no trace of infection.*

Case II.

Chestnut stallion, 6 years old, observed 9-22 May, 1887.

This horse had only a few farcy boils. The contents of the boil were collected with antiseptic precautions, and the following animal was inoculated.

Inoculation of an old stallion. He was inoculated three times : the first time on May 18th, on the left side ; the second time on May 21st, on the right side, and the third time on July 13th, on the right side of the *septum nasi.* The material for the last was obtained from another farcy patient. Changes were as follows:—

On the second day after the second inoculation, there was a profuse discharge of transparent *mucus* from both nostrils. On the 5th day both intermaxillary glands swollen, hot

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† The *Journal of the Centr. Vet. Assoc. of Japan*, vol. VI, No. 1,2&3, 1893. [中央獸醫會雜誌第六輯一二及三卷] *Centralblatt f. Bakteriologie*, XIX Band, No. 4/5.

‡ Casuistics are arranged according to the date of observation.

and painful to the touch. On the 7th day a pea-sized fungoid ulcer appeared at the inoculated place on the right side of the *septum*. On the 11th day appeared a pearl-cord-swelling arising from the intermaxillary space, which was then much swollen, extended over the maxillar border to the masseteric region, and showed partial fluctuation. On the 12th day the abscess opened of itself and evacuated abundant pus. After that the swelling and nasal discharge diminished day by day and the case terminated in complete recovery.

After the third inoculation, there was, for some time, only mucous discharge from both nostrils ; 31 days after the inoculation appeared at *locus inoculationis* a big fungoid and many smaller similar ulcers, and a transparent mucous discharge from both nostrils. On the 65th day the ulcers became confluent, forming an extended ulcer, 2 inches in diametre. On the 115th day many minor ulcers appeared around the chief ulcer, which was then much enlarged ; nasal discharge stopped, and a pea-sized ulcer and a hazelnut-sized nodule appeared at *regio buccalis*, close to *angulus oris dexter*. After that time the morbid process became regressive ; on the 184th day the animal was apparently recovering. On May 11th the horse was destroyed and dissected.

Postmortem appearance:—Locus inoculationis of nose showed an indistinct cicatrization. Both kidneys showed multiple *herds* grey white in color, hard and fibrous. Microscopically they consisted of connective tissue, in which a few rudimentary urinary tubes were visible. To the nature of this change we will advert later on. No other change due to the inoculation.

Case III.

Old bay mare of indigenous breed, observed from February to May, '88.

Clinical remarks :—Reduced condition. Some subcutaneous nodes of walnut-hazelnut size on the breast, the right thoracic wall along the spur vein, and on the xyphoid region. The case was observed for some time, but neither progressive nor regressive changes were recognized. Destroyed on May 7th and dissected on the 8th.

Postmortem appearance:—The subcutis of breast, chest, and xyphoid region showed nodules loosely connected with the sur-

rounding tissue; each nodule consisted of a fibrous capsule containing *cheesy matter* inside. In both kidneys numerous *herds* of sinapis-hazelnut size, yellowish white in color, hard, fibrous, and even cartilaginous, and prominent over the surface of the organ, which looked knotty and uneven. On the cut surface the *herds* appeared trapezoidal or pyramidal, some were irregular in form, and they were exclusively situated in the cortical substance. Many small nodules were also found in the depth of the cortex. The right posterior lobe of lung showed a circumscribed subpleural thickening; otherwise lungs were normal. The remaining organs free from nodules or metastasis.

Microscopically no special microbe could be found in the content of subcutaneous nodules or in the renal *herds*; the nodule contained fatty *detritus* mixed with lime, the renal *herds* consisted chiefly of fibrous tissue enclosing some rudiments of uriniferous tubes.

Inoculation :—Two guinea pigs, inoculated subcutaneously at the inguinal region, with the *herds* of lungs and kidneys, showed *no reaction*.

Case iv.

Bay stallion, 2 years old, observed in June 1888.

Clinical remarks :—Farcy changes on the lips, the zygomatic and masseteric region, on the left side of neck, shoulder, extremities, praeputium, and also on the chest and abdomen; only the right side of neck and perineum were free from farcy. Muco-purulent discharge from both nostrils; the Schneiderian membrane especially on the right side showed exaggerated ulceration. Conjunctiva pale red, swollen, and covered with purulent secretion. Nutrition bad, extreme emaciation, and difficulty in moving. Temperature 39.1°C., pulse 68, small and irregular, respiration 9, very difficult, and blowing at the nose; lessened appetite. Physical examination of the chest negative. The horse was destroyed on June 16th, 10 a.m.

Postmortem appearance :—Numerous nodules in the subcutis: they were partly hard, and the cut surface greyish white or reddish grey; partly softened containing creamy pus. Subcutis of the right anterior extremity showed reddish serous infiltration.

Lymphatic glands of axillary, cervical and inguinal regions

in medullary swelling, but free from nodules; the intermaxillary glands not at all affected. The Schneiderian membrane on both sides covered with polypous or fungoid new formations and ulcers of different size and shape, miliary, linseed, pea to coin size, and partly hidden behind the turbinated bones. The right false nostril entirely blocked up with such new formations; larger nodes showed partial softening. Sinus and Eustachian valves and the remaining portion of tubus respiratorius free from affection. The right testicle contained a number of *herds* of pea-hazelnut size, having the same appearance as subcutaneous nodules, quite circumscribed and spherical in form; the cut surface looked like that of round-cell-sarcom: similar nodules also found in *tunica vaginalis communis* and epididymis. The left testicle contained only 2 nodules, while the epididymis was full of them. Remaining internal organs and articulations free from affection.

Microscopically we found in the preparation stained with *Loeffler's* methylene blue, *granular aggregations*, which were, as later on ascertained, the *grains of saccharomyces*.

Culture experiment on the potato pudding was *negative*.

Inoculation of guinea pigs:

Guinea pig No. 1 inoculated on June 15th with nasal discharge. On the next day, observed a strong local inflammatory reaction, weakness and lessened appetite; inoculated part distinctly swollen. From the 3rd day the swelling gradually decreased and the animal became more active. On the 5th day the animal was destroyed, and autopsy revealed local suppuration and slight enlargement of plica gland. No internal change.

Male guinea pig No. 2 similarly inoculated. At first, the symptoms were the same as in No. 1. Complete recovery on July 18th (33 days after inoculation).

On June 16th the following guinea pigs were inoculated;—

No. 3 with the nodule of testicle.
No. 4 and 5 with the new formation of nose.
No. 6 with the hyperaemic lung tissue.

These 4 guinea pigs reacted nearly in the same way as in No. 2; the lymphatic glands were distinctly swollen, but no abscess was formed.

Case v.

Light bay stallion, 4 years old, observed in July, '88.

Clinical remarks:—According to *anamnesis* the first change appeared in January '88, at the xyphoid region, whence it spread over the breast, scrotum, penis, back, &c. *Status praesens* was as follows;—extremely meagre; temperature 39°C., respiration 17, pulse 65 and irregular. Nodes and ulcers, characteristic of Japanese farcy, over the body, especially on the front, lips, axillary region, anterior extremities down to phalanges, back, chest, right side of haunch, xyphoid region, scrotum, penis, and the thigh of both posterior legs; the right tarsus uniformly swollen. The Schneiderian membrane on the left side extensively ulcerated, while on the right side it showed only a few ulcers: destroyed and dissected on July 23rd.

Postmortem appearance:—Many nodes found in the subcutis more especially of shoulders and of the internal surface of posterior extremities. In the latter, the intermuscular tissue and periost were also affected. Lymphatic glands of intermaxillary, inguinal, pubic and femoral region were swollen. The left testicle and epididymis contained plenty of characteristic *herds* of pea to hen egg size; many of the same *herds* were also found in the right epididymis and spermatic cord, and a few in the proper testicle. Both nose cavities extensively ulcerated; three ulcers of hazelnut size in the frontal sinus. Internal organs free from changes.

Microscopical appearance was the same as in the preceding case.

Inoculation:—Guinea pigs No. 7 and 8 were inoculated, on June 22nd with nasal discharge, No. 9—12, on June 23rd with metastatic *herds* of testicle, and No. 13 and 14, with ulcerative tissue of nose. Results were as follows;—

No. 7, inoc. with nasal discharge. On the 3rd. day redness and swelling appeared at the *locus inoculationis;* on the 5th day, preputium and scrotum swollen. 9th day, an ulcer appeared on the scrotum; the left plica gland swollen and hard, 2 cm. in diameter. The right plica gland also swollen, and it

continued to the thigh. On the 13th day, the animal was destroyed for dissection. *Postmortem* revealed suppuration of the left plica gland, no internal changes.

No. 8 and 9, with nasal discharge resp. the *herd* of testicle. Course nearly the same as in No. 7. No. 8 recoverd; No. 9 destroyed and dissected on August 4th; neither local nor internal changes observed.

No. 10, with the *herd* of testicle. Slight glandular swelling, which disappeared in a fortnight. July 20th, the animal died from acute gastroenteritis. *Postmortem* revealed 3 small abscesses at *locus inoculationis;* no internal change.

No. 11, with the *herd* of testicle. Course was nearly the same as the preceding. Died, on July 20th, from acute gastro-enteritis. *Postmortem* revealed hyperplasia of plica gland; no internal change.

No. 12, with the *herd* of testicle. Course was nearly the same as the preceding. Besides inguinal glands, udder swollen, and hazelnut-sized abscess appeared at *locus inoculationis.* Complete recovery afterwards.

No. 13, with *ulcus nasi.* Course and termination the same as in No. 10.

No. 14, with *ulcus nasi.* Besides the usual inflammatory reaction, a pea-sized abscess appeared at the wound border. Destroyed and dissected on June 28th. Autopsy revealed local abscess and slight swelling of plica gland; no internal change.

Culture experiment with pus from guinea pigs No. 7, 10 and 14 *negative* in results.

Case VI.

Light bay stallion, middle age, observed in June, '88.

Clinical remarks:—Good condition. Characteristic farcy eruption at the thigh of the right posterior extremity, the sheath of penis and scrotum: the ulcers in the skin fungoid, on the scrotum hollow and funnel shaped; both covered with yellow scabs. Destroyed and dissected on June 25th, '88.

Postmortem appearance:—Changes found besides in the external skin, in the glans and corpus penis, where the ulcers looked funnel like, the cavity being blocked up with a greyish

white smeary mass (wound secretion + smegma). The right femoral gland swollen and partly turned to abscess; both inguinal and preputial gland swollen to fist size; the cut suface greyish white and medullary; the left testicle contained a walnut-sized *herd*, full of fatty *detritus;* many miliary to pea-sized nodules in the epididymis. The right epididymis also affected as on the left side; the testicle contained only a few small nodules. In the liver a metastatic abscess of linseed size containing *pus bonum*: but neither haemorrhagic nor degenerative zone around it. In the right nose cavity, a linseed-sized nodule. Remaining organs without special changes.

Culture experiment of pus *negative.*

Inoculation of guinea pigs:—The result nearly the same as in the preceding case. Generally in the first week an acute inflammatory swelling appeared locally, and in most cases from the 5th-7th day followed a swelling of the plica gland with more or less intensity.

Male guinea pig No. 15, inoculated with the content of a farcy boil, showed slight swelling of plica gland.

Male guinea pig No. 16, inoculated with farcy product of testicle, showed a little stronger reaction. The right plica gland was swollen to hazelnut size; the left gland also a little swollen.

Male guinea pig No. 17, with farcy product of testicle. Local swelling extended over the scrotum.

In these cases the swelling of lymphatic gland went rather quickly over, and there was no evidence of suppuration.

Inoculation of horses:—Bay stallion No. 1, 6 years old and apparently healthy. On June 25th farcy matter (ulcerative tissue and abscess-content) inoculated in the nose and subcutis (in the nose a scarification was made on the right side of *septum nasi* and morbid matter was rubbed into it. The subcutaneous inoculation was made on the right side of the chest.) On the next day, a strong swelling appeared on the chest, and purulent discharge from the nose; these symptoms persisted for many days, whereby the condition was reduced. On July 14th (19th day after inoculation) the surrounding part of the wound showed an induration: still purulent mucous discharge from the

nose. On July 18th (23rd day) nasal discharge ceased, and there was no lesion in the Schneiderian membrane: on the chest, a thumb-sized induration still persisting. July 27th (32nd day), at the upper part of the subcutaneous induration, an egg-sized ulcer appeared with profuse granulation. The ulcer gradually increased in size until July 31st; afterwards it became smaller day by day, and on August 8th it was 3 cm. long and 1 cm. broad, yielding a little yellowish semitransparent fluid. On August 10th the horse was destroyed and dissected: internal organs were quite healthy.

Bay mare No. 2, 4 years old, inoculated on July 25th, in the same way as No. 1. Local reaction also nearly similar, and skin wound completely healed on July 14th. No special changes in the nose.

Case VII.

Black bay stallion, 4 years old, observed in June, 1888.

Clinical remarks:—Condition meagre; characteristic nodes and ulcers at the right cervical region, both shoulders and anterior extremities down to fetlock, both posterior extremities, sacral region, &c. Destroyed and dissected on June 28th.

Postmortem appearance:—Besides cutaneous and subcutaneous changes, there were some ulcerative nodules in the nose cavity and a few nodules in the epididymis; lymphatic glands normal.

Inoculation of 5 guinea pigs (No. 18–22), on June 28th, with ulcerative tissue of nose and metastatic nodules of epididymis. Besides local inflammatory changes, in 4 guinea pigs, more or less swelling of plica gland appeared, but this swelling afterwards subsided. Two of the animals died on July 15th from acute gastroenteritis; the internal organs free from farcy changes.

Case VIII.

Light bay stallion, 4 years old, observed in June '88.

Clinical appearance:—According to *anamnesis* first symptoms of farcy appeared in the previous December, on the right shoulder, whence it extended over the abdominal wall, both posterior extremities, and at last over the left anterior extremity. Nasal discharge was first noticed in May (1888).

Status presens on June 29th ;—farcy eruption on the head, right shoulder, thorax, both anterior extremities, right hypochondrial and sternal region, left hind quarter, both thighs, hock joint of the left posterior extremity, praeputium, &c. The left anterior extremity, right carpus and both posterior extremities swollen ; intermaxillary glands slightly enlarged and hard to the touch. Bluish yellow mucous fluid discharged from both nostrils ; many ulcers visible in the m.m. of both nose cavities. Temperature 39.1°C. Destroyed and dissected.

Postmortem appearance:—Many ulcers in nose cavities ; nodular *herds* in both testicles ; plenty of miliary nodules in lungs.

Inoculation of guinea pigs on June 29th.

Male guinea pig No. 23, inoculated with pulmonary nodules, showed, from the next day, a local inflammatory swelling. July 7th (9th day), the plica gland swollen to pea size, and on the 16th (18th day), to hazelnut size ; the swelling afterwards reduced, and on July 25th (27th day) it became again of pea size. On August 10th (42nd day), quite healthy.

Male guinea pig No. 24, inoculated with nodules of lung, showed, from the next day, a strong local inflammation, and then a swelling of plica gland to pea size. July 23rd (25th day), the animal died from gastro-enteritis. Autopsy revealed a small suppurative *herd* in the swollen plica gland. *Culture* experiment of the pus on *bacillus mallei* was *negative.*

Male guinea pig No. 25, inoculated with nodules of lung. Local and glandular symptoms nearly the same as the preceding but slighter in degree. Result : *recovery.*

Male guinea pig No. 26, inoculated with ulcerative tissue of nose. Local and glandular swellings stronger than in the preceding. Plica gland swollen to hazelnut size ; afterwards complete resorption.

Case IX.

Bay stallion, 6 years old, examined on June 30th, 1888.

Clinical remarks :—According to *anamnesis*, the first farcy nodes appeared, in January, on the right thorax, breast, axillary region, and then on the inferior belly. From April the nose

was affected and thenceforth the condition more or less reduced. *Status praesens*;—medium condition; polypous or fungiform nodes (1–3 cm. heigh) on *dorsum nasi* and at the inner angle of the right eye; they were hard and painful to the touch. Many the same eruptions scattered over the in ferior border of neck, anterior breast, lower part of lateral wall of chest, shoulder, back, hip, right flank, &c. From the right nostril discharge of greyish transparent fluid, and in the depth of this cavity an elongated ulcer 2·5 cm. long and 1 cm. broad, covered with a yellowish white crust; on removing the latter many irregular granulations in the bottom of the ulcer visible.

Postmortem appearance:—Characteristic ulcerative changes in the Schneiderian membrane on both sides of nose; many nodular *herds* in testicles, and some metastatic abscesses in the liver. Lymphatic glands free from affection.

Inoculation of guinea pig No. 27, with ulcerative tissue of nose. On July 1st (2nd day) *locus inoculationis* red and swollen; July 2nd (3rd day), the plica gland swollen to pea size. July 15th (16th day), scrotum together with the left testicle (inoculated side) distinctly swollen. July 19th (20th day), the swollen testicle no longer dislocable. July 22nd (23rd day), the testicle was more swollen attaining the size of a hazelnut, painful and showing partial fluctuation. July 28th (29th day), the animal destroyed and dissected. Necropsy revealed a *suppurative destruction of the anterior half of the left testicle*, forming an abscess of hazelnut size; swelling and *partial suppuration of the plica gland, and one miliary nodule in the spleen.*

Culture experiment:—On potato pudding, which had been infected with the content of the testicle-abscess from the guinea pig No. 27, appeared, after 48 hours, a white zone around the inoculation, and on the 4th day the latter showed a reddish brown color. On the 6th day a distinct vegetation of a reddish brown colony appeared, which became gradually prominent and at the same time spread over the surface of the medium, and on the 18th day the colony attained a horizontal dimension of 3 cm. The same culture was again obtained from the content of the glandular abscess. By recultivation on fresh medium, the vegetation became easier and more vigorous; thus, the 2nd generation showed a distinct vegetation on the 3rd day, and the 3rd

generation on the very day after inoculation. The colony on the potato medium was composed of *very small and short bacilli*, smaller than the tubercle bacilli; they performed, in a hanging drop, an active vibratoy movement, and were not easily stained with *Loeffler's* blue, but better with *Ziehl's* solution: they were very liable to undergo involution, soon assuming a dumbbell or diplococcen-like, form, after which the staining became much more difficult. In the pus of an inoculated guinea pig they appeared larger and longer, even longer than the tubercle bacilli, and afforded, when stained, a charateristic interruption of colour. This microbe was not cultivable directly from the horse, but always through the medium of experimental animals, and was pathogenic to the guinea pig and horse, as seen in the following experiment:

Inoculation of guinea pigs with pure culture of the bacilli; the result was as follows;—

Male guinea pig No. 28, inoculated on August 7th, '88, showed on the next day strong local inflammatory reaction, the praeputium, scrotum, &c. being swollen, reddish, and painful, and a bloody purulent discharge from the wound. These acute symptoms gradually subsided, while the general condition was getting worse day by day. On the 8th day after inoculation, the inguinal gland was swollen to pea size, and three nodules, and an ulcer appeared on the scrotum. On the 13th day the right carpal joint was found swollen, reddish, and painful, and another small ulcer appeared on it; afterwards the swelling became larger. On the 16th day the animal was destroyed and dissected: a small abscess in the scrotum, and an induration of para-articular tissue of the right carpus, with collateral oedem in the surrounding tissue; the parenchym of testicles, lymphatic glands and internal organs free from affection.

Male guinea pig No. 29, inoculated on August 7th, '88. Acute symptoms in the 1st stage similar to No. 28. On the 8th day after inoculation a pea-sized ulcer was found at *locus inoculationis;* on the 9th day the animal was destroyed; the *postmortem* revealed only local ulceration, no internal change.

Male guinea pig No. 30, inoculated on August 7th, '88, showed the same symptom in the beginning. On the 8th day after inoculation 2 small abscesses at the sheath of penis and

scrotum were found; on the 9th day the animal was destroyed and dissected, and the *postmortem* was similar to No. 29.

Male guinea pig No. 31. Inoculation-date and the first symptoms were the same as in the preceding. On the 8th day a dry ulcer appeared at the *locus inoculationis;* on the 13th day both carpal joints, scrotum and the sheath of penis swollen, and the latter partly fluctuating; on the 16th day an ulcer appeared on the dorsal surface of carpus. The *postmortem* was nearly the same as in No. 28.

Male guinea pig No. 32. Inoculation-date same as the preceding. Reaction was similar to No. 29.

From the pathological products of the above mentioned guinea pigs, we obtained always a *pure culture of the same bacillus* as the original.

Inoculation of experimental horses with pure culture:—A stallion of Japanese breed No. 3, 3 years old, quite healthy, was inoculated, on August 9th 7 a.m., with pure culture, in two places, in the subcutis of the right shoulder and in the mucous membrane on the right side of the *septum nasi.* On the next day temperature 38.3°, pulse 64, respiration 34-35, profuse purulent discharge from the right nostril; inoculation place of the right shoulder was swollen to the size of an apple, but the horse was still active. On the 3rd day temp. 40.6°C., pulse and resp. also accelerated; profuse purulent discharge from both nostrils; subcutaneous swelling increasing, and both intermaxillary glands a little swollen. On the 4th day temp. 39.3°C., and the scarified wound of nose changed to a big ulcer, 3 cm. in diameter. On the 5th day temp. 39.3°C., pulse 56, resp. 11; the subcutaneous swelling smaller and flatter, and the inoculation—wound gaping covered with yellow scabs; nasal discharge lessened. On the 6th day temp. 39.2°C.; on the 7th day temp. 39°.C., both intermaxillary glands enlarged to thumb-size, but still dislocable. In the whole course the horse showed lessened appetite and fell gradually in his condition, and at last, on the 8th day, the horse was destroyed for dissection. *Autopsy:* ulcerative destruction of the Schneiderian membrane on both sides of *septum nasi,* and swelling (medullary) of intermaxillary gland; internal organs free from changes.

Young stallion of Japanese breed No. 4. Inoculated also on August 9th 7. a.m., on the right side of nose and on the right

shoulder. On the 2nd day temp. 38.6°C., pulse 45, resp. 20; local symptoms similar to the preceding. On the 3rd day temp. 40.2°C.; purulent discharge from the nose and skin wound; intermaxillary gland swollen. On the 4th day temp. 39.1°C. On the 5th day temp. 38.8°C., pulse normal, respiration a little difficult; *locus inoculationis* of shoulder much swollen; ulceration in the mucosa of nose, and appetite diminished. On the 7th day the cutaneous swelling a little reduced, while adjacent lymphatics were swollen to finger size, leading from the inoculated *focus* up and downwards; intermaxillary glands swollen to thumb-size. On the 10th day 5 nodules appeared at the anterior border of neck and many ulcerative nodes of pea-hazelnut size, at the margin of the right nostril. Soon destroyed for dissection.

Postmortem appearance:—Local suppuration and ulceration. Lymphatics on the right shoulder in suppuration. Changes in the nose and intermaxillary gland similar to the preceding.

Young stallion of Japanese breed No. 5. Inoculated in the same way as No. 4. On the 10th day destroyed for dissection; nearly the same changes as the preceding. (As these experiments had been conducted in Sendai and discontinued for want of time, further observation was impossible.)

Old stallion of Japanese breed No. 6, inoculated with pure culture on Sept. 19th on the right side of *septum nasi* and in the subcutis of the left thorax. 2nd day (after inoculation), *locus inoculationis* of thorax was swollen and painful; the nasal wound was covered with a yellow crust; no abnormal discharge. 5th day, bloody purulent discharge from the thoracic wound; a big ulcer appeared at the *locus inoculationis* of nose, and the intermaxillary gland a little swollen. 6th day, the ulcer of nose getting larger and both *alae nasi* swollen. 8th day, the thoracic swelling more extended, and a cord-like swelling appeared over the shoulder; nasal ulcer much more enlarged; from both nostrils discharge of stinking, purulent mucous fluid; left anterior fetlock swollen, and hind quarters weak; death on the 10th day after inoculation.

Postmortem appearance:—Condition bad and anaemic. At *locus inoculationis* of thorax an abscess filled with thin ichorous pus, from this abscess a varicose swelling leading forwards over the shoulder. In the mucous membrane of the

septum nasi and turbinated bones of the right nose cavity, numerous miliary to pea-sized ulcers, each surrounded with a hyperaemic or haemorrhagic zone, the bottom looking yellowish and lardy. In the lungs numerous nodes of pea-hazelnut size, each node looking greyish yellow, quite circumscribed and round in shape; the superficial nodes surrounded with a red or blackish red zone. The mucous membrane of trachea and larynx hyperaemic. In the larynx coin-sized haemorrhagic erosions, and in the trachea many small haemorrhages. The subcutis of the right posterior fetlock with serous infiltration; the intermaxillary gland slightly swollen.

5 guinea pigs (No. 33-37) inoculated with nodular *herds* of the lungs from the stallion No. 6, 2 of them died, within 2 days, from acute septicaemia, due to mixed infection with oedem bacillus and streptococcus. The 3rd died on the 10th day with symptoms of acute glanders. *Postmortem* revealed ulcerative changes in the nose, ulcerative destruction of scrotum and praeputium, and slight medullary swelling of plica gland. The 4th (No. 36) died 42 days after inoculation. *Postmortem* showed ulcerative destruction of the local skin and subcutis, suppurative *herd* in the plica gland and in the left testicle, and numerous millet to pinhead-sized, grey white nodules in the spleen, liver, lungs, and even in the pancreas. No. 37 (the 5th) died 62 days after inoculation. *Postmortem* appearances were more conspicuous than in the preceding; we found, besides local ulcerative destructions, ulceration in the mucous membrane of nose, formation of abscess in the inguinal, axillary and lumbar gland, and grey white nodules in lungs, liver, and spleen. From the guinea pigs (3rd-5th) pure culture of original bacillus was obtained.

An old stallion No. 7 inoculated, on July 1st, with pure culture on the right side of nose and on the right shoulder. After inoculation appeared a local suppuration. On Oct. 25th (115 days after) the horse was destroyed and dissected. *Postmortem:* a few nodules in the lungs.

The same generation of the bacilli has repeatedly been inoculated in a great number of experimental animals. In the course of time the virulency of the bacillus was gradually weakened; the reaction being mostly limited to the *locus inoculationis.*

Case X.

Bay stallion 8 years old, observed on June 30th, '88.

Clinico-anatomical appearances :—According to *anamnesis* the horse had been suffering from farcy since December '87, its condition getting gradually worse. *Status praesens* :—Characteristic eruptions over the whole body including the ears; extremities, especially the right posterior, much swollen, the skin being destroyed by ulceration, covered partly with bad stinking secretion and partly with yellow-brown or reddish brown scabs; temp. 39.6°C. *Postmortem* section revealed ulcerative changes in the nose and nodular *herds* in the testicles.

Inoculation of guinea pig (No. 38) with morbid tissue of testicle. *Locus inoculationis* was swollen for some time: this swelling soon subsided and the wound quickly healed.

Case XI.

Black bay mare, 6 years old, observed on June 2nd, '88.

Clinico-anatomical appearances :—This was a slight case, there being a few nodular ulcers on the right posterior extremity. According to *anamnesis* the owner first noticed the disease this spring ('88); since that time neither progression nor regression. *Postmortem* revealed a few nodules and ulcers in the Schneiderian membrane.

No *inoculation*.

Case XII.

Fallow stallion, 8 years old, observed on July 3rd, '88.

Clinico-anatomical appearances :—Meager stallion with characteristic eruptions on both sides of face, both shoulders, down to the axillary region, in the posterior extremities, especially on the left side, and on the scrotum. Discharge of reddish fluid from nostrils, and in the Schneiderian membrane of both nose cavities ulcers of lentil to pea size. According to *anamnesis* this horse was affected twice during the previous year and was successfully treated. At the end of the last year

he took the disease the 3rd time and the latter still persisting. *Postmortem section*: polypous ulcers in the Schneiderian membrane, pharynx, and on the posterior surface of epiglottis, and numerous medullary *herds* in both testicles.

No *inoculation.*

Case XIII.

Bay stallion, 7 years old, observed on July 3rd, '88.

Clinico-anatomical appearances:—Fungiform ulcers in the skin of the upper lip, cheek and left eye lid. Conjunctiva and cornea of the left eye entirely destroyed and covered with irregular reddish yellow granulations, and greenish yellow muco-purulent secretion. A few nodes on the breast and left axillary and thoracic region; the left testicle enlarged; discharge of muco-purulent fluid from both nostrils, and many ulcers in the Schneiderian membrane; the right intermaxillary gland a little swollen. *Postmortem appearance*:—Ulcerative destruction of skin, subcutis and mucous membrane of nose; metastatic nodules and parenchymatous haemorrhage in the left testicle.

No *inoculation.*

Case XIV.

Dun stallion, 3 years old, observed on July 5th, '88.

Clinico-anatomical appearances:—Good condition; temp. 39.6°C. Characteristic eruptions (nodes and ulcers of hazel to walnut size) on the lip, left shoulder, breast, lateral side of right forearm, fetlock joint, right flank, croup, left posterior extremity, inferior surface of abdomen, praeputium, &c. Mucous discharge from the left nostril, and an irregular ulcer on the right side of *septum nasi*; frequent snorting; thumb-sized swelling in the intermaxillary space, and slight swelling of upper cervical gland. According to *anamnesis* the first farcy appeared in November 1887 on the right flank region. *Postmortem section*; besides cutaneous and subcutaneous changes, nodules and ulcers in the mucous membrane of nose and in the testicles.

Inoculation of 2 guinea pigs (No. 39 and 40) with morbid tissue of testicle. In both animals swelling of plica gland was observed. One of them died on the 19th day after inoculation, from acute gastro-enteritis ; no other internal changes. The 2nd animal recovered in about a month.

Case XV.

Bay mare, 5 years old, observed on July 5th, '88.

Clinico-anatomical appearance :—A few farcy nodules in the thigh and posterior aspect of the left hind extremity ; nose and other organs were quite free from farcy.

No *inoculation.*

Case XVI.

Bay stallion, 4 years old, observed on July 12th, '88.

Clinico-anatomical appearances :—Many farcy boils over the body including the external genital organs. A small quantity of purulent discharge from both nostrils and ulcerative nodules in the Schneiderian membrane ; intermaxillary gland not swollen. *Postmortem :* numerous fungoid ulcers in both nasal cavities, some in the pharynx and larynx ; a few medullary nodules of millet to linseed size in both lungs ; some nodules and abscesses in the testicles.

Inoculation of guinea pigs :—A male guinea pig No. 41 inoculated with ulcerative tissue of nose. Besides local inflammatory reactions, the animal showed on the 7th day after inoculation, a swelling of plica gland and, on the 17th day, a slight swelling of left inguinal papilla of the udder ; these swellings afterwards gradually lessened and disappeared on the 29th day after inoculation. The second guinea pig No. 42, inoc. with ulcerative tissue of nose, showed on the next day a strong local swelling, and died on the 3rd day from malignant oedem. 2 guinea pigs No. 43 and 44, inoculated with morbid tissue from testicle, showed on the 5th day a swelling of plica gland, which attained, on the 15th day, the size of a pea ; afterwards it was gradually reduced and resorbed.

Inoculation of a horse :—Young bay mare of Japanese breed

No. 8 inoculated with morbid tissue from the case XVI, on the left chest, breast, plica genu, and in the nose cavity. On the 3rd day after inoculation a distinct local swelling appeared in the skin, and stinking purulent discharge from both nostrils ; these symptoms persisted for some days, and from the 2nd week the swelling and nasal discharge gradually lessened. Complete recovery on the 27th day after inoculation.

Case XVII.

Black stallion, 4 years old, observed on Aug. 9th, '88.

Clinico-anatomical appearances:—Farcy boils on the inferior lip, breast, inferior part of thorax, and in the preputium ; slight swelling of both intermaxillary glands. According to *anamnesis*, the farcy was first noticed on July 2nd, 1888. *Postmortem section :* numerous nodules in the subcutis even in intermuscular tissue. Numerous nodules and ulcers from miliary to pea size in the Schneiderian membrane of both nasal cavities ; one nodule in the epiglottis : a few miliary nodules in lungs, and an apple-sized abscess in the left testicle.

No *inoculation*.

Case XVIII.

Dark chestnut stallion, 8 years old, observed on Aug. 9th, '88.

Clinico-anatomical appearances :—Many farcy boils on the breast, both shoulders, the left side of chest, the sheath of penis, &c. According to *anamnesis* the first symptoms appeared this May in the abdominal region, whence it spread over the body. *Postmortem section* ; characteristic ulcers in the depth of nose cavity and on the epiglottis ; a few sinapis-sized nodules in lungs. Testicles and other organs normal.

No *inoculation*.

The cases IV–XVIII were observed in Sendai during the summer of 1888. Our object was, at that time, to prove whether this skin disease was veritable farcy or of a different nature. Consequently we followed, in undertaking our experiments, the method prescribed by *Schütz* and *Loeffler*. The content of farcy boils and morbid tissues from various organs were subjected to a

careful microscopical examination, the tissue being cut fresh or in a hardened state. For staining we used, in most cases, *Ziehl's* fuchsin and *Loeffler's* methylene blue. We always found in the content of farcy boils, certain kinds of *cocci.* In the stained preparation of tissue we could not clearly demonstrate the presence of any special kind of bacilli, which might be considered as pathogenic, except an irregular heap of grains, which was, as later on ascertained by the author, an aggregation of *saccharomyces* usually present in the morbid matter of Japanese farcy—it has since been found in all alcoholic specimens collected in Sendai. Only in one case, CASE IX, have we succeeded in raising a pure culture of bacilli, which may be considered as identical with *Schütz-Loeffler's bacillus.* Thus out of 15 cases, one was true glanders, while the remaining 14 were of a saccharomycotic nature.

CASE XIX.

Black stallion of Japanese breed, 16 years old, observed during Nov.–Dec., '89.

Clinical appearance :—Condition bad and meagre, mucopurulent discharge from both nostrils; skin of the intermaxillary space thickened and hairless ; the intermaxillary gland not swollen ; no farcy changes in the skin.

Postmortem appearance :—Skin and subcutis free from farcy. Both anterior lobes of lungs in partial hepatization, with many miliary to walnut-sized irregular nodules and abscesses. On the left side of *septum nasi* ulcers of linseed to coin size ; these ulcers were hollow with indurated bottoms and borders, which looked yellowish white and lardy.

Inoculation of guinea pig No. 45, on Nov. 29th, with nasal discharge. On the next day appeared a local swelling, which turned to a bad ulcer ; plica gland swollen. On the seventh day the animal was dissected. *Postmortem section* revealed a suppurative *herd* in the plica gland. *Culture* experiment was positive : we obtained from the pus a pure culture of *bacillus mallei.* Another guinea pig No. 46 was similarly inoculated, and the reaction was nearly the same as in

the preceding case. Swelling of the lymphatic gland persisted for a long time, but no abscess was formed, and finally disappeared. The 3rd guinea pig (No. 47) inoculated on Dec. 3rd, '89, with ulcerative tissue of nose. After inoculation appeared local ulceration covered with bad pus. Death on the 10th day after inoculation. *Postmortem section*; numerous gray, transparent nodules of miliary size in lungs. In a 4th inoculated guinea pig (No. 48) changes were nearly the same as in the preceding case. On the 15th day after inoculation the local swelling subsided, and the skin wound healed. Both inguinal glands, were swollen to finger size; this swelling gradually disappeared.

A number of guinea pigs (17) and a horse were inoculated with the pure culture. The guinea pigs showed strong local reaction, and malleous changes in lungs, testicles, &c. In the horse the inoculation only caused a local swelling and suppuration.

Case XX.

Stallion of Japanese breed, observed in Oct., '90.

Clinical remarks:—This horse was admitted to our Hospital for treatment. According to *anamnesis* the first node appeared on the right flank, and the affection gradually extended over the neighboring parts. We found besides a slight swelling of the intermaxillary glands. The skin affection was treated with different medicaments, but there was no marked improvement. On Oct. 10th, '90 the horse was destroyed for dissection.

Postmortem appearance:—Farcy nodes of different sizes in the subcutis of the right flank, hypochondriac, and inguinal region; they were surrounded by hyperaemic and infiltrated zones, partly turned into abscesses containing a thick cheesy pus. Lymphatic glands in the plica genu and inguinal region swollen, and partly turned to suppuration; the intermaxillary glands also swollen containing inspissated pus. Lungs showed here and there small *herds* of hepatization: in the liver a small metastatic abscess.

Inoculation of 7 guinea pigs (No. 49–55) on Oct. 10th. Three of them (No. 49–51), which were inoculated with the content of farcy, intermaxillary and liver abscesses, died from

septicaemia within 3 days after inoculation. The 4th (No. 52), inoc. with lung tissue, showed local ichorous ulceration for some time, but ultimately recovered. The 5th (No. 53), inoculated with lung tissue showed the same local ulceration, and afterwards died with symptoms of acute gastro-enteritis : postmortem revealed no special change in the internal organs. The 6th (No. 54), inoculated with the local ulcerative tissue of the preceding (No. 53), died with symptoms of acute septicaemia. The 7th (No. 55), inoculated with the content of farcy boil, showed no special reaction. The postmortem appearances of No. 49–51 and 54 were all similar,—strong serous infiltration of subcutis, reddish serous effusion in the thoracico-abdominal cavity and dim swelling of parenchymatous organs. In these effusions oedaem-bacilli and streptococci were found in abundance.

Case XXI.

Old stallion of Japanese breed, observed during Sept.–Nov., 1891.

Clinical appearance :—Farcy boils over the whole body, especially on the inferior border of neck, thorax, the upper part of anterior extremities, haunch, scrotum, &c. This horse was observed for a long time. Meanwhile its condition was considerably reduced, though it had a good appetite ; died on Nov. 4th.

Postmortem appearance :—Farcy boils mostly seated in the cutis ; some reaching the subcutis and in such places lymphatics were swollen like a cord. Inguinal lymphatic glands much enlarged, cut surface looking medullary, but free from nodules. Intermaxillary glands on both sides swollen to thumb-size with a purulent *herd* in the centre. *Tunica Dartos et Vaginalis* contained many nodules, by which the latter was agglutinated with the testicle ; the parenchym of the testicle, however, free from changes. In the left nose cavity, a finger-sized ulcer on the inner surface of the wing, and many pea-sized ulcers in the deeper part especially over the inferior turbinated bone ; on the right side similar ulcers only on the *septum nasi.*

Inoculation of 4 guinea pigs (No. 56–59): No. 56, inoculated with the ulcerative tissue of nose, showed swelling and ulceration *in loco* and swelling of the inguinal gland. No. 57, inoculated with the same substance, showed only a local swelling. No. 58, inoculated with the content of farcy, died on the 4th day from malignant oedem. No. 69, inoculated with the content of farcy boil, showed local suppuration for a long time, but gradually recovered.

In No. 58 we found, *postmortem*, a small abscess in the epididymis, and from the content we obtained a pure culture of *bacillus mallei.*

CASE XXII.

Old summer black stallion, observed in April, 1892.

Clinical remarks :—This horse was purchased for experimental purposes. When he arrived he had farcy on the head, shoulder, neck, back, posterior extremities, &c., here and there ulcers being confluent to an extended superficial ulceration covered with thin bloody fluid. Condition bad and lame in the right posterior extremity.

Twice *mallein* was injected. Afterwards the process made more rapid progression; purulent discharge took place from the nose, and ulcers appeared on both sides of *septum nasi;* the intermaxillary glands not swollen. Death on June 13th, 1892.

Postmortem appearance :— Numerous nodules, abscesses, and ulcers scattered over the whole body. As in the foregoing case, the nodules mostly situated in the cutis; in those places, where the skin was destroyed—shoulder, axillary region, posterior extremities, &c., the morbid process was propagated in the subcutis along the course of lymphatics, which were swollen to a varicose chain, forming here and there nodes or abscesses of pea to wal-nut size; the content of abscess consisted of pus of mucilaginous consistency. The cutaneous ulcers on transection funnel-like, their bottom indurated and greyish white. In the extremities nodes distinctly prominent and polypous, whose apex being in a state of caseous metamorphosis. On the head, ulcers reached the periost. Subcutis of both posterior extremities showed

serous infiltration, and the local veins were blocked up with tight thrombi. Mucous membrane of the upper respiratory tract covered with numerous polypous ulcers and abscesses ; miliary-sized abscesses were seated in the subepithelial tract. The chiefly affected parts were *septum nasi* on both sides, ethmoidal shells, Eustachian valves, guttural pouches, pharynx, sinus Morgagni, epiglottis, vocal ligament, and trachea down to its bifurcation : ulcers were 2–3 mm. prominent with convex or concave surface; on cutting the tissue looked greyish white and medullary, studded with spotty or thready haemorrhages. Lungs emphysematous and free from nodules. Spleen showed hyperplasia of pulpa and on its lateral surface near the basis 2 metastatic abscesses, one sinapis and the other linseed in size, containing *pus bonum.* Axillary and inguinal glands were enlarged and partly in suppuration : intermaxillary and upper cervical glands were slightly enlarged. Scrotum and testicles on both sides contained many nodules of pea-hazelnut size, and in the left testicle, a big node of wal-nut size, a part of which was already softened and turned to a creamy substance.

Inoculation of guinea pigs:—18 guinea pigs (No. 60-77) were inoculated with various mordid products. Three of these inoculated with farcy-content, showed no special changes. Of the remaining 15, inoculated with the new formation of the nose and testicles and the metastatic *herd* of the spleen, 12 died on the 2nd and 3rd days after inoculation, with symptoms of malignant oedem ; in one of them, inoculated with nasal tissue, we found partial hepatization of lungs, with which another guinea pig was inoculated in order to prove the presence of malleous bacilli ; the latter died of malignant oedem and culture was impossible. The revived guinea pigs (inoculated with the new formation of nose and testicles) showed a swelling of plica gland, which was gradually resorbed ; in one of them a walnut-sized abscess in *loco inoculationis* ; culture experiment with the content was *negative.*

Inoculation of horse :—Morbid matter of testicle was inoculated in the subcutis of the left cervical region of a stallion No. 9. After inoculation local swelling and suppuration appeared , these symptoms soon subsided, and the wound healed by cicatrization.

Case XXIII.

Black stallion, 10 years old, height 137 cm., observed during January–February, 1893.

Clinical remarks :—Anamnesis not known. *Status praesens* was as fellows ;—The right posterior extremity swollen and elephantiac. From the thigh down to the fetlock of the same extremity, showed extended ulceration covered with purulent haemorrhagic exsudation, and the picture was the same as *Himushi*,—another skin affection of the horse, which is also common in Japan. By close examination we found, in the ulcerated surface and the neighboring parts, many characteristic nodes and abscesses as found in Japanese farcy. The nodes were crater-like with a central excavation, which was filled up with a glutinous, fibrino-purulent coagulum. On the periphery of the ulcerated surface, were abscesses, containing a dim fluid mixed with cheesy particles. *Saccharomyces* was abundantly found in the pus and morbid tissues.

This horse received 3 injections of *mallein :* to the result of this injection we will revert later on. Afterwards the process gradually extended over the pubic and inguinal region ; death resulted on February 20th ; dissected on the 22nd.

Postmortem appearance :—The right porterior extremity showed extensive ulceration and was much swollen. Many nodes and abscesses, hazel-walnut in size, were found in the inguinal and pubic regions. On transection, the thickened part of the said extremity showed tight fibrous structure, in which numerous medullary nodules were embedded : the process, however, reached neither the periost, nor the articulation nor the sheath of the tendon. In the left nose cavity miliary till linseed-sized nodules, seated in the parenchym of mucosa ; 8 nodules on the turbinated bone, 12 on the septum, 16 on the ethmoidal shells ; the right nasal cavity free from affection. In the larynx a miliary nodule on the inferior side of *ligamentum vocale sinistrum.* Superficial and deep inguinal and crural glands on both sides, and the right lumbar gland much swollen, the crural gland being 6 cm. long, 3 cm. thick and 5 cm. broad ; the cut surface looking partly hyperplastic and partly medullary. Intermaxillary gland was a little enlarged and showed on transection a pea-sized abscess filled with thick

yellowish pus. Both testicles contained a number of meduallary *herds*.

Microscopically we found numerous *saccharomyces* in every morbid product and tissue. In the lymphatic glands they were abundantly found in the medullary swelling, while in fhe hyperplastic portion they were scanty. Long diameter of the microbe 4.0 μ. and the transverse 3.6 μ. It contained a granule of the diameter 0.5 μ. The microbes were partly free and partly contained in pus corpuscles, measuring 13–21 μ. Most of the microbes did not stain with common aniline dyes, or with haematoxlin, carmine, &c., but were easily stained with picric acid and iodine ; the granules and those saccharomyces, full of protoplasm and perhaps younger ones, could be easily stained with aniline dyes. Besides this we found, in the intermaxillary abscess, a few *diplococci* and *streptococci*.

Culture experiment :—The content of inguinal abscess was cultured on and in the following media,—potato slices, nutrient gelatine, glycerine-agar, and beef bouillon. Until the 22nd day there was no apparent vegetation. Microscopically we found in the gelatine and agar media some *saccharomyces*, which were swollen to larger spherical corpuscles, nearly double the original size,—6–7 μ. in diameter. These swollen corpuscles contained a number of granules, 2 μ. in diameter. We watched for a longer time, but no furiher changes were observed. In simple, not neutrallized horse bouillon, appeared on the next day flocculent precipitate of *streptococci* and after a month we found among the swarm of *streptococci* some *saccharomyces* which were spherically dilated.

Inoculation :—3 guinea pigs (No. 78–80) were inoculated on February 22 with farcy matter ; 2 of them showed locally a pea-sized abscess, which turned to an elongated ulcer. The pus from the abscess contained numerous *saccharomyces* in association with different bacteria and those pus corpuscles, which contained the former were often supplied with protoplasmic feet in the form of pseudopodia. In one guinea pig the ulcer soon healed by cicatrization. In the other the ulcer persisted for a long time, and the animal died on March 13 from pleuro-pneumonia ; in the pleural exsudation and diseased part of the lungs, we could not find any *saccharomyces*. In the third guinea pig there was no proper reaction.

Guinea pigs (No. 81 and 82) were inoculated, on Febr. 22, with the morbid matter from the inguinal and intermaxillary gland. A slight swelling of the plica gland was observed, but no further changes.

Inoculation of 6 white rats with inguinal and intermaxillary gland-substances. In 4 of them appeared locally a pea-sized abscess, in which *saccharomyces* could be demonstrated only for a few days; the wouud rapidly healed.

Case XXIV.

Black stallion, 12 years old, observed in February, 1893.

Clinical remarks :—Old meagre horse with purulent mucous discharge from both nostrils; a few nodes and ulcers on the left flank region near the plica genu. This horse received one injection of *mallein.* Died on Febr. 11, p.m., '93; dissected on the 12th.

Postmortem appearance :—Besides the cutaneous and subcutaneous changes, we found one miliary nodule in the intermaxillary gland, whieh was a little enlarged, and partial hepatization in the right anterior lobe of lung. Microscopically *saccharomyces* and a few *cocci* were found in the subcutaneous nodule, while in the pulmonary and intermaxillary nodules, no *saccharomyces* but *diplo*-and *streptococci*, and in the pulmonary *herd*, a number of short thick bacilli, whose nature was not fully determined, but they were distinctly larger than *Schütz-Loeffler's bacilli.*

Culture experiment as to *saccharomyces* and *B. mallei* was *negative.* No *inoculation.*

Case XXV.

Light bay stallion, 5 years old, observed in February, 1893.

Clinical remarks :—Bad condition: on the left saddle region, behind the shoulder, there was a dollar-sized ulcer, whence a cord-like swelling, which was hard and not fluctuating, leading forward over the shoulder and terminating at the anterior border of the latter; the intermaxillary glands not swollen.

This horse received 3 injections of *Mallein.* The cutaneous lesion was afterwards treated by Prof. *Suto* and the lesion underwent some improvement, the *saccharomyces* in the wound secretion decreasing in number. Meanwhile a profuse purulent discharge appeared from both nostrils; respiration became difficult ond dyspnoe threatened. On June 18th tracheotomy was performed, but it was of no avail to avert a quick lethal termination of the disease. Autopsy was performed on the 19th.

Postmortem appearance:—Long cicatrices on the left scapular and thoracic region, and hard nodules of pea to linseed size, 5-6 in number, on the perineum. In the right testicle one metastatic *herd* of pigeon-egg size; the intermaxillary glands not much enlarged, free from nodules. The lungs full of circumscribed *herds* of hazel-nut size, round or oblong and medullary on cut surface, and in both anterior lobes the interstitial tissue distinctly thickened; the remaining lung tissue was partly atelectatic and partly oedematous with some old thrombi in the branches of art. pulmonalis. No farcy changes in the trachea, bronchi, and the lymphatic glands of chest. One pea-sized nodule on the right side of *septum nasi.* Microscopically a few *saccharomyces* were found in the *herd* of the lungs and testicle.

Culture experiment of *saccharomyces* on different media, *inoculation* of guinea pigs (No. 83 & 84) and *auto-inoculation* were *negative.*

Case XXVI.

Bay stallion, 10 years old, purchased on February 10th, '93, for experimental purposes.

Clinical remarks:—Moderate nutrition; a number of ulcers found on the chest and left anterior and posterior extremity; these ulcers were of coin size, slightly prominent over the skin and covered with reddish yellow or brownish scabs. The left intermaxillary gland a little swollen, but smooth and dislocable. Thin purulent discharge from the left nostril; the Schneiderian membrane, on this side, was covered with many small fungoid ulcers. This horse received 3 injections of *mallein.* After that the animal showed thick purulent and at times bloody

discharge from both nostrils, and ulcers on the right side of *septum nasi.* Rapid emaciation and cachexia, and death on May 3rd.

Postmortem appearance :—Farcy changes over the whole body including the genital apparatus. Intermaxillary, inguinal, plical, and axillary glands more or less swollen and partly turned to abscess. In one testicle a metastatic abscess of hazelnut size. Mucosa of both nose cavities showed abundant ulceration. Pharynx and larynx and upper part of trachea were also affected by ulceration. Guttural pouches and sinus free from farcy ; so also the internal organs. Microscopically *saccharomyces* found in abundance. Blood showed a slight degree of leucaemia

Culture experiment :—The content of farcy was inoculated in common gelatine and agar, and different sorts of fluid media. In the gelatine medium the *saccharomyces* assumed on the 5th day a spherical transformation as already mentioned ; but further growth was not possible. On the agar medium, the cells received, on the 31st day, not only spherical but also elongated dumb-bell form. No vegetation was stated in the bouillon prepared with fresh testicle of the horse, and in the influsion of horse dung.

Inoculation:—A guinea pig, No. 85, was inoculated, on Feb. 20, with farcy content. Local swelling and ulceration in preputium, which caused paraphimosis, and death from uraemia on March 11th. *Postmortem section* revealed a swelling of the right inguinal gland, in which, and also in the left gland, which was apparently normal, we found a number of *saccharomyces.* The latter were even found in the pancreas, which looked otherwise normal.

Case XXVII. Japanese Farcy: recovery and subsequent inoculation of Bacillus mallei.

Black stallion, 20 years old, purchased for experimental purposes on Febr. 14th, '93.

Clinical remarks :—Bad condition, lame in the right posterior extremity. A few nodes and ulcers were found on the lip, cheek, the right jugular region, the right shoulder, breast, the knee fold, forearm and coronary region of the right anterior extremity, the left hypochondrium, the umbilical and right

inguinal region, the left posterior extremity and the perineum. Nothing abnormal in the lymphatic gland or nose cavity. This horse received one injection of *mallein*, and was treated afterwards by surgical operations. The treatment was successful, and the animal apparently recovered.

On Oct. 10, '93, the horse was inoculated subcutaneously with pure culture of *B. mallei* obtained from Prof. *Schützes* laboratory. The following changes were observed in succession; local swelling and induration, formation of nodes, oily purulent discharge from inoculation wound, the diffuse swelling and eruptions of farcy boils and ulcers on the posterior extremity, similar eruptions on the right side of neck, sternal region, left flank, and on the internal thigh, swelling of the right anterior extremity; eruptions in the skin of tracheal region and of the right posterior extremity. From these foci the morbid process quickly spread over the neighboring parts. Then appeared nasal discharge, which was even bloody. Wound secretion of *locus inoculationis* and nasal discharge were quite characteristic of genuine glanders, and we could easily demonstrate *bacillus mallei* in these discharges; while nodes and ulcers in other regions of the body were prominent, and had the appearance of Japanese farcy, and in these eruptions we found numerous *saccharomyces*. The horse died on November 21, '93; and was dissected on the 22.

Postmortem appearance:—Extreme emaciation: mucous discharge from both nostrils. Farcy boils and ulcers on the head, the inferior cervical, left praescapular and sternal region, the inferior and lateral abdominal wall, the thigh of the left posterior extremiy, the scrotum, and the heel of the right anterior and left posterior extremities: the subcutis of the last mentioned extremities showed elephantiac thickening. The subcutaneous abscesses, which were abundantly found, contained thick yellowish pus characteristic of Japanese farcy; in some of them, the content was a little thinner and mucilaginous. Ulcers showed infiltrated border, but were not polypous as commonly met with in Japanese farcy. In the nose cavity, especially on the right side, numerous ulcers, pea-linseed in size; they were mostly hollow with infiltrated bottom and border, and the larger ulcers with pale irregular granulations: the Eustachian valves and larynx showed a number of smaller

ulcers. The lungs esp. the anterior lobes and anterior part of posterior lobes contained numerous nodules, linseed-sinapis-millet in size, their number varying from 3-4 in one cubic centimetre to 1 in every 2 cubic centimetre of the parenchym. They showed quite characteristic features of true malleous nodules. The intermaxillary, axillary, inguinal and pubic glands, especially on the left side, showed medullary swelling, but were free from nodules; the remaining internal organs also free from malleous changes. Under the microscope we found a few *saccharomyces* in the content of the farcy boils, while in the pulmonary nodules and nasal ulcers only *bacillus mallei* and no *saccharomyces*.

Culture experiment:—On glycerine-agar we obtained a a pure culture of *bacillus mallei*. As regards the *saccharomyces*, culture experiment was negative (for this purpose we employed different media with the addition of different ingredients, different sorts of sugar, peptone, organic acids, &c.)

Case XXVIII.

Bay stallion, over 20 years old, purchased on March 13, '94, for experimental purposes.

Clinical remarks:—Reduced condition; farcy nodes on the breast and pectoral region, extending from the inferior part of *canalis jugularis sinister*, downwards along the margin of pectoral muscle and the course of spur vein on the left side as far as the *nevcau* of cartilago xyphoidea. These nodes were situated in the subcutis, hard to the touch and easily dislocable, neither painful nor hot.

We extirpated 3 nodes, which were encapsuled with a thin fibrous membrane containing an inspissated creamy matter. Under the microscope we found that, the content was fatty *detritus* composed of fatty granules, fat drops, lime corpuscles and elementary granules, and a few degenerated *saccharomyces*, partly broken or shrunken and apparently empty. The lime corpuscles had the same size as the *saccharomyces* and appeared to be the remains of the latter; otherwise free from germs.

Culture experiment was *negative*.

Case xxix.

Old farm stallion, passing patient, observed on March 17th, '94.

Status pracsens :—Farcy nodes in the form of polypous chains on the shoulder and left anterior extremity, stretching from the inferior part of *fossa jugularis sinistra* downwards along the anterior border of deltoides, then the inner side of the left anterior extremity to the fetlock, and in these nodes *saccharomyces* were found in abundance. Otherwise in a sound state of health.

Some pieces from the nodes of the skin inoculated on different artificial media. On glycerine-agar there was no macroscopical vegetation until the 6th day after inoculation; under the microscope we found most of the *saccharomyces* swollen to spherical corpuscles containing 2, 4 or more granules. Similar granules were also found in pus corpuscles. After a long time there appeared on the medium a number of granular colonies more or less prominent over the surface; the same vegetation appeared also in the gelatine medium.

Case xxx.

Bay stallion, about 20 years old, purchased on April 21st, '94, for experimental purposes.

Clinical remarks :—Bad condition with characteristic farcy changes on the head, right anterior extremity, and on the chest. Bloody purulent discharge from both nostrils, and extended ulceration in the Schneiderian membrane, so that the breath was stinking; no swelling stated in superficial lymphatic glands. Later on, the affection extended over both anterior extremities, which became swollen and, as the animal continually rubbed the affected extremities, the disease was transferred to the lips; and then the intermaxillary glands, on both sides, were swollen. The animal fell considerably in condition and died on May 25th. Dissected 4 hours after death.

Postmortem appearance :—Extreme emaciation. Except the posterior aspect of body, the skin was everywhere affected, and covered with characteristic polypoid ulcers; the anterior left extremity strongly swollen and elephantiac. The left

testicle contained nodules of pea-walnut size, 5 in number; the intermaxillary glands on both sides a little enlarged and partly turned to abscess; the inguinal glands swollen to walnut size and the cortical substance, on transection, grey white and dim. Schneiderian membrane on both sides entirely destroyed by ulceration, some ulcers being hollow, others prominent and fungoid. A few ulcers were found in the mucosa of the pharynx, larynx and of the upper part of trachea. In the thoracic cavity we found pleuritis sicca and partial hepatization of anterior lobes of lungs.

Under the microscope we found, in the morbid parts, besides *saccharomyces*, many coccen-like granules also collapsed and semilunar *saccharomyces*, partly in pus corpuscles, and partly free in the plasma. Long diameter of *saccharomyces* 3.7—4.0 μ., short diameter 2.4-3.2 μ.; the internal granule 0.5 μ. and free granule 1.0-2.0 μ. The granules made an active Brownian movement, strongly refracting the rays of light. The free granules did not take any aniline stain; they appeared like *micrococci* or fat grains, probably the spores of *saccharomyces*. In the lungs and pleural exsudation *saccharomyces* were absent, we found *diplo-* and *streptococci*.

Culture experiment:—In this case we tried hanging drop cultivation of *saccharomyces* with different fluid media, different bouillons, hay infusion, horse dung infusion, with or without addition of pepton or of sugars, in alkaline or acid reaction. In those to which pepton had been added, vegetation took place as early as on the 7th day of cultivation. No vegetation observed in hay infusion, horse dung infusion without pepton and with or without grape sugar. In test tube cultivation with different fluid media, which contained 2-4% pepton in slight acid reaction, we noticed, after 17 days, the vegetation of *saccharomyces* in the form of granular precipitate; the same vegetation was observed in simple not neutralized beef and horse flesh bouillon. Under the microscope the *saccharomyces* were in different formal modifications, some being elongated to a kind of *hyphen*. In common gelatine medium, kept in room temperature, the vegetation appeared first on the 56th day on the surface and along the inoculation-line in the form of yellowish white sandy granules, prominent on the surface; there was no indication of liquefaction. The colony was compact and not easily divisible. Microscopically we found even

varicose *hyphen* containing differing numbers of granules. On glycerine-agar and not-neutralized-pepton-agar media kept in a thermostat, we noticed, after 30 days, the vegetation of *saccharomyces* in the form of granular colonies similar to those in gelatine medium. On the 43rd day, the colony attained the size of 1-4 mm., distinctly prominent and irregularly wrinkled. On the coagulated blood serum from the horse, with or without glycerine, the vegetation was feeble ; on the potato medium vegetation appeared first on the 29th day ; the colony was nearly the same as agar-colony. In every occasion slightly acid media were more favorable for the vegetation than the alkaline. Dimensions of the vegetative *saccharomyces* were as follows :—

	Longit. diam.	Transv. diam.
Little grown cell	2.50-3.652 μ.	1.66-2.50 μ.
Medium grown cell	6.64	4.98
Much grown cell	12.28	12.45*
Hyphen form	16.66-19.92	
Granules (largest)		3.486-5.000
ditto (smallest)		0.830-1.660

Thus a vegetative form was larger by 2/3-3/4 than the original size, and the maximum was even triple or fourfold.

Inoculation with the *culture of saccharomyces* :—An experimental horse No. 10 was twice inoculated subcutaneously with pure culture, 1st on Apr. 16th and 2nd on June 14th. After the first inoculation, induration and suppuration appeared locally ; after the second, again local induration appeared, which persisted for a long time (14/VI-IX) and gradually turned to abscess. The abscess opened of itself on Oct. 20th, and in the pus we found numerous *saccharomyces*. Both lesions were circumscribed, and without further changes they completely disappeared. The culture was introduced in the subcutis and abdominal cavity of guinea pigs and rabbits, but there was no specific reaction.

Anaerobic cultivation in hydrogen atmosphere was negative, so far as *saccharomyces* were concerned. One kind of small short *bacilli*, facultative anaerobe, was isolated ; this caused strong suppuration when introduced in the subcutis of a horse.

Inoculation with morbid matter:—Two guinea pigs (No. 86-87), inoculated with farcy pus, showed only local suppuration. Of guinea pigs (No. 88-90) inoculated on May 15th, with morbid tissue of skin, two died from malignant oedem and the 3rd

* Exceptional dimension.

showed no special reaction. From 5 guinea pigs (No. 91-95) inoculated on May 25th with the new formation of testicle, one died from malignant oedem, the other 4 guinea pigs showing local suppuration and ulceration and a swelling of the plica gland to pea-size. Under the microscope, the local pus exhibited various kinds of bacteria, but no trace of *saccharomyces*. The wound in all guinea pigs quickly healed.

Hares were inoculated subcutaneously with the content of farcy ; a big abscess appeared locally full of thick stinking pus, in which *saccharomyces* could be found for some time. No reaction in rats, similarly inoculated.

Three young pigs were inoculated on April 25th with farcy tissue. There was only local suppuration ; *saccharomyces* were found in the pus until May 30th ; then they disappeared.

An old strong stallion No. 11 was inoculated repeatedly with morbid tissues and pus on different parts of the body, subcutaneously or by repeated rubbing in the skin ; also in combination with pure culture of *streptococci* and *staphylococci* isolated from the content of farcy or first producing artificial ulcers and then inoculating in them. All these trials were of *negative* result.

Case XXXI.

Old pack horse, passing patient, observed on Jan. 7th, '95.

Clinical appearance :—Farcy boils on the right jugular, axillar, right and left hypochondriac and cardiac region; the content of the boil consisted of dim fluid and cheesy sediment, in which numerous *saccharomyces* were found. According to *anamnesis* this horse was kept in an infested stable, where the first symptoms of farcy appeared at the root of his tail. Inoculation of 4 guinea pigs (No. 96-99) and hares was *negative*.

Case XXXII.

Old stallion, observed on Febr. 20th, '95.

Clinical appearance :—Farcy boils on the left anterior extremity, the right superior part of chest, external genitals and nose cavity; the intermaxillary glands swollen. Numerous *saccharomyces* found.

Inoculation:—Two guinea pigs (No. 100-101) inoculated with morbid tissue of farcy. One died from malignant oedem; the 2nd showed, on the next day, a local swelling, which had soon disappeared.

CASE XXXIII.

Old mare observed in June, 1895.

Clinical appearance:—Bad nutrition; the left anterior extremity in bear-footed attitude with soreness in the skin of the heel. In the hollow of fetlock an extended ulceration, where the skin and subcutis much thickened, the appearance being that of *Himushi*. From this ulcer a cordy swelling led upwards as far as the arm. Besides this, we found some nodes on the thigh of both posterior extremities. Numerous *saccharomyces* were found.

In course of time the morbid process had gradually extended over the inferior abdominal wall, shoulder, thorax, lips, praeputium, vulva, &c. The horse was destroyed and dissected on June 28th, '95.

Postmortem appearance:—Characteristic fungoid ulcers in the right nose cavity; walnut-sized abscess in the axillary gland; hyperplasia of intermaxillary and inguinal glands. In the right posterior lobe of lungs an indurative *herd* of hazelnut size, which showed, on transection, numerous miliary purulent *herds*; no *saccharomyces* found in them, while in the cutaneous and nasal ulcers and in the affected lymph glands were numerous *saccharomyces*.

Inoculation of guinea pigs (No. 102–111) with morbid tissue; 4 of them died from septic infection (streptococcen infection); the remaining 6 showed no special reaction.

A horse (No. 12), 5 years old, was inoculated subcutaneously with morbid matter, but the result was *negative*.

We have hitherto dealt with mere objective descriptions of cases. Let us now make some critical remarks.

In 3 cases (IX, XIX and XXI), out of 29 (VI-XXXIII), we have found a special kind of *bacillus*, which may, according to its morphology and biology and to the result of inoculation, be regarded as identical with *Schütz-Loeffler's bacillus*; thus, these 3 cases were undoubtedly true farcy-glanders, and

case XIX was pure glanders with pulmonary complication.

In 11 cases (XIII-XXXIII) *saccharomyces* were actually demonstrated, but it was not possible to find the presence of *bacillus mallei*; in these cases the clinical and postmortal appearances were quite characteristic of Japanese farcy. In cases I and IV-XXII *saccharomyces* were not directly examined; we have, however, stated the presence of the latter in the alcoholic specimen of morbid tissues collected from these cases. There is hence no doubt that all our cases, except the above 3 and cases II and III, which were not examined for *saccharomyces*, were those of *saccharomycotic farcy*. In cases III and XXVIII the subcutaneous nodes were in process of healing without surgical operations.

Case XXVII was an example of *mixed infection of genuine and sacchayomycotic farcy*. It is interesting to note that, both groups of symptoms were combined. The anatomical characters of cutaneous and subcutaneous nodes and ulcers were quite the same as in Japanese farcy. The following were the chief deviations from the latter :—

1. Acute course.
2. Nasal ulcers were hollow and not fungoid.
3. Purulent discharge from nose was oily and mucilaginous.
4. Distinct pulmonary lesion.
5. Histologically the nasal and pulmonary *herd* consisted of a typical granulation tissue, while in Japanese farcy the tissue elements or leucocytes are in an early stage destroyed by the invasion of microbes.

It is also interesting to observe that, *B. mallei* which was inoculated, became *causa incitans* for the recidivum of saccharomycosis and that, in the further course of disease the number of *saccharomyces* decreased and finally disappeared in most of the abscesses. Very likely the recidivum of saccharomycosis was not due to the favorable influence of *bacillus mallei*, but to the favorable condition of the anatomical changes prepared by the latter. To the question whether symbiosis of both microbes is possible or impossible, our observations were not sufficient to enable us to give a definite answer. Nevertheless we may consider this case as a mixed infection. Cases IX and XXI too may

fr. anatomical characters be enumerated under the same category, though actual statement on *saccharomyces* was wanting.

The next question is whether the usual saccharomycotic farcy, met with in practice, is entirely free from malleous infection. Here we must take into consideration the result of clinico-anatomical observations and inoculation experiments in connection with bacteriological researches. *Clinico-anatomically*, in simple farcy in which no internal changes were found, there is the least suspicion of malleous infection. As to those cases, however, in which metastasis was found in the internal organs, we must be careful in deciding the question. As to pulmonary lesions, pleuropneumonia with caseous and hepatization *herds* (XXIV, XXX), in which we found *diplo-* and *streptococci*, seems to belong to *Brust-seuche*, which is very common in Japan. Chronic indurative pneumonia, found in cases XX, XXV and XXXIII, is undoubtedly the secondary change of saccharomycosis. Grey nodules of sinapis to linseed size, found in cases VIII, XVI, XVII and XVIII, resemble malleous nodules, but the characteristic hyperaemic zone was wanting, and the nodules were mostly very few in number; further we could not prove the existence of *bacillus mallei*. We sometimes find irregular calcareous nodules in the lungs; they are mostly the residua of catarrhal bronchitis or of parasitary nature. Point-shaped multiple extravasations, which were found in cadavers, destroyed for dissection, are undoubtedly the result of disturbed circulation at the stage of agony. Metastasis in the spleen and liver found in cases VI, IX, XX and XXII appear to be of malleous nature: case IX was true glanders; In case XX inoculation failed to decide the nature, while in cases VI and XXII, we were unable to prove the presence of *malleous bacilli*. The *herd* of the kidney, observed in cases II and III was anatomically a chronic interstitial nephritis and appears to be of the same nature as the chronic process found in the lungs.

Result of inoculation:—In guinea pigs, inoculated with morbid materials of farcy, we found nearly similar reactions, only differing in intensity. Shortly after inoculation there was local inflammatory swelling in different intensity either limited to *locus inoculationis* or extending over the neighboring parts, praeputium, scrotum, &c.; these symptoms gradually passed away, and at the end of the first week appeared a second group of changes; viz., the

formation of abscess and ulceration *in loco* and the swelling of the next lymphatic gland (plica gland) and, in exceptional cases, of the testicles. In fact the reaction was dependent on : 1, the mass of morbid tissue inoculated and, 2, the purity of the substance. The larger the mass introduced in the subcutis, the stronger was the local reaction. The reaction was stronger and more conspicuous in those animals, which had been inoculated with ulcerative tissue from exposed parts, skin and nose, than in those, which received morbid tissue from fresh cadavers and from internal organs, as the testicles. Certainly different septic microorganisms, which may easily cleave to organic matter, have played the chief part in producing local reactions. Old cadavers of horses are soon loaded with them, and the latter often interfered with the result of inoculation. In the usual course there was local swelling, suppuration or formation of abscess, ulceration, and the swelling of the next lymphatic gland, the latter being in proportion to the intensity of local ulceration. All these changes were not so characteristic of *malleus*, and mostly terminated in recovery. For easier reference we give the result of inoculation in the following table :—

No. of Case:	No. of Guinea pig:	Materials inoculated:	Changes after inoculation:	Termination and postmortem:	Result of inoculat. for glanders-farcy:
IV.	1.	Nasal discharge.	Strong local and slight glandul. swell.	Destroyed: no internal change.	?
„	2.	„	Nearly the same as in the preceding.	Recovery.	Negative.
„	3.	Herd of testicle.	„	„	„
„	4.—5.	Ulcus of nose.	„	„	„
„	6.	Lung tissue.	„	„	„
V.	7.	Nasal discharge.	Strong local swelling and ulceration and distinct swelling of gland.	Destroyed: Lymphadenitis apost.	Relative positive.
„	8.	„	„	Recovery.	„
„	9.	Herd of testicle.	„	„	„
„	10.	„	„	Death: Gastroenteritis and local abscess.	„
„	11.	„	„ (in slighter degree.)	Ditto: Gastroenteritis; no abscess.	Negative.
„	12.	„	„ (and besides udder affected.)	Recovery.	Relative positive.
„	13	Ulcus of nose.	„	Death: Gastroenteritis; no other change.	„
„	14.	„	„	Destroyed: no internal change.	„
VI.	15.	Farcy content.	Slight local and glandular swelling.	Recovery.	Negative.
„	16.	Herd of testicle.	Local and distinct glandular swelling.	„	Relative positive.
„	17.	„	Strong local and gladular swelling.	„	„

VII.	18.	Herd of testicle.	Slight local react. and swell. of gland.	Recovery.	Negative.
,,	19.—22.	Nose and testicle.	Nearly the same as in the preceding [No 18.	,,	,,
VIII.	23.	Nodules of lung.	Local react. and strong glandul. [swell.	,,	Relative positive.
,,	24.	,,	Strong local react. and distinct swell. [of gland.	Death: Gastroenteritis and lymphad. [apostaematosa.	,,
,,	25.	,,	Slight local and glandular reaction.	Recovery.	Negative.
,,	26.	Ulcus of nose.	Stronger local and glandular swell.	,,	Relative positive.
IX.	27.	,,	Ditto and besides suppurat. in testicle.	Destroyed: Orchitis et adenitis apostaematosa and metast. in spleen.	Positive.
X.	38.	Herd of testicle.	Slight local react. and glandul. swell.	Recovery.	Negative.
XIV.	39.—40.	,,	Ditto: One recovered and the other [died.	No internal change.	,,
XVI.	41.	Ulcus of nose.	Ditto (besides udder a little swollen).	Recovery.	,,
,,	42.	,,	?	Death: Malignant oedem.	Failure.
,,	43.—44.	Herd of testicle.	Local reaction and glandular swell- [ing.	Recovery.	Negative.
XIX.	45.	Nasal discharge.	Local ulcer. and suppurat. of gland.	Destroyed: Lymph adenitis apost.	Positive.
,,	46.	,,	,,	Recovery.	Relative positive.
,,	47.	Ulcus of nose.	Local ulceration.	Death: pleuropneumonia.	Positive.
,,	48.	,,	Ditto and strong glandular swelling.	Recovery.	,,
XX.	49.—50.	Intermaxillary abscess, &c.	?	Death: Malignant oedem.	Failure.
,,	51.	Herd of liver.	?	,,	,,
,,	52.	Lung tissue.	Local ulceration.	Recovery,	Negative.

XX.	53.	Lung tissue.	Local ulceration.	Death : Gastro-enteritis.	Negative.
,,	55.	Farcy content.	Slight local swelling.	Recovery.	,,
XXI.	56.	Nasal ulcus.	Local ulcer. and swelling of gland.	,,	Relative positive.
,,	57.	,,	Local swelling.	,,	Negative.
,,	58.	Farcy content.	?	Death : Malignant oedem. Epididymitis suppur.	Positive.
,,	59.	,,	Local ulceration for long time.	Recovery.	Negative.
XXII.	60.—62.	,,	No special reaction.	,,	,,
,,	63.—74.	Testicle nose and spleen.	?	Death : Malignant oedem.	Failure.
,,	75.—77.	Testicle and nose.	Local abscess and swelling of ing. gland.	Recovery.	Relative positive.
XXIII.	78.—79.	Farcy content.	Local abscess and ulceration. Hefe found in the pus of abscess.	,,	Negative (Positive for saccharo.)
,,	80.	,,	Local ulceration.	Death : pleuro pneumonia.	,,
,,	81.—82.	Abscess of gland.	Local ulcer. and slight swell. of gland.	Recovery.	,,
XXV.	83.—84.	Pulmonary herd.	No special reaction.	,,	,,
XXVI.	85.	Fercy content.	Strong local ulceration and swell of gland.	Death : Lymphadenitis ; hefe in different organs.	,, (Positive for saccharom.)
XXX.	86.—87.	,,	Local ulceration.	Recovery.	,,
,,	88.—89.	Farcy tissue.	?	Death : Malignant oedem.	Failure.
,,	90.	,,	No special reaction.	Recovery.	Negative.
,,	91.—95.	Herd of testicle.	Local ulcerat. and lymph adenitis.	Death : Malignant oedem. Recovery.	Failure 1. Negative 4.

XXXI.	96.—99.	Farcy tissue.	No special reaction.	Recovery.	Negative.
XXXII.	100.	„	?	Death : Malignant oedem.	Failure.
„	101.	„	Local swelling.	Recovery.	Negative.
XXXIII.	102.—111.	„	4. Died of malignant oedem. 6. Recoverd.	Death : Malignant oedem. Recovery.	Failure 4. Negative 6.

If we consider such reactions as local swelling or swelling of the next lymphatic gland without suppuration, as totally negative, and those, which consist of distinct swelling of the lymphatic gland and extensive local ulceration and abscess-formation, and in which culture and microscopical examination were negative, as relative positive reactions, then we obtain the following numbers :—

Of 99 guinea pigs, inoculated with morbid products.—

Result of inoculation:	No. of Guinea pigs :	Number of Cases :	No. of observed cases for :	Result of inoculation in % of obs. cases :
Failure.	24.		20.	
Negative reaction.	53.	11.	20.	55. %
Positive reaction.	5.	3. (IX, XIX, XXI.)	20.	15. %
Relative positive reac- ⌈tion	17.	4.	20.	20. %
(Positive fo saccharo- ⌈mycosis.	2.	2. (XXIII, XXIV.)	7.	28.6 %)

Relative positive cases were V, VI, VIII and XXII. The Clinico-anatomical appearances of these cases were shortly as follows :—

Case V, farcy changes in the skin, subcutis, nose, sinus, testicles and lymphatic glands ; internal organs free from affection.

Case VI, ditto in a slighter degree (and no change in sinus). One metastatic abcess in the liver.

Case VIII, ditto in severer degree, and plenty of miliary nodules in the lungs.

Case XXII, ditto in severer degree, and 2 metastatic *herds* in spleen.

From these data we may consider *these 4 cases as suspected mixed infection*, although the bacteriological researches failed to give a positive result. Also case XX was probably one of the mixed infection.

As regards the *saccharomycosis*, the result of inoculation was mostly *negative*. In 2 guinea pigs (No. 78–79) which were inoculated with farcy nodules, appeared local ulceration and suppuration, in which *saccharomyces* was for a long time found, in association with different pyogenic bacteria. In No. 85 we

found *saccharomyces* in different organs. In all other cases the result was entirely negative; the *saccharomyces* were found in the wound secretions so long as the inoculated tissue remained in the subcutis. When the latter was absorbed no more was found.

Result of horse-inoculation was different. Of 7 horses, inoculated with morbid matters, we found distinct reaction only in one case (case II); in other cases the reaction was always local—local suppuration and ulceration, the process never extended, and the wound quickly healed. Infection was also impossible by continued rubbing into the skin, by cutaneous inoculation, and by cohabitation.

In pigs, sheep, hares and rats (also dogs and cats) the result of inoculation was *negative*.

Culture of *saccharomyces* was possible in 4 cases. *Diplo—staphylo*—and *streptococcus* often appeared in culture.

In short, *this skin disease, commonly known as farcy, may be classified into 3 categories; saccharomycotic farcy, genuine farcy, and farcy of mixed infection. The first is the most common; next comes mixed infection, while pure glanders and farcy (malleus) seems to be of rare occurrence, at least in the indigenous breeds of the horse.*

Characteristica of Saccharomycosis equi.

Saccharomycosis or saccharomycotic farcy may be defined as an enzootic skin disease caused by the invasion of a special kind of *saccharomyces*, the clinical and anatomical symptoms being nearly the same as in genuine farcy.

I. Clinico-anatomical features.

Chief characteristicum is the eruption of the so called *farcy boils* in the skin and subcutis, and in many cases the mucous membrane of *tubus respiratorius*, the testicles and lymphatic glands and sometimes internal organs are affected. At first a small nodule of linseed to pea size appears in the skin. This soon decays and is transformed into abscess and ulcer of

pea-to hazelnut-size. The process rarely remains circumscribed, but is mostly propagated by the mediation of the lymphatic system in larger extension over the skin and subcutis or deeper to intermuscular tissue or periost, also to the articulation of the extremities, to the next lymphatic gland and testicles, and seldom, by blood circulation, to distant organs. The disease is not seldom propagated by direct contact from one to another extremity or, as the patient rubs the affected part with its teeth, so it is often transferred to lips, cheek, &c. In a similar manner the disease is propagated to the nose cavity.

Certain parts are specially predisposed to this disease.

The following table will show the number of cases, observed, in reference to the affected organs. Of 25 cases (III-XXXIII) ‡:—

organs affected :	No. of cases :	in % of total cases :
Testicle	16.	64. %
Nose	21.	84. %
Intermaxillary gland	12.	48. %
Lungs	9.	36. %
Pharynx and larynx	7.	28. %
Eyes (conjunctiva)	2.	8. %
Liver	3.	12. %
Spleen	1.	4. %
Nose affect. without swelling of intermax. gland	10.	40. %
Only skin affected	3.	12. %
Skin and nose affected	1.	4. %
Skin, nose and testicle affected	3.	12. %
Skin, nose, testicle and lymph. gl. affected	7.	28. %
Skin, nose and viscera affected	2.	8. %
Skin, nose, testicle, lymph. gland and viscera affected	2.	8. %
Skin, nose, testicle and viscera affected	3.	12. %
Skin, nose and intermax. gland affected	2.	8. %
Skin, intermaxi. gland, lungs and liver affected	1.	4. %
Skin, nose, gland and viscera affected...	1.	4. %

As the above table shows, the part most disposed is, after the skin, the mucosa of the nose, then comes the testicle, the intermaxillary gland, the lungs, the upper part of the respiratory tract, the liver, the eyes, and finally the spleen. Here I must say that, most of the above cases were inveterated ones, and hence the percentage of internal changes was greater than expected.

‡ Case XXIX & XXXI (passing patients), case XIX (pure glanders) and case XXI, XXVII & IX (mixed infection) are omitted.

Saccharomycosis cutanea et subcutanea:—The youngest *nodule* is usually situated in the cutis. Subcutaneous nodules appear when the cutis is perforated by cutaneous nodules; then the process is extended over the neighboring parts, mainly through the lymphatic vessels. Thus appear subcutaneous nodules in the form of pearl cord. Clinically a fresh nodule is at first hard, not dislocable and not very warm, but frequently painful to the touch. The cut surface of a fresh nodule looks grey yellow and medullary. The connective tissue round the nodule is generally infiltrated and jelly-like, and we sometimes find thrombi in the local veins. Microscopically a fresh nodule consists of round cells, loaded with a number of *saccharomyces*, and such cells are sometimes provided with processes like pseudopodia. As the microbe increases in number, the hostile cells are gradually destroyed, and this results in the *softening of the nodule.* Unlike a veritable malleous nodule, in which softening begins from the centre, the saccharomycotic nodule generally softens *in toto* at the same time. This difference may perhaps be accounted for by the fact that, while the softening in the former case is the result of necrobiosis due to nutritive disturbance, the softening of the latter is the result of more mechanical interference exerted by the microbe.

By the process of softening, the nodule is gradually transformed into an *abscess* of hazel to walnut size, which in turn perforates the skin, evacuates its content, and becomes an *ulcer.* The *content of abscess* consists of thick glutinous pus, like tin-milk, or of bloody or dim fluid with cheesy floccules held in suspension. Microscopically we find abundant *saccharomyces* associated with numerous granules and often with pyogenic microbes, *cocci* or *bacilli.* The quality of the ulcer differs according to the condition of the animal; in a weak individual the ulcer is hollow with inactive granulations. In the majority of cases, especially in strong young horses, vigorous granulation arises from the bottom and border of the ulcer, whereby the latter soon becomes prominent over the surface of the skin, in the form of fungi or polypi, 2-3 cm. in height—*Ulcus fungosum s. polyposum, tumor polyposus* or properly called *saccharomycom.* Such polypous ulcers appear especially at the inferior part of the extremities; as they grow longer, the peripherical end is subjected to decay and is torn off piece by piece. Another form of ulcer,

which is also common and is transitory between the asthenic hollow ulcer and the polypoid ulcer, is the *crater-like ulcer*, which is more or less prominent over the skin, and is generally covered with red brown or orange brown scabs; on removing the latter we find, at the centre of the ulcer, a small opening of bean-size surrounded by a salient border. The ulcer looks reddish yellow, and the central hole is often blocked up with glutinous matter consisting of fibrine coagulum mixed with red and white corpuscles and the microbes. By mechanical injury, such as biting, rubbing, &c., there may appear an extended ulceration, necrosis, or a diffuse thickening of the skin and subcutis, resulting either in an *extensive destruction of tissue or elephantiasis.* In such cases different septic and pyogenic microbes, which have access to the wound, accelerate the progress of the disease. When the ulcer heals it leaves in the skin a funnel-shaped *cicatrix* destitute of hair. The following table shows how special parts of the body are attacked; the data are the reduction of the reports[1] of veterinary students on the excursion to Fukushima prefecture in 1892. Of 157 cases:—

Regions affected:	No. of cases:	Percent.	Regions & organs affected:	No. of cases:	Percent.
Lateral wall of chest.	64.	40.7 %	Withers and back.	9.	5.7 %
Shoulder.	58.	36.8 %	Loin and haunch.	8.	5.0 %
Neck (esp. jugular region)	48.	30.4 %	Perineum.	3.	1.9 %
Breast.	41.	30.1 %	Intermax. gland.	31.	19.7 %
Lateral wall of abdomen.	36.	22.9 %	Schneider. memb.	24.	15.2 %
Anterior extremity.	34.	21.6 %	Nose and interm. gl.	9.	5.7 %
Inferior abdom. wall.	14.	8.8 %	Face and interm. gl.	4.	2.5 %
Pectoral region.	14.	8.8 %	Nose without gland. affect.	15.	9.4 %
Head.	13.	8.2 %	Nose without skin affect.	1.	0.6 %
Posterior extremity.	10.	6.2 %	Only face is affected.	1.	0.6 %

It will be seen that the anterior part of the body is more affected than the posterior. The percentage of nasal affection is too low; this is perhaps due, in the first place, to the fact that

(1) These reports have been supplied by Prof. *Katsushima.*

by the clinical observation alone, any deeper lesion can not be explored, and that, the cases, according to the reports, were mostly the slightly affected. Very interesting is that case in which the skin was not affected. The affection of the external genital apparatus, which is common enough, is here absent. The following data[1] are the extracts from the report of the vetenary section of the Agricultural School of Miyagi. Of 38 cases :—

Regions affected :	No. of cases.	Percent.	Regions & organs affected :	No. of cases.	Percent.
Anterior extremity.	30	78.9 %	Chest.	10.	26.3 %
Breast.	17.	44.7 %	Udder and ext. genitals.	8.	21.0 %
Neck.	14.	36.8 %	Face.	6.	15.9 %
Abdominal wall.	11.	28.9 %	Schneiderian memb.	2.	5.2 %
Posterior extremity.	11.	28.9 %			

According to our experience, exposed parts, such as the axillary region, breast, back, &c., and more especially the harness region, are most affected. The most common seats are the breast and the anterior extremities ; in the posterior extremity the disease appears generally at the internal thigh along the course of the saphena.

Saccharomycosis of nose and respiratory tube :—The affection of these regions appears generally as a complication of cutaneous changes. Here the infection takes place either by aspiration or *per continuitatem* from the skin of the face ; primary nose affection is very rare. When cutaneous farcy is far advanced, it is mostly propagated to the nose cavity, whence to the pharynx, larynx, and trachea, and exceptionally to the larger bronchi, the anatomical changes always decreasing in intensity in a supero-inferior direction.

Nose affection is generally bilateral ; and the anatomical changes correspond to cutaneous farcy. At first miliary nodules appear in the mucous membrane, mostly in its superficial layer ; such young nodules look grey or milky white and, until a certain size is attained, they preserve a spherical form. As they increase in size they become prominent over the mucosa and are

(1) Cf. *Kasauma-torishirabe-sho ;* the percentages have been calculated by the author.

turned to ulceration. Often in an early stage softening takes place in the centre of the nodule, and it is transformed into a small abscess.

Hollow ulcers are rarely found. Generally profound granulation rises from the bottom of the ulcer resulting in the formation of polypous growth, in the same manner as in the skin. The anatomical picture depends on the degree and age of the affection. In slight cases single nodules are hidden behind the turbinated bones ; in another case the whole meatus is filled up with granulation tissue, or the mucous membrane is extensively destroyed, or the *septum nasi* is perforated and blocked up with granulation tissue. The star-shaped cicatrix is rare at least in an evident case of saccharomycosis.

Clinically in slighter cases of nasal affection there is no discharge from the nostrils ; in another case we find discharge of thin fluid or mucous or muco-purulent or bloody or ichorous fluid, and the breath is often stinking. When stenosis takes place, respiration becomes difficult and snuffling.

Saccharomycosis of lymph. glands s. Lymphadenitis saccharomycotica. It is interesting to note that the intermaxillary gland is less affected, and is not in all cases a complication of nasal changes. In an advanced nasal affection both intermaxillary glands are swollen ; but in slighter cases this is not always so. The same swelling is observed when the face is affected.

Clinically the swelling is moderately hard and freely movable ; not knotty nor so hard as in true glanders ; it is also not so extensive as in strangles. Anatomically the swelling consists either of simple hyperplasia or of medullary swelling or medullary *herds* or nodules are embedded in the hyperplastic cortex. Sometimes small abscesses are found ; in the pus and medullary *herds* a certain number of *saccharomyces* is always present, while in the hyperplastic portion the latter are very seldom or never found.

More common is the affection of lymph. glands of the axillary, inguinal, and plical regions, as the extremities are commonly affected. In all cases the induration of the gland, in the strict sense of word, has never been stated, at least in the observed cases. The anatomical character is quite the same as in the skin.

Saccharomycosis of the testicle, epididymis, and the external genitals (Orchitis, epididymitis, funiculitis saccharomycotica):—The morbid process begins here mostly at the scrotum or praeputium, and by dessemination it is propagated over the tunica vaginalis, testicle, epididymis, and the spermatic cord. By this process an intergrowth of tunica vaginalis between the visceral and parietal layers takes place. It is rarely the case that the testicle is primarily affected without local cutaneous changes—*metastasis*. The *herd* of the testicle is always circumscribed and spherical in form, and its anatomical character is simulating that of the lymphatic gland ; frequently it softens and is transformed into an abscess. The content of the latter is thick and milky; under the microscope we find in it myriads of *saccharomyces*, lymph corpuscles enclosing the microbes, free *nuclei*, *cocci*-like granules, fat grains, &c. In the skin of the external genitals, scrotum, penis, praeputium, the ulcers are funnel-shaped, the cavity being filled up with wound secretion mixed with smegma, and in most cases the local skin and subcutis show a diffuse thickening.

Saccharomycosis of internal organs:—The *lungs*, which are often the seat of glanders, are rarely affected. What we find are *chronic indurative pneumonia*, *pleuro-pneumonia*, and in limited cases *grey nodules* simulating the malleous nodule. The chronic pneumonia often appears in the anterior lobes, consisting of irregular *herds* of variable sizes, pea, walnut, hand-breadth, and even larger, either circumscribed or diffuse : on the cut surface smaller nodules of from linseed to pea size are found embedded in the primary *herd*. Anatomically it belongs to the lobular pneumonia consisting of interstitial cell infiltration around bronchioli and alveoles (Pl. III, Fig. 2), and in this tissue *saccharomyces* may be found but in limited numbers, and not in all cases. The *grey nodules* are of sinapis to linseed size, semitransparent and hard, either a few or many scattered over the whole of the lungs, particularly met with in the case of an extended nasal saccharomycosis. Unlike proper malleous nodules a hyperaemic zone is here wanting. In the *spleen* and *liver* we sometimes find a few *metastatic abscesses* containing ordinary pus free from *saccharomyces*, and in the *kidneys* multiple *herds* of *chronic indurative nephritis*. Thus, internal changes in general, are not characteristic of Jap. farcy, and according to my present knowledge, they seem to be secondary

changes caused by the irritation of morbid products aspired or absorbed by blood vessels and lymphatics. Most pulmonary changes, for instance, would not be the result of direct irritation of *saccharomyces*, but due to the irritation of morbid materials or pyogenic bacteria aspired from the ulcerative surface of the nose. The same view can equally hold good with other internal changes. The morbid products absorbed by blood vessels may occasion metastasis or irritate any excretory apparatus, especially the kidneys, through which they are eliminated from the body.

On the general state of health:—In slighter cases of Jap. farcy, when the process is localized in a small circumference, there is no evidence of general disturbance ; the patient is active, has a good appetite, and no febrile symptoms ; even in advanced cases the animal can do its ordinary work. When the nose is affected, or when cutaneous changes are far advanced, the condition of the animal quickly falls, emaciation sets in, and the result is cachexia and death. In most advanced cases the appetite is more or less disturbed, and the temperature is always above 39° C.—*hectic fever.*

The disease is always of long continuance, and may last for months or even years. Acute cases, in the true sense of the meaning, never occur. The disease assumes an acute character when it is spread over a large part of the skin and of the mucous membrane of *tubus respiratorius.* Exact details as to the duration are wanting.

Termination and possibility of treatment:—As the disease is progressive, so in the natural course it generally terminates in death. Complete recovery is possible by radical operation, but only in slighter cases, in which the process is still localized in the skin. We must, however, remind the fact that, cure was also possible without any surgical operation (Case XXVIII), in which case the subcutaneous nodules were successfully encapsuled by connective tissue. In order to ascertain whether the cure, as commonly spoken of, is apparent or complete, we have dissected a number of horses, which had recovered from farcy. The *anamnesis* and *status praesens* were as follows :—

1. Black stallion, 7 years old ; dissected on July 2nd, 1888. *Anamnesis:* affected in the spring, 1887 treated and cured. *Status praesens:* many cica-

trices over the body, keratitis traumatica in the right eye.

2. Black bay stallion, 10 years old ; dissected on July 6th, '88. *Anamnesis* was the same as the preceding. *Status praesens:* many cicatrices arranged in chains were found on the right side of neck and the left side of thorax.
3. Chestnut stallion, 10 yars old ; dissected on July 6th, '88. *Anamnesis* not exactly known. *Status praesens:* many cicatrices on the right jugular region.
4. Bay stallion, 12 years old ; dissected on July 7th, '88. *Anamnesis :* 7 years ago affected and successfully treated. *Status praesens :* no trace of cicatrix ; one nodule of uncertain nature in the skin.
5. Dark chestnut stallion, 5 years old ; dissected on July 8th, '88. *Anamnesis :* affected in November, 1886, and successfully treated. At that time the intermaxillary gland was also swollen and turned to abscess. *Status praesens :* 17 cicatrices on the left jugular and scapular region.
6. Light chestnut stallion, 10 years old ; dissected on Aug. 8th, '88. *Anamnesis* not exactly known. *Status praesens :* 5 cicatrices on the breast ; extensive saddle gall.

Postmortem we found in one case a very small nodule in the lungs, in another, a cicatrix in the nose, and in the 3rd (5.), a slight thickening of the intermaxillary gland with deposit of lime. The changes found in the latter 2 horses were certainly old traces of farcy, but we may regard them as cured ; for, there was no evidence of actual processes going on. The pulmonary nodule was of doubtful nature. In other respects there was no sign of actual existence of the disease. According to the experience of veterinary practitioners in farcy districts, the cutaneous form without nasal complication is mostly curable by surgical treatment. But we must not forget that, nasal affection and the affection of testicles and lungs are by no means uncommon, and in such cases, except for slight affections of the testicle, complete cure is questionable. According to a report from Miyagi-ken total morbidity for 5 years (1887-1891)

was 3462, of which 84 succumbed and 48 were slaughtered. The remainder 3320 (3462-94-48) must be considered as recoveries. But this calculation furnishes too high number to be accepted as a reliable statement.

2. Aetiology.

The *contagium* of Japanese farcy—*Saccharomyces farciminosus*—is an oval or eye-shaped corpuscle provided with a thick membrane, and with more or less homogenous content. The transverse diameter fluctuates within 2.4-3.6 μ. Both poles are generally pointed ; sometimes at one pole we find a but-like appendix, or 2-3 cells are joined together pole to pole ; the content is either homogenous and transparent or finely granulated, usually a coccen-like granule, 0.5-1.0 even 2. μ in diameter, is suspended in the content. The granule is either colorless or faintly yellow, has a strong refractive power and performs a lively mollecular movement, wandering in the content ; generally it is found near one pole. Sometimes also collapsed semilunar cells are found ; they are probably old varieties, whose content has been evacuated.

Saccharomyces are abundantly found in the morbid tissue and products, partly free in the plasma and partly enclosed in pus corpuscles, which are often loaded with 10, even 20-30 of them, and are thereby enlarged to double or triple the normal size, 13-21 μ in diameter. The protoplasm together with nucleus is pressed against the periphery, and the remaining space is occupied by the microbes.

Besides *saccharomyces*, we find, both in plasma and pus corpuscles, many granules, which look similar to that contained in the microbe. These granules are either solitary or joined to a kind of *diplococcus*. The smaller ones are colorless and bright ; the larger ones look homogenous, less bright and faint yellow.

In young nodules of the testicle, lymph. gland, &c., *saccharomyces* are mostly found in the lymphoid cells, while in the larger soft nodules many are free in the interstitial space.

Young *saccharomyces*, which are full of protoplasm, easily take aniline stains, so also the granules contained in them ; while those, which contain fluid plasma, never

take the usual bacterial stains, also those granules, which are free in the *liquor puris*, can not be stained.

This microbe can hardly grow on artificial media, such as bouillon, nutrient gelatine, nutrient agar, potato, &c. The growth is exceedingly slow, and requires a considerable space of time before the vegetation becomes apparent. After a week the oblong cells are dilated to larger spherical corpuscles and the central granule or nucleus is also soaked, enlarged, and divided into 2 or more daughter granules of faintly yellowish and homogenous quality. The swollen microbe often attains a diameter of 6, 7 even 12·45 μ, and the granule of 2-5 μ. After a time the spherically swollen microbe assumes an oblong, cylindrical or dumbbell form, and then by partition it is divided into 2, 3 or more segments, and finally developes into a kind of *hyphen*; the latter is thinner in diameter than the spherical form, showing varicosities in different parts. In further course of time there appear by budding a number of secondary *hyphens*, and the tertiary from the secondary *hyphen*. Meanwhile the granules increase in number and accumulate especially in the terminal segment of the *hyphen*.

Upon the nutrient agar, the vegetation first becomes apparent after 30 days in the form of greyish white grains. After 40-50 days a single colony attains a diameter of 1-4 mm, and becomes distinctly prominent over the surface of the medium. In a fully grown colony, the surface is wrinkled by *gyri* and *sulci*; the colony is very compact, difficult to dissect with a platinum wire or to crush under a covering glass. Microscopically it consists of conglomerated *pilzrasen*, composed of *hyphen*, spherical cells and a great number of free granules. The addition of grape sugar or glycerine to the medium has no influence on the vegetation. In the nutrient gelatine the vegetation takes place especially on the upper *stratum*; 56 days after, the colony appears as a yellowish white sandy mass of an irregular shape, 1-3 mm. in diameter; the gelatine is not liquefied. When the gelatine is accidentally molten and the colony sinks, the growth is no longer continued. On potato slices the colony looks more brownish; otherwise it is similar to the agar-colony. Fluid media may also be used for the cultivation of this microbe, but pepton must be added. It does not grow in horse-dung infusion, hay infusion, sugar solution, &c. The optimal tempera-

ture is not yet determined. A slightly acid medium is more suitable than an alkaline one.

Here again a few words are needed about the nature of intra- and extacellular granules. Our observation is not yet sufficient to draw a positive conclusion whether they are spores, as recently stated by *Hansen* in contradiction to the theory of *Brefeld H. Moeller*, &c. *Hansen* was successful in following up the germinative process of granules contained in some of the zymogenic *saccharomyces*. According to the staining property, as already mentioned, the central or internal granule appears to be a nucleus which by further division seems to be transformed into spores. Until the question is definitely settled, we will not say they are really spores, but we are inclined to accept, at least as to free granules, the opinion of *Hansen*.

As already mentioned, the *saccharomyces* are often associated with *staphylococcus*, *diplococcus* or *streptococcus* and certain kinds of *bacilli*, which are especially met with in the content of farcy boils and in the lymphatic glands. But the occurrence of these bacteria is not constant ; they are generally few in number and in deeper organs they are frequently absent ; they belong mostly to the pyogenic variety.

According to the result of inoculation most of the experimental animals, rats, hares, pigs, &c. seem to be refractory to this *saccharomyces*. When the horse is inoculated with the pure culture, the result is sometimes the development of nodules and abscesses, in which characteristic *saccharomyces* can be demonstrated. In many cases, however, there is no positive reaction.

About these *saccharomyces*, as far as we know, there is no mention in German literature. Nor does it seem to be known in England or America. In the year 1883 *Rivolta* and *Micellone* mentioned a special kind of corpuscle, called by them *cryptococcus farciminosus*, in so-called African farcy or *farcino criptococchico* of the horse, but they were ignorant of the biology of that micro-organism. *Peuch*, 1888, wrote something about *Farcin d'Afrique* and to the aetiology of that disease he added that "the *contagium* forms on potato medium a grey white colony, which is different from that of *bacillus mallei*." Afterwards many Italians attempted culture experiments of *cryptococcus* found by

Rivolta, but none of them met with success, and hence some authorities, among them *Canalis*, *Piana*, *Gali-Valerio*, &c. considered that, the *cryptococcus* is a kind of *sporozoa*. Recently in 1895 *Busse* observed a kind of *saccharomyces* in sarcoma-like new formation at the tibia of a woman and *C. Fermi* and *E. Aruch* have since reported the result of culture experiments of *cryptococcus* of *Rivolta*, and they say that the microorgmism was easily cultivable and the inoculation of the culture was positive.

According to the description of *Rivolta* and others, the *saccharomyces*, which we have found in Japanese farcy, are undoubtedly identical with the *cryptococcus farciminosus* of African farcy. The culture experiment of *Fermi* and *Aruch* does not agree with my experiment, especially on the morphology of the vegetative form of *saccharomyces*. According to our experiment the *vegetation of the saccharomyces of Japanese farcy is very slow and gradual*, and it never forms so distinct a colony in the 3rd day as observed by *Fermi*. He got only a spherical vegetative form. And from these differences it is doubtful whether *Fermi's* culture was the same as that obtained by me. Recently I have tried peritoneal inoculation of my culture and also of the content of farcy, on guinea pigs and hares, but the result was not promising.

How does natural infection take place?

The postmortem and clinical facts that the morbid process begins mostly in the cutis and that it appears generally in exposed parts of the skin, indicate that the infection takes place from the skin more especially from superficial wounds. In single cases we observed infection from natural openings of the skin, hair follicles, sebaceous glands, &c. For proper infection, however, as indicated by the result of inoculation, the praedisposition of the animal body plays a greater part, and this praedisposition seems to depend on the age and constitution of animal; sex, color of skin, &c., have no influence. The following data were supplied by *Prof. Katsushima* (a), *Miyagi Agricultural School* (b) and by *Mr. Shinozaki* (c), Military veterinary officer of the Remounting depot of Kajiyasawa, and the number has been reduced by the author. The 3rd is the average of 2 years (1890 and 1891).

Age:	(a) of 139 cases:			(b) of 38 cases:			(c) of 507 cases:			Average of 3 observations:	
	Total cases.	Average for each age.	%	Total cases.	Average for each age.	%	Total cases.	Average for each age.	%	Average for each age.	Average. %
1—2	5.	2.5	1.8	—	—	—	4.	2.0	0.4	2.3	1.0
3—4	12.	6.0	4.3	19.	9.5	25.0	189.	94.5	18.0	36.6	16.0
5—6	15.	7.5	5.4	10.	5.0	13.1	91.	45.5	8.6	19.0	8.3
7—8	18.	9.0	6.5	4.	2.0	5.3	88.	44.0	8.4	18.3	8.0
9—10	17.	8.5	6.1	3.	1.5	3.9	69.	34.5	6.6	14.8	6.5
11—15	36.	7.2	5.2	0.	—	—	43.	8.6	1.6	5.3	2.3
over 16	26.	2.6	1.9	2.	0.6	1.6	25.	2.0	0.4	1.7	0.7
Total	139.			38.			507.				
Under 1 year	2.		1.4%								

Thus most cases occur in the 3rd and 4th years of age. We must, however, remember that the average standard of the age of a horse varies in different districts. So, in breeding and raising districts, Miyagi for instance, younger horses predominate, while in those places, where horses are kept for service, there are more older ones ; and thus, for exact statement, allowance must be made for these differences. Praedisposition seems greater in weaker than in stronger individuals, in cold seasons than in hot, chiefly owing to the difference in hygiene. Whether disposition disappears after one attack, as believed by quacks, is questionable, and it requires further investigation.[1]

The following circumstances may be enumerated as occasional causes ;—1. Long persistent pressure, which causes contusion and abrasion of skin, such as the pressure of saddle, harness, &c. 2. All kinds of skin wounds especially at the inferior part of the extremities. 3. Bad management especially of skin and hoof. During the winter season most farm horses have to stay many weeks in a dusty stable with a dusty coat and depend on a poor supply of winter rations. Here the resistence of the

(1) *Peuch* says, of African farcy, disposition diminishes after one attack.

body is lessened, and the skin is loaded with germs and is easily infected. The under surface of the hoof is also generally rotten, and the sensible tissue of hoof is thus exposed to infection. 4. Defective stables. Farm stables are generally badly ventilated; the floor is hollowed a foot deep or even more, and this excavation is specially provided for the preparation of stable manure, the most favorable condition for the propagation of disease germs. 5. Terrulic influences. The prevalence of this enzooty is closely related to meteorological and geographical peculiarities. It prevails more in low marshy districts than in mountainous localities. When the former is once infected, the disease becomes stationary and is quickly propagated. The disease may appear in all seasons, but specially prevails from autumn to spring as shown in the following table (from official reports):—

January	291·8	July	37.2
February	326·6	August	59·8
March	364·4	September	34·0
April	306·0	October	18·0
May	74·8	November	33·0
June	63.0	December	274·8

It prevails more in rainy years and seasons and also after inundations.

The above mentioned facts indicate that this disease belongs to the group of *miasmatic-contagious diseases*, the source of infection being the ground. The infection goes on chiefly by vehicles, soil, stables, stable utensils, harness, saddle, litter, fodder, transitory parasites, such as *Ixodes*, *Tabanides* and *Muscides*. Immediate infection from horse to horse seems rarely the case. About *incubation* there is no exact statement.

3. Action of Mallein on Saccharomycosis.

Since April, 1888, we have tried injections of emulsion of *bacillus mallei* on Jap. farcy patients. Result was mostly negative,

i.e. to say, there was no febrile reaction, except in one case, which was tried at Nishigahara (with the emulsion prepared by me). The result was as follows :—

0·5 ccm. of emulsion injected on March 28th 1 p.m., '92.

Date :	Tempeature.	Date :	Temperature.
28/III 1 p m.	37°8 C.	28/III 12 p.m.	39° C.
„ 5 p.m.	38°4	29/III 1 a.m.	38°4
„ 7 p.m.	38°7	„ 8 a.m.	38°3
„ 9 p.m.	38°8	„ 10 a.m.	38°3
„ 10 p.m.	39°2	„ 12 a.m.	38°1
„ 11 p m.	39°4		

Thus the temperature began to increase from the 5th hour and attained its maximum at the 11th hour ; the difference was 1.6° C.

Later on, in the year 1893 we have received from Drs. *Preusse* and *Troester* of Germany 3 bottles of fluid *mallein*, prepared on July 27, and Sept., 1892, and one tube of dry *mallein*. The result of the injection[1] was as follows :—

(1) The farcy horses, cases XXIII-XXVII, served for experiment; case XXIII, 10 years old, with farcy changes on the right posterior extremity, in the testicle, nose, pharynx, larynx, and lymphatic gland : Case XXIV, 12 years old, with farcy changes on the left flank, in the lymphatic gland, and lungs : Case XXV, 15 years old, with farcy changes on the shoulder and thorax, in the testicle, nose, lymphatic gland, and lungs : Case XXVI, 10 years old, with farcy changes on the right hypochondrium, loin, thorax, praeputium, extremities, in the nose, testicles, lymphatic gland, and pharynx, and case XXVII with farcy changes on the head, neck, right shoulder, chest, abdomen, extremities, and perineum. The *mallein* was diluted, each time, with 0.5 % phenol-solution in the proportion 1 ÷ 9.

(1)

Fluid *mallein* 0.1 c.cm.

Date of injection: 8 a.m., Feb. 10, '93.

Date:	Case XXIII.	Case XXIV.	Case XXV.	control.
7/2 p.m.	37°7 C.	37°6 C.	—	
8/2 a.m.	37°6	37°5	37°5 C.	
„ p.m.	37°9	38°1	38°1	
9/2 a.m.	37°5	?	37°3	
„ p.m.	38°2	38°0	38°1	
10/2 10 a.m.	37°7	36°0	37°5	38°6
„ 12 m.	38°2	36°0	38°0	38°4
„ 2 p.m.	38°3	35°1	38°2	38°3
„ 4 p.m.	38°6	36°3	38°3	38°4
„ 6 p.m.	38°6	37°4	38°4	38°8
„ 9 p.m.	38°6	37°7	38°4	38°7
11/2 a.m.	37°1	?	37°1	—

(2)

Fluid *mallein* 0.5 c.cm.

Date of injection: 8 a.m., Feb. 14, '93.

Date:	Case XXIII.	Case XXV.	Case XXVI.	Control.
Before injection.	37°5-38°2	37°5-38°1	37°5	37°5
14/2 12 m.	37°3	37°5	37°5	37°2
„ 3 p.m.	38°3	38°4	38°4	37°5
„ 5 p.m.	38°6	38°0	38°7	37°5
„ 8 p.m.	38°5	38°1	38°5	37°5
15/2 9 a.m.	37°8	37°5	37°5	—

(3)

Dry *mallein* 0.1 gram.

Date of injection : 8 a.m., Feb. 17, '92.

Date :	Case XXIII.	Case XXV.	Case XXVI.	Case XXVII.	Control.
Before injection.	36°5-37°	37°5	37°3	37°4	—
17/2 10 a.m.	36°2	37°5	37°3	37°4	36°8 ?
„ 12 m.	36°5	38°0	37°8	37°7	36°7 ?
„ 2 p.m.	36°7	38°1	38°0	37°7	36°8 ?
„ 4 p.m.	37°2	39°2	38°9	37°9	36°7 ?
„ 6 p.m.	37°8	39°5	39°5	38°4	38°8
„ 8 p.m.	38°2	39°4	38°8	38°5	38°7
„ 10 p.m.	38°0	38°8	38°5	38°2	38°6
18/2 8 a.m.	37°3	38°1	37°8	37°0	—

(4)

Fluid *mallein* 0.5 c.cm.

Date of injection : 6 a.m., March 2, '92.

Date :	Case XXV.	Case XXVI.	Control.
1/3 a.m.	36°7	37°2	37°7
„ m.	36°7	37°3	38°3
„ p.m.	37°1	37°3	38°4
2/3 6½ a.m.	37°1	37°0	37°8
„ 8 a.m.	37°1	36°8	37°7
„ 10 a.m.	37°1	37°2	37°9
„ 12 m.	37°3	37°4	37°7
„ 2 p.m.	37°4	37°3	38°0
„ 4 p.m.	37°6	37°6	38°4
„ 6 p.m.	37°6	37°7	38°2
„ 10 p.m.	37°3	37°5	—

Résumé:

Experimental animals:	Kind of *mallein*:	Dose:	Maximum temperature:	Time of max. tem.:	Temperature difference:
XXIII.	Fluid m.	0.1 ccm.	38°6 C.	8th h.	0.4 C.
XXIV.	„	„	37°7	13th h.	
XXV.	„	„	38°4	10th h.	0.3
Control.	„	„	38°8	10th h.	0.4
XXIII.	„	0.5 ccm.	38°6	9th h.	0.4
XXV.	„	„	38°4	9th h.	0.3
XXVI.	„	„	38°7	9th h.	1.2
XXIII.	Dry m.	0.1 gram.	38°2	12th h.	1.0
XXV.	„	„	39°5	10th h.	2.0
XXVI.	„	„	39°5	10th h.	2.2
XXVII.	„	„	38°5	12th h.	1.1
XXV.	Fluid m.	0.5 ccm.	37°6	10th h.	0.5
XXVI.	„	„	37°7	12th h.	0.4

The reaction of fluid *mallein* was insignificant. With 0.1 c.cm. *mallein* there was no reaction: with 0.5 c.cm. the temperature increased to 38.7°C. in one case, out of five, and the difference was 1.2°C. Should we consider this as positive reaction, then it would make 20%.[1] With dry *mallein* there was a distinct rise of temperature and if we admit the conclusion of *Foth* * and others and exclude those reactions, in which the difference was below 2°, then positive reaction makes 50%.[2] After each injection appeared general weakness and slight depression and locally a swelling of hen-egg size; these symptoms lasted for a short time. Skin affection made quicker progression than before. Case XXIV died soon after the first injection.

In the year 1895 *mallein*-injection was repeated by Prof. *Katsushima* in Tochiki-ken. The *mallein* was of the date

* According to the statement of *Foth* the diagnostic value of different sorts of *mallein* are as follows:—With potato *mallein* of *Preusse* and *Priesz* 89% of those horses, who

Oct. 23, '94, prepared by Dr. *Preusse.* His result was as follows :—

Patients:	Age:	Farcy changes found on:	Max. temp.: (in C.)	Difference: (in C.)	Time of max. temp.:	*Mallein* dose:
No. 1.	15.	Neck, shoulder, breast, chest, anterior extr. & gl.	39°0	1°4	8°30′	
No. 2.	9.	Pectoral region and praeputium.	38°0	0°9	8°20′	
No. 3.	12.	Flank and praeputium.	38°1	0°5	8°00	
No. 4.	13.	Shoulder and chest.	38°2	0°6	?	
No. 5.	12.	Flank and umbilical region.	38°2	0°5	12°00	0.5 c. cm.
No. 6.	9.	Shoulder and chest.	38°3	1°2	11°30′	
No. 7.	5.	Shoulder, breast and flank.	37°8	−0°2	—	
No. 8.	11.	Breast and chest.	38°7	1°4	12°00	
No. 9.	4.	Head and intermaxillary gland.	38°1	−0°1	9°30′	
No. 10.	4.	Chest, shoulder, nose cavity & intermax. gl.	38°5	0°9	8°00	
No. 11.	8.	Breast and pectoral region.	38°3	0°4	8°00	

In No. 1, 6, and 8, temperature difference was more than 1° C., but the maximum was, in all cases, too low. If we admit these 3 as positive then it will make 27.2%.[3] This nearly coincides with my experiment. Taking both together into consideration the following conclusions are reached :—

1. Solid *mallein* in the dose 0.1 gram, injected in Japanese farcy patient gives positive febrile reaction at 50% (according to *Foth* 48%).

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have shown the temp. difference above 1°5 C. were glanders ; in those of temperature difference 1°-1°4 C., 70.5 %, and in those of below 0,9°C., 11 % were glanders ; thus,

difference above 1°5 c.	positive	89 %
„ „ 1°-1°4 c.	„	70.5 %
„ below 0,9 c.	„	11 %

With dry *mallein* of *Foth*, positive reaction was as follows :—

Difference above 2° c.	positive	96 %
„ „ 1°9-1°2 c.	„	46 %
„ below 1°1 c.	„	0

i.e. to say the temperature difference below 1°1C. indicates that, the horse is free from glanders. If we make this allowance for our result, then we find the following numbers :—

(1)	*Preusse's mallein.*	14.1% (20 × 70.5%)
(2)	Dry *mallein.*	48 % (50 × 96 %)
(3)	*Preusse's mallein.*	19.1% (27.2 × 70.5%)

2. Fluid *mallein* in the dose 0.1 c.cm. gives no reaction.
3. Fluid *mallein* 0.5 c.cm. gives positive reaction at 27–33% (14.1–19.1%).
4. Preexisting morbid process was accelerated after the injection of *mallein*.
5. Febrile reaction was more distinct in more severely affected horses.
6. Highest temperature was in our cases always below 39.5° C. and the maximum difference was 2.2° C.
7. The maximum was attained at the 8th—10th hour after injection.

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4. Differential Diagnosis.

i. *Malleus farciminosus et humidus.*

As already mentioned the clinical and anatomical characters of *saccharomycosis* are more or less allied to those of proper glanders, and differentiation is often difficult. The following points may serve for this purpose.

1. Clinico-anatomically:—Saccharomycosis appears chiefly in the skin. Changes are less frequent in the internal organs and lymphatic glands, while true glanders often attack the internal organs, especially the lungs. Cutaneous eruption of saccharomycosis is very characteristic, especially fungoid new formations, which are at least rare in true glanders and farcy. Pus in the case of saccharomycosis is thick and glutinous like condensed milk, or it consists of a dim fluid mixed with cheesy floccules, unlike thinner quality of the content of the veritable farcy. Nasal affection is, in saccharomycosis, mostly bilateral with fungoid ulcerations, while in true glanders one side is generally affected with hollow ulcers which often terminate in star-shaped cicatrices. Such cicatrix is rarely found in saccharomycosis. Swelling of the intermaxillary gland is not in every case the complication of nasal affection; the swelling, if present, is generally bilateral, corresponding to nasal affection; proper induration is never found. True glanders are mostly incurable, while sac-

charomycosis is curable in many cases. Diagnosis is more surely ascertained by microscopical examination and by inoculation.

2. Inoculation :—Guinea pigs are sensible to the *contagium* of true glanders ; for saccharomycosis they are, at least for subcutaneous injection, entirely refractory.

3. *Mallein* injection may serve for this purpose only by the intensity of reaction. But as the reaction is very irregular, we can scarcely depend on it.

Special attention must be called to the fact that mixed infection of *saccharomyces* and of *B. mallei* is not impossible. According to our experiments the *contagium* of true farcy may give an opportunity for the development of saccharomycosis in faster progression. Very important is the fact that the anatomical picture in the case of mixed infection appears, according to our observation, quite the same as in saccharomycosis. In such a case differential diagnosis is very difficult, as microscopical examination may easily lead to the misdiagnosis of a case. Hence for exact diagnosis we must closely examine each doubtful case in all directions as hitherto mentioned.

ii. *Himushi.*[1]

Himushi is another skin affection, which is also common in Japan, and which appears in farm horses exclusively in summer. It is at first acute, and suddenly developes with strong inflammatory symptoms, resulting in an extended necrobiosis of cutis and subcutis. Thus arises a big ulcer with exaggerated granulation on the bottom and border of wound, combined with an enormous thickening of the skin and subcutis. Then it assumes a somewhat different aspect and is often liable to be confounded with saccharomycosis. The following are cardinal points of difference :—

1. *Himushi* always appears in a single part of the body, and is never disseminated.

2. *Himushi* is very itching.

3. Morbid changes of *Himushi* consist of connective tissue

(1) *Bouley* described one skin disease of horse—*Dermatite granuleuse or plaies estivale*, in which *Rivolta* has found a small nematode—*Filaria irritans*. Whether *Himushi* is similar to that disease or not is not yet decided.

proliferation resulting in elephantiasis with vigorous big and vasculous granulations, and in the latter we find cavities, filled up with atheromatous matter, which is never absent in *Himushi*, while nodes and abscesses, characteristic of Jap. farcy, are wanting.

4. The wound secretion consists not of *pus bonum*, but of thick, thready fluid somewhat resembling *synovia*.

5. *Himushi* always appears in summer, and when the weather cools the wound heals spontaneously.

iii. *Gangrenous grease and some other kinds of phlegmone of extremities.*

These affections may lead to confusion, when they result in a chronic thickening or ulceration of the skin and subcutis. Recently we observed an epizooty of gangrenous grease in the *Tram-car Company* at Shimbashi. The epizooty suddenly appeared with a profound phlegmone, hot and painful swelling and febrile symptoms followed by gangrenous destruction of the skin and subcutis. Then appeared round or oblong ulcers of different sizes, dollar to hand-breadth or even larger, with distinct thickening at the border and bottom of the ulcer. The clinical appearance was nearly the same as that of *Himushi*, without, however, the symptoms of itching and atheromatous degeneration. The seat was mostly the hollow of fetlock and also the upper part of the extremities. We found a special kind of pathogenic *streptococcus*,[1] whose aetiological relation had been proved by inoculation experiment. In the case of extended ulceration confusion is possible with saccharomycosis ; but this disease is, like *Himushi*, confined to a single part especially of the extremities, and it shows neither nodules nor ulcers so characteristic of saccharomycosis.

iv. *Traumatic ulcer.*

This can be easily diagnotized, but such wound of extremities is frequently infested with *saccharomyces* (Case XXXIII). On watching a further course we find, in the case of infection, a cordy swelling or formation of abscesses in the neighbourhood along the course of the lymphatics.

---

(1) *Malze* found *streptococci* in the grease of horse and concluded it to be the same affection as erysipelas in men (Jahresbericht B. IX).

v. *Oedematous swelling of extremities.*

vi. *Elephantiasis, Verrucous grease or Straubfuss, and other chronic swellings of joint.*

Verrucous grease is found at the hollow of fetlock, which is much thickened, covered with warty prominences, and shows often excoriation and exsudation, but never cord-like swellings or abscesses.

vii. *Traumata of external genital organs.*

In most cases of saccharomycosis, we find changes in the scrotum, praeputium, or penis. Ulcers are here mostly hollow and funnel-shaped ; so, sometimes liable to be confounded with traumatic ulcers.

viii. *Cicatrix of different origin.*

This can be distinguished by *anamnesis*, by the form and arrangement of cicatrices and localities, where they appear. Chain-like cicatrices on the neck, breast, flank region, &c. are mostly the remains of former saccharomycosis.

ix. *Sarcocele, hydrocele, haematocele.*

The latter two may be easily distinguished by palpitation. Sarcocele may be distinguished by smooth and often enormous swellings and also by the absence of cutaneous lesion, which is always found in saccharomycosis.

x. *Saddle and harness galls.*

These may be ascertained by watching the course.

xi. *Bothriomycosis.*

It may appear at the spermatic cord after castration or on the saddle or harness region. There is no cordy swelling : the tissue is spongy, containing multiple purulent *herds*, in which characteristic *pilz*-grains can be found. The course is also different.

xii. *Actinomycosis.*

Recently many cases of equine actinomycosis have been reported. *Maile*, 1888, found in the scrotum of a horse, sarcomatous changes, in which *Rivolta* has found actinomyces-like micro-organisms. *Leblanc* and *Baranski*, 1888, found it in the intermaxillary gland, *Perroncito*, 1890, at the patellar region of the horse, and *Hamburger*, 1889, noted osseous actinomycosis of the horse. Although we have not yet found it in our horses, yet we must bear in mind these statements. Differentiation may be possible in the same way as in bothriomycosis.

xiii. *Tumors and parasitary nodules of skin and subcutis.*

Here for differential diagnosis may be mentioned metastatic tumors, especially sarcom, melanosarcom (in intermaxillary gland), carcinom, fibrom, lymphadenom (especially in intermaxillary gland), fibroma verminosum (*Spiroptera reticulata*), which is sometimes met with in Japanese horses at the saddle region, myiasis, ear fistule, cholesteatom at the false nostril, &c.

xiv. *Exanthemata as Eczema, Urticaria, Pemphigus, Impetigo, &c.*

Take generally an acute course.

xv. *Adenitis equorum and its complications as the catarrh of guttural pouches, sinus, &c.*

These are liable to be confounded with nasal saccharomycosis. But by experience we know that nasal saccharomycosis without cutaneous changes is an exception. Besides glandular swelling in the case of strangles is extensive and mostly turned to a big abscess.

xvi. *Dermatitis contagiosa Canadensis pustulosa.*

Acne contagiosa equorum or Canadean horse pox is an acute infectious exanthem of the horse characterized by eruption of pustules in the skin of back and thorax, more especially on the saddle and scapular region ; the pustules dry up and are transformed to a thick yellow crusts which afterwards detach together with hairs, and the ulcers, thus left behind, heal without

cicatrization. According to *Dieckerhoff* and others the process is often propagated in the subcutis attended with the swelling of the next lymphatic vessels and glands. Quite recently a similar exanthem prevailed in Kiushu, in which the author has found the same *bacilli* as discovered by *Grawitz* in the Canadean horse pox. In our case [1] the eruption was chiefly found on the inferior wall of thorax and abdomen, more especially on the scrotum, and it was complicated with a strong oedematous swelling of subcutis, while changes in lymphatic vessels and glands were never observed; severe cases terminated in death.

This disease can be distinguished by the shorter course, the stronger infectiousness, by the seat and size of pustules, which are smaller than in farcy, and are situated in the superficial layer of skin (*rete mucosum*), by the absence of cord-like swelling, and finally by means of inoculation and bacteriological researches—guinea pigs are very sensible for the *contagium* of Canadean horse pox.

xvii. *Lymphadenitis in the case of inflammation, suppuration or necrosis of different nature.*

This can be diagnotised by the primary lesion.

xviii. *Osteoporosis of facial bones.*

This is often observed in Japanese horses especially in the cross-breeds raised at Hokkaido. It can not be confounded with saccharomycosis, as in this case there is no cutaneous affection, and the course is very chronic—only liable to the confounded only with veritable glanders.

xix. *Traumata of Schneiderian membrane.*

In this case wound border and bottom are not much infiltrated and fungoid ulcerations never appear. The wound generally looks flat and smoother than in saccharomycosis. The course is also different.

xx. *Acute catarrh of respiratory passage.*

This can be distinguished by strong redness of the mucous

(1) These clinical remarks mainly owe to the report of Assist. Prof. *Imai* who was sent to the plague district. The details of the investigation, carried on by the author, will be reported in another occasion.

membrane, profuse nasal discharge, &c. The course is also different. Sometimes nasal saccharomycosis is higher situated or hidden between turbinated bones, and is invisible from the outside.

Morbus maculosus, degeneratio amyloidea of mucosa of nose (*Wolff*), retention cysts, haemorrhagic ulcers in the case of pseudoleucaemia, &c., also require to be mentioned for differential diagnosis.

In all these cases microscopical examination is the safest means of diagnosis, provided that there is no sign of mixed infection. For this purpose pus or any morbid matter should be mounted with the physiological solution and examined without staining and with a narrow diaphragm.

II. In Cattle.[1]

(Saccharomycosis bovis.)

About saccharomycosis in cattle my observation is limited. In the year 1890 we had to examine one cattle patient covered with numerous hazel-nut-sized round subcutaneous nodules, which were freely dislocable. According to *anamnesis*, these nodules had existed for a long time, without any progressive or regressive change. For microscopical examination we extracted some nodules and found numerous *saccharomyces* identical with those of the horse.

Later on, 1893, we received from one veterinarian of Tochiki-ken, similar nodules extracted from cattle patients. According to his information, the clinical symptoms were shortly as follows :—

"No. 1. Bull calf, 1 year old, of medium condition, suffering from skin affection. Subcutaneous nodules of hempseed-hazelnut-size were found on the neck, shoulder, dewlap,

---

(1) *Zschokke* and *Nocard* mention bovine farcy, in which *Nocard* found special kind of bacillus (*Recuill* p. 70, '88.). This seems to be different from the case in point.

Prefecture:	1887.		1888.		1889.		1890.		1891.		1892.		1893.		1894.		1895.		Total morbidity for 9 years:	Total mortality for 9 years:	Average number of horse:	No. of morbidity per 1000 of horse in each pref.:
	Morbidity:	Mortality	Morbidity:	Mortality	Morbidity:	Mortality:	Morbidity:	Mortality:	Morbidity:	Mortality:	Morbidity:	Mortality:	Morbidity:	Mortality	Morbidity:	Mortality:	Morbidity	Mortality				
Tokyo	30.	16.	14.	4.	3.	1.	7.	2.	8.	3.	3.	1.	4.	1.	6.	6.	8.	5.	83.	39.	2797.	29 67
Kanagawa	102.	6.	—	—	31.	2.	65.	8.	38.	3.	5.	—	4.	—	4.	—	—	—	249.	19.	10298.	24.17
Saitama	11.	1.	1.	—	20.	2.	24.	—	75.	4.	16.	2.	15	2.	8.	1.	27.	2.	197.	14.	27441.	7.17
Chiba	47.	—	31.	3.	75.	2.	90.	1.	182.	7.	34.	3.	105.	1.	102.	—	63.	0.	729.	17.	48882.	14.91
Ibaragi	1.	—	26.	1.	169.	8.	141.	7.	79.	9.	18.	4.	63.	2.	246.	9.	147.	10.	890.	50.	61067.	14.57
Gunba	3.	1.	—	—	—	—	1.	—	85.	3.	69.	1.	203.	14.	118.	11.	86.	5.	565.	35.	32657.	17.30
Tochiki	60.	6.	21.	2.	4.	—	67.	4.	577.	19.	165.	9.	148.	13.	90.	4.	139.	4.	1271.	61.	50081.	25.37
Fukushima	26.	3.	71.	3.	211.	7.	71.	3.	768.	5.	175.	—	100.	3.	348.	3.	290.	10.	2060.	37.	85425.	24 11
Miyagi	753.	17.	536.	39.	590.	20.	470.	33.	608.	12.	338.	12.	380	19.	249.	21.	217.	15.	4141.	188.	64881.	63.82
Iwate	182.	18.	135.	17.	652.	25.	504.	62.	953.	90.	957.	70.	390.	43.	226.	14.	185.	13.	4184.	352.	92632.	45.16
Yamagata	5.	—	1.	—	5.	1.	5.	—	8.	1.	32.	1.	66.	5	2.	2.	11.	—	135.	10.	25107.	5.37
Aomori	7.	3.	34.	7.	61.	50.	18.	8.	18.	5.	8.	1.	12.	—	4.	1.	4.	—	166.	75.	63649.	2.60
Shizuoka	204.	3.	130.	13.	204.	3.	304.	6.	127.	8.	41.	1.	76.	4.	9.	4.	7.	1.	1102.	43.	17021.	64.74
Tokushima	3.	2.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3.	2.	19024.	0.15
Hiroshima	1.	1.	—	—	1.	1.	—	—	—	—	—	—	—	—	—	—	—	—	2.	2.	21747.	0.09
Kagoshima	2.	1.	—	—	1.	—	—	—	—	—	—	—	—	—	—	—	—	—	3.	1.	150171.	0.02
Ōita	4.	2.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4.	2.	51234.	0.07
Akita			1.	—	37.	—	1.	—	—	—	84.	—	5.	1.	23.	—	83.	4.	234.	5.	68535.	3.41
Aichi			1.	1.	5.	—	—	—	1.	1.	—	—	5.	1.	10.	1.	7.	—	29.	4.	12633.	2.29
Hokkaido			55.	10.	—	—	12.	7.	63.	8.	40.	11.	10.	3.	4.	8.?	32.	5.	216.	52.	44958.	4.80
Hyogo							1.	—	—	—	—	—	—	—	—	—	—	—	1.	—	7311.	0.13
Yamanashi							1.	—	—	—	178.	—	18.	—	5.	—	14.	3.	216.	3.	17722.	12.18
Shiga							1.	—	—	—	—	—	—	—	—	—	—	—	1.	—	1306.	0.76
Niigata									1.	1.	—	—	—	—	—	—	—	—	1.	1.	41433.	0.02
Ōsaka											1.		—	—	—	—	7.	1.	8.	1.	(134.	59.70)
Nagano															2.	—	1.	—	3.	—	56631.	0.05
Gifu																	2.	—	2.	—		
Wakayama																	2.	2.	2.	2.		
Total:	1441.	80.	1057.	100.	2069.	122.	1783.	141.	3591.	179.	2164.	116.	1604.	112.	1456.	85.	1332.	80.	16497.	1015.		

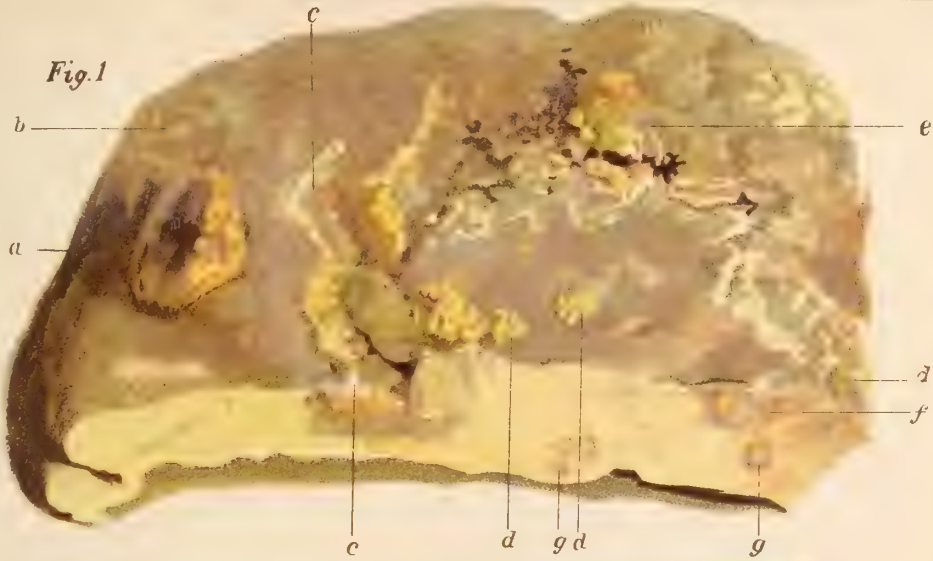
EXPLANATION OF PLATES.

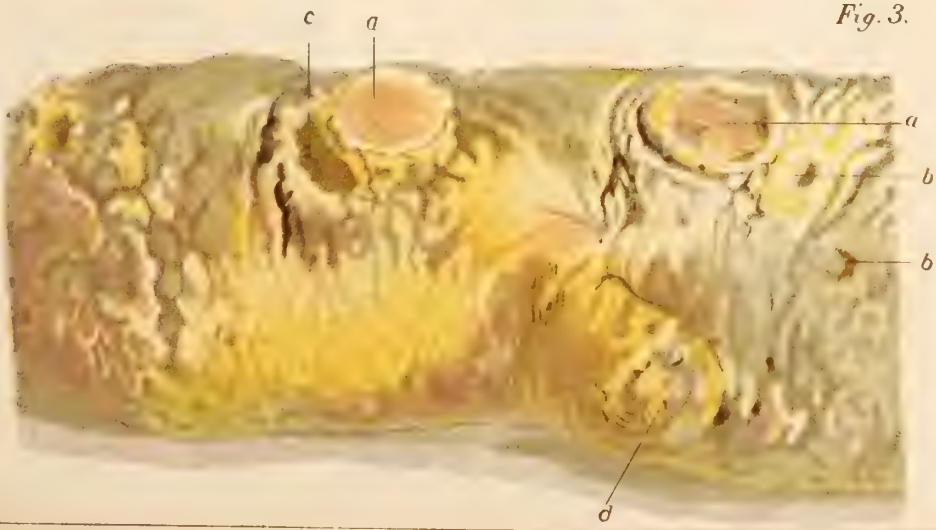
PLATE I. Saccharomycotic changes in different parts of the body (horse): natural size. Fig. 1: A part of skin, *a* sacchar. ulcer partly covered w. scab, *b* crater-like ulcer, *c c* confluent ulcers, *d d d* fungoid or nodular ulcers, *e* the same confluent, *f g g* cutaneous and subcutaneous nodules. Fig. 2: A part of nasal septum with nodular ulcers *a b*. Fig. 3: A part of ext. genitals; *a a* saccharomycotic ulcers, *b b* crater-like ulcers, *c* funnel-shaped ulcer, *d* larger crater-like ulcer.

PLATE II. Fig. 1: Subcutaneous node; Fig. 2: Cutaneous nodes w. crater-like opening *a*; Fig. 3: Fungoid ulcer; Fig. 4: Saccharomycotic changes in hair follicles and in the corresponding subcutis; Fig. 5: Transection through cutaneous nodules, *a* circumscribed in the skin, *b* cutaneous nodule propagated over the subcutis.—All in natural size. Fig. 6: Section of skin (picro-carmine prep.; *Zeiss* Ocul. 2, Object. A); *a* epidermis, *b b* hair follicles, *c* sebaceous gland, *d d d* saccharomycotic *herds* in the thickened skin and subcutis. Fig. 7: Different forms of saccharomyces; *d* mono-granulated, *b* with finely granulated content, *c* with 2 granules, *d d* semilunar form, *e* apparently empty, *f* with larger granule, *g* 3 cells conjoined, *h* with bud-like appendix; 1–2 pus corpuscles containing many saccharomyces, 3 the same with granules, 4–5 connective tissue corpuscles with saccharomyces. Fig. 8: Colony of saccharomyces on glycerine-agar (about 7 months old). Fig. 9: Vegetative form after a fortnight, *a* original, *b* swollen, *c* spherical form with a number of granules, *d* dumb-bell form, *e* young hyphen, *f* extracellular granule; Fig. 10: The same two months old; Fig. 11: The same more than one year old.

PLATE III. Fig. 1: Microscop. section of a part of the Schneiderian membrane (horse), *a* cartilage, *b* mucons gland, *c c* saccharomycotic *herds*; Fig. 2: The same fr the lung with chr. broncho-pneumonia (*Zeiss* Ocul. 2, Object. D), *a* bronchiolus, *b* para-bronchiolar and alveolar tissue with cellular infiltration; Fig. 3: Saccharomyces from the content of abscess (*Zeiss* Ocul. 4, Object. J Immers.)

(The plate I painted by the artsit *Yokoyama*; Fig. 1–5 of the Plate II drawn by Assistant Professor *Tanaka* and Fig. 5–11 by the author; photograms of the Plate III were made by Dr. *Okura* and the author with the apparatus devised by themselves).





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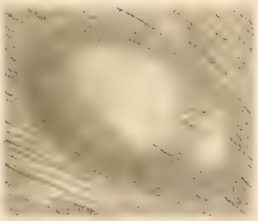


Fig. 1.

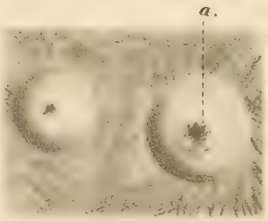


Fig. 2.

Fig. 3.

Fig. 6

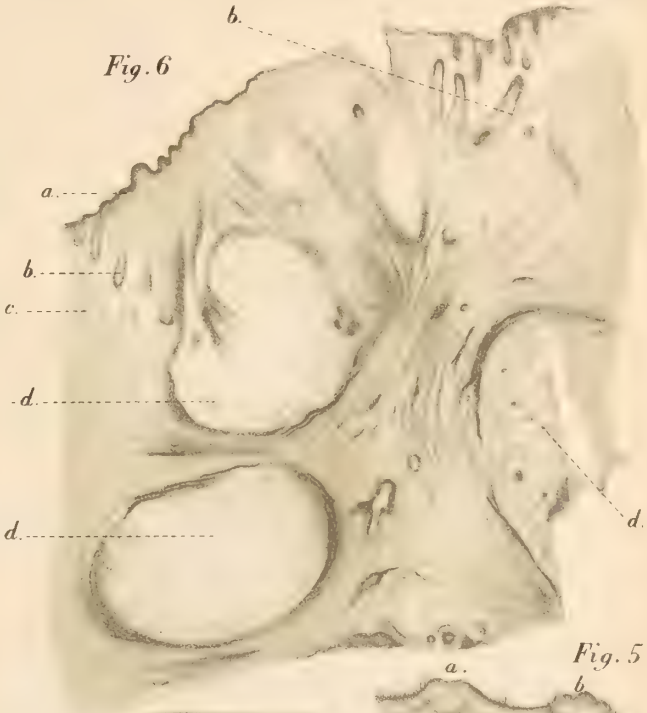


Fig. 4.

Fig. 5

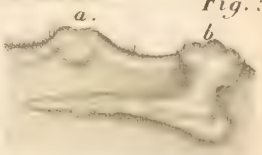


Fig. 7

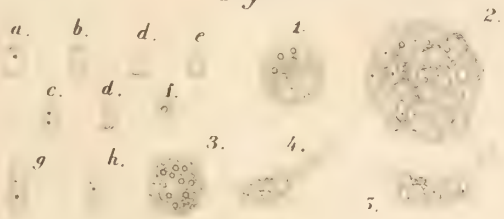
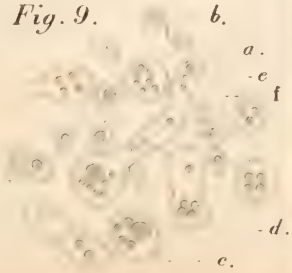


Fig. 8.

Fig. 11.

Fig. 10.

Fig. 9.



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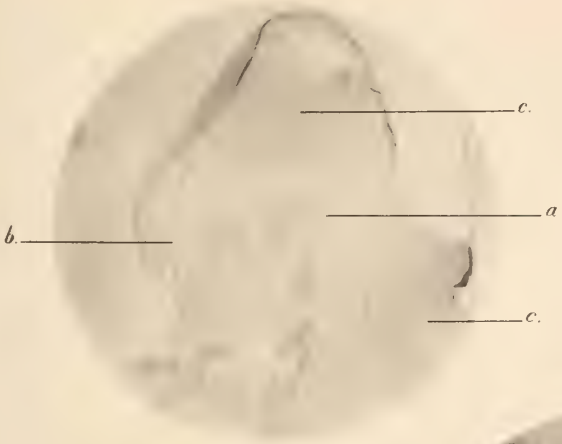

Fig. 1.

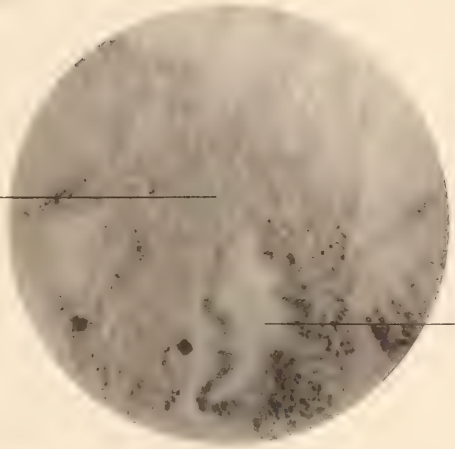

Fig. 2.

Fig. 3.

K. Sawa

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The Chemistry of Soja Sauce Manufacture.

BY

Y. Nishimura, *Nōgakushi.*

INTRODUCTION.

The manufacture of soja sauce forms one of the important industries of Japan and the export of the article increasing from year to year.[1] The production in 1893 was 2,307,844 hectolitres (=1,279,238 koku). The number of brewers is now nearly 10,000.

One of the factories in Tokio alone employs 250 workmen and manufactures annually 45,000 hectolitres.

Soja sauce is a dark brown liquid with an agreeable smell resembling that of toast. *I. Murai*[2] investigated the composition of 40 different samples, of which we mention the following two analyses :—

Specific gravity	1.1850	1.2300
Dry matter	37.607	39.923
Total nitrogen	1.484	1.086
Glucose	2.696	3.334
Dextrin	0.688	1.100
Acidity (as lactic)	1.183	0.801
Inorganic matter	10.476	25.254
(Sodium chloride	16.032	23.012)
(Phosphoric anhydride	0.530	0.389)

N. Nagai and I. Murai[3] in addition to *Tahara* and *Kitao*[4] obtained the following results :—

(1) Every Japanese uses daily in place of common salt from 50 cc. to 80 cc. of this sauce as a food condiment.

(2) Tokio Eiseisiken Ihō. Vol. 8, p. 35,1897.

(3) *König.* Menschliche Nahrungs- und Genussmittel, 1884.

(4) Yakugakuzasshi, Vol. 61 (1887), and Révue internationale des falsifications, 1889. Bd. II, 159.

Isono (Journal of the Tokio Chemical Society, Vol II. 1, 1882), compared also the composition of soja sauce in three stages of preparation, but the samples taken were not from the same original materials.

	(*a*)	(*b*)
Water	73.60	67.42
Total nitrogen	0.74	1.18
Soluble albumin	0.68	—
Peptone	1.79	—
Ethereal extract	0.49	1.07
Carbohydrates	4.25	2.76 (as sugar.) 1.30 (as dextrin.)
Mineral matter	17.03	17.47
Sodium chloride in ash	12.47	—
Organic matter	—	15.11
Volatile acid (as acetic)	—	0.16
Fixed acid (as lactic)	—	0.83
Alcohol	—	0.43
Ammonia	—	0.21
Leucine	—	0.46

The Chinese soja sauce, for the preparation of which *Aspergillus Wentii* is used in Java, is according to *Prinsen Geerlig* (Chem. Zeitg. 1895) a blackish brown ropy liquid of the following composition :—

Specific gravity		1.254
Nitrogenous matter	soluble in alcohol	4.87
	insoluble ,, ,,	2.62
Non-nitrogenous matter	soluble in alcohol	0.25
	insoluble ,, ,,	0.78
Sugars		15.00
Sodium chloride		17.11
Other mineral matter		1.65
Water		57.12

The nitrogenous matter insoluble in alcohol consists of peptone and legumin, which latter is precipitated with water. This is not observed with Japanese soja sauce, which remains always clear on the addition of water.

Many erroneous reports have been published about the preparation of soja sauce.[1] Thus it has been recently asserted that bacteria have much influence on the ripening process as in

(1) See e.g. Belohowhik, Z. Brauw, 1889. p. 433.

the case of cheese.[1] From my investigations, however, I infer that bacteria are not concerned to any extent, and that besides the fungus *Aspergillus Oryzae* (so important in the preparation of sake), only some kinds of *Saccharomyces* come into consideration.

Soja sauce is prepared from wheat (sometimes also from barley), the soja been,[2] and a salt solution by a slow process, which requires from one to two years and sometimes more.[3] We may distinguish four principal stages :—

I. Preparation of the wheat and soja bean.
II. Preparation of the soja koji.
III. The ripening process.
IV. Pressing and boiling.

PREPARATION OF WHEAT AND SOJA BEAN.

The composition of the wheat and soja bean (so-called *itachi* bean), used in my investigations, was as follows :—

	Wheat.	Soja bean.
Water	14.33%	11.16%
In 100 parts of dry matter.		
Ash	1.81	4.68
Organic matter	98.19	95.32
Crude protein	13.46	46.30
Ether extract	1.86	19.73
Crude fibre	3.55	4.94
Total nitrogen	2.154	7.408
Albuminoid nitrogen	2.008	6.777
Non-albuminoid nitrogen	.146	.621
Starch	74.02	21.11[4]
Dextrin	4.7	3.31
Glucose	.44	—
Weight of 1000 grains	31.339 grm.	111.866 grm.

(1) The view that a slow after-fermentation takes place is incorrect. The large percentage of sodium chloride prevents bacterial growth ; however, in very warm weather a scum of Saccharomyces may be observed, which is altogether an unwelcome appearance.

(2) The so-called yellow soja bean (*itachi*) which principally serves for the manufacture of soja sauce is rather small and has a certain lustre. Sometimee the gray soja bean is used, but never the black variety.

(3) All materials for my investigation were obtained from the great soja sauce factory, *Asamasa*, at Nakano near Tokio. I herewith tender my thanks to the proprietor for the liberality with which he assisted me in my work.

(4) The soja bean contains galactan in place of starch.

The preparation of the wheat grains consists in roasting them in a flat iron pan while soja beans are thoroughly boiled.

About 2.2 kilos of the wheat grains (3 litres) are roasted at at one time, being vigorously stirred for about 2 minutes. The workmen take care to obtain merely a brown colour by avoiding too much heat. The wheat loses thereby 2.77% of dry matter. The following table shows the loss by roasting :—

	Fresh wheat.	Roasted wheat.
Dry matter	100.00	97.23
Ash	1.81	1.87
Organic matter	98.19	95.36
Crude protein	13.46	13.28
Ether extract	1.86	2.25
Crude fibre	3.55	4.30
Total nitrogen	2.154	2.125
Albuminoid nitrogen	2.008	1.959
Non-albuminoid nitrogen	.146	.116
Starch	74.02	68.25
Dextrine	4.70	6.41
Glucose	.44	.85

Thus, nitrogenous matter and carbohydrates have decreased by the roasting action, while the ether extracts and crude fibre have apparently (relatively) increased.

The roasted wheat is broken, each grain into two or three pieces, with a stone mill, before it is mixed with the boiled soja bean.

The soja beans (about 563 kilos at a time) are first well washed with water, then poured into a large boiler of about 10 hectolitres capacity with 6 hectolitres of water. The mixture is kept vigorously boiling for 4 hours, then for 3 hours more on a small fire, and is finally left standing for 12 hours.[1] Then the boiled soja beans are spread out and left to cool to about 30°C. The soja bean by absorbing water increases about 51.83% by weight and loses 6 to 6.5 per cent. of organic matter.

Comparing the composition of the boiled soja bean with that of the original, we observe principally a decrease in carbohydrates. The following table shows the changes in composition by the boiling :—

(1) The aqueous liquor (*ame*) run off from the boiler is used for feeding cattle.

	In 100 parts of day matter of original soja bean.	In the boiled soja beans obtained therefrom.
Dry matter	100.00	93.47
Ash	4.68	4.51
Organic matter	95.32	88.96
Crude protein	46.30	45 30
Ether extract	19.73	18.98
Crude fibre	4.94	4.93
Total nitrogen	7.408	7.248
Albuminoid nitrogen	6.777	6.715
Non-albuminoid nitrogen	.631	.533
Galactans	21.11	7.52
Dextrine-like substance and sugars.[1]	3.31	12.19

PREPARATION OF SOJA KOJI.

The soja koji is prepared in a long narrow chamber built of brick or stone, or sometimes in a sort of cellar. Both sides are occupied by wooden trays, called koji-buta, upon which the mixture of boiled soja beans and coarsely ground roasted wheat is spread. The quantity of the mixture on each tray is about 1.5 kilos (2 litres) ; 2 parts of wheat for 3 parts of soja bean. At the factories which I visited, one of the koji chambers had a length of 10 m., a height of 3 m. and a breadth of 3 meters, and a very small entrance. Several small windows are situated at the opposite end to regulate the temperature within.

At first several small charcoal fires are started to produce a temperature of 36°C.

The mixture of boiled soja bean and roasted wheat is not directly inoculated with the spores of *Aspergillus oryzae*, because after the chamber has been used for this operation for some time, the walls, ground, and vessels contain so many spores that special infection[2] is not required.

It suffices to keep the mixture three days in this warm chamber to cover it thickly with the mycelium of that fungus. By the fungoid growth much heat is produced, which makes a fre-

(1) A portion of this sugar in the boiled soja bean (7.57%) was soluble in strong alcohol and, like maltose, its reducing power increased by inversion.

(2) Only a new chamber, used for the first time, requires a special infection; the spores are sold under the name of *tanekoji*.

quent stirring necessary. The temperature of the mixture in the chamber changes from 30 to 40°C.

The soja koji which served for my investigations had a weak acid reaction, contained 17.767% in the dry matter of soluble materials, and lost upon exposure to air 19.16% of water; it had the following composition:—

Total moisture	28.97%
In 100 parts of dry matter.	
Ash	3.68
Organic matter	96.32
Crude protein	33.91
Ether extract	13.35
Crude fibre	9.11
Total nitrogen	5.426
Albuminoid nitrogen	4.965
Non-albuminoid nitrogen	.461
Starch and galactans	15.39
Dextrin-like carbohydrates	2.91
Sugars	21.85

The changes produced by the growth of the fungus may be seen from the following analyses:—

	Original mixture.	In the soja koji obtained therefrom.
Dry matter	100.00	89.92
Ash	3.34	3.31
Organic matter	96.66	86 61
Crude protein	30.58	30.49
Ether extract	11.06	12.00
Crude fibre	4.84	8.19
Total nitrogen	4.893	4.879
Albuminoid nitrogen	4.476	4.464
Non-albuminoid nitrogen	.417	.415
Starch and galactans	39.97	13.94
Dextrin-like substance	5.63	2.62
Sugar	4.75	19.65

The loss of material by the development of the fungus amounts to 10.10% of total dry matter and concerns principally the carbohydrates, while on the other hand an increase of crude fibre by fungoid growth took place.

The soja koji is now transferred into the fermentation vat which has about 80 hectolitres capacity ; here it is mixed at 20-30°C. with salt solution, and now forms the soja sauce wort (*moromi*).

The salt used is sea salt, but only of the better quality, containing a very small quantity of sulphates. Further, hard water is preferred to soft by the manufacturer. The salt solution employed in the factory during my experiments had the following composition :—

Specific gravity	1.164 at 18°c.
Sodium chloride with some potassium chloride	20.05
Magnesium chloride	.79
Magnesium sulphate	.28
Calcium chloride	.56

CHEMICAL PROCESSES DURING THE RIPENIG OF SOJA SAUCE WORT (*MOROMI*).

Hitherto there have been no detailed investigations as to the extent of the gradual changes going on at different periods of the "ripening" process. During the long time required for "ripening," the mash is stirred twice daily in summer, but in winter only once, every two or four days. By this stirring not only is fresh air introduced, but also the mould which would be otherwise developed on the surface is prevented.

The temperature in the soja souce wort of the fermenting vat from May 6th, 1895 to April 6th, 1896, was observed in the factory above named as follows :—

		Air.	Wort.			Air.	Wort.
May. (1895)	Maxim.	26.°2	19.°8	Nov.	Maxim.	20.°7	16.°0
	Minim.	9.°2	17.°0		Minim.	1,°6	11.°5
June.	Maxim.	32.°1	22.°5	Dec.	Maxim.	18.°1	11.°0
	Minim.	12.°6	19.°0		Minim.	−4.°7	9.°0
July.	Maxim.	31.°9	27.°0	Jun. (1896)	Maxim.	7.°2	8.°0
	Minim.	15.°7	21.°5		Minim.	−5.°6	6.°0
August.	Maxim.	33.°6	28.°0	Feb.	Maxim.	16.°6	7.°0
	Minim.	20.°6	26.°0		Minim.	−4.°7	6.°0
Sept.	Maxim.	32.°2	28.°0	March.	Maxim.	18.°9	8.°0
	Minim.	14.°9	21.°0		Minim.	−4.°3	6.°0
Oct.	Maxim.	26.°1	21.°5	April.	Maxim.	24.°1	8.°0
	Minim.	7.°3	17.°0		Minim.	1.°2	

The coarse mixture gradually assumes a pasty appearance becoming very thick, and at the same time the colour of the

mixture turns dark brown, which is due perhaps to the solution of the dark substance produced by the roasting of wheat. The contents of the wheat grains soften more and more and after 8-9 months the solid contents have softened so much that by pressing the grain between the fingers only a small amount of paste issues from the hollow husks.

In order to observe the extent of the changes going on at different stages, I took samples from the centre of the same great vat at the following dates:—

I.	4th June, 1895. ..	30	days	after	preparation	of	the wort.
II.	4th August.	90	,,	,,	,,	,,	,,
III.	2nd October	150	,,	,,	,,	,,	,,
IV.	5th December ...	210	,,	,,	,,	,,	,,
V.	2nd Feb., 1896...	270	,,	,,	,,	,,	,,
VI.	6th April..... .	330	,,	,,	,,	,,	,,

Each sample was well crushed in a mortar to a fine pulp before being used for analysis, which was carried on according to the usual methods. The results may be seen from the following tables:—

Composition of the soja sauce wort at six different stages of the ripening process:

	I. June.	II. Aug.	III. Oct.	IV. Dec.	V. Feb.	VI. April.
Age	30 days.	90 days.	150 days.	210 days.	270 days.	330 days.
Water	58.87	62.37	62.64	62.23	62.01	61.82
Dry matter	41.13	37.63	37.36	37.77	37.99	38.18
Total organic matter	41.13	37.63	37.36	37.77	37.99	38.18
Substances soluble in cold water	24.61	25.01	26.01	27.20	27.71	27.76
Organic	12.86	12.89	13.73	14.54	14.90	14.92
Mineral	11.75	12.12	12.28	12.66	12.81	12.84
Volatile acid	.0364	.0419	.053	.0588	.0181	.0252
Fixed acid	.0508	.0378	.044	.054	.0486	.0505
Alcohol	1.02	1.87	2.53	2.64	1.87	1.24
Crude protein	9.87	9.93	10.08	10.23	10.24	10.05
Ethereal extract	5.76	6.06	7.10	7.62	7.84	7.85
Crude fibre	2.61	2.44	2.46	2.47	2.53	2.51
Total nitrogen	1.583	1.588	1.613	1.636	1.638	1.608
Albuminoid nitrogen	1.159	1.038	.798	.580	.542	.533
Non-albuminoid nitrogen	.424	.550	.914	1.056	1.095	1,075
Ammonia	.055	.083	.159	.182	.194	.171
Starch and galactans	1.28	1.21	1.18	1.17	1.05	.77
Dextrins	1.24	1.15	.27	.57	.75	.83
Sugars	7.18	3.68	3.08	2.15	2.07	2.38
Total ash	13.18	13.27	13.33	13.59	13.75	13.96
Sodium chloride	11.67	11.71	11.81	12.03	12.21	12.28

The following table shows the composition of the *dry matter* compared with the dry matter of the freshly prepared wort (koji and sodium chloride):—

Age	Koji and sodium chloride.	I. June. 30 days.	II. Aug. 90 days.	III. Oct. 150 days.	IV. Dec. 210 days.	V. Feb. 270 days.	VI. April. 330 days.
Total organic matter	70.01	67.53	64.47	64.32	64.02	63.81	63.56
Substances soluble in cold water.	41.08	59.87	66.46	69.62	72.01	72.94	72.71
Organic	—	31.31	36.91	36.75	38.50	39.22	39.08
Mineral	—	28.56	29.55	32.87	33.51	33.72	33.63
Volatile acid	—	.088	.111	.142	.156	.048	.066
Fixed acid	—	.123	.100	.118	.143	.128	.132
Alcohol	trace.	2.48	5.00	6.77	7.00	4.92	3.25
Crude protein	24.30	24.65	26.38	26.98	27.08	26.95	26.32
Ethereal extract	9.57	14.00	16.10	19.00	20.17	20.65	20.56
Crude fibre	6.53	6.35	6.46	6.58	6.54	6.66	6.57
Total nitrogen	3.889	3.848	4.220	4.317	4.332	4.312	4.212
Albuminoid nitrogen	3.558	2.819	2.756	1.751	1.535	1.426	1.396
Non-albuminoid nitrogen	.331	1.029	1.464	2.566	2.797	2.886	2.816
Ammonia	—	.134	.226	.426	.482	.511	.448
Starch and galactans	11.03	3.11	3.22	3.16	3.10	2.76	1.84
Dextrin	2.09	3.01	3.06	.72	1.51	1.97	2.17
Sugars	15.66	17.45	9.77	8.24	5.69	5.45	6.24
Total ash	29.99	32.22	53.28	53.68	35.98	36.19	36.56
Sodium chloride	28.35	28.37	31.61	31.61	31.85	32.14	32.16

Essential alteration in the chemical composition, therefore, only took place during the first 210 days, and the greatest change during the first two months.[1] Not only was the nitrogenous matter altered,—albuminoid nitrogen decreasing greatly, while the non-albuminoid increased,—but also the carbohydrates were considerably affected, showing a decrease of starch and the production of alcohol. Also the crude fibre was affected by the enzymes of the koji fungus, especially in the first month after the preparation of the wort. The amount of soluble matter was gradually very much increased. The apparent increase of sodium chloride is, of course, due to the evaporation of a certain amount of water.

It was clear to me *that the whole ripening process consisted principally in the action of the powerful enzymes of Aspergillus oryzae* upon the carbohydrates and proteids in the soja bean and wheat, and further in the development of an agreeable flavour.

(1) In the special case serving for my investigation, it happened that the first month was one of the warm months. The changes in the first month will, of course, be much less significant with a wort prepared in winter.

The production of the small amount of lactic acid and acetic acid by bacteria seems not essential, as it only takes place at the surface of the wort in summer time. The great amount of salt added is intended principally to prevent bacterial growth and the fermentations caused by it; but at the same time the action of enzymes is very much retarded by the high percentage of sodium chloride.

Thus *O. Kellner*, *Mori* and *Nagaoka*[1] proved that by adding 9% of sodium chloride to the mixture of koji extract and starch, the amount of sugar formed at 40°C. after 2 hours was only $\frac{1}{5}$ of that in the control solution without sodium chloride. In another experiment they found that with 12% of sodium chloride only 4.0% and that with 20% of sodium chloride only 1.6% of sugar, in comparison with that formed under normal circumstances.

In another experiment, an addition of 20% of sodium chloride decreased the amount of the sugar produced to 7.7% of the normal quantity.

If we heat the soja sauce wort to 80-100°C. no action whatever is noticed. Of course, the enzymes are killed by this operation.

As the present method of manufacture of soja sauce requires much time and therefore a considerable amount of unremunerative capital, it seemed to me of great importance to find some way by which the processes could be shortened. Two points seemed to me worthy of consideration.

1. To hasten the action of enzymes.

2. To produce the agreeable taste and flavour in the same measure as the enzyme action is hastened.

These processes seemed to me independent of each other.

In order to hasten the action of the enzymes of the soja koji, I crushed freshly prepared wort so as to increase the surface to be acted upon.

In the factory neither the soja beans nor the wheat are finely pulverized, hence the changes must be much retarded, as the enzymes penetrate but very slowly into the grains.

And farther I diluted the mixture with an equal amount of water, thereby diminishing the percentage of salt, and hence accelerating the action of enzymes; of course by this means the conditions for the development of certain bacteria were rendered

(1) Bull. College of Agriculture; Vol. I, No. 5. 1889.

more favourable than before. Still I believed there was sufficient sodium chloride present to retard considerably at least the lactic fermentation.

This mixture I digested at a temperature of 30-35°C. for one week, whereby the amount of organic matter that went into solution was 15.04%. This amount would correspond to six months stage of the present mode of manufacture. The microscopical investigation revealed the presence of micrococci but not that of bacilli. The original mouldy odour was not more perceptible, but neither was the normal flavour of good soja sauce developed. The colour of the mixture was dark brown, and its taste decidedly sour.

To the mixture just mentioned was added 2% cane sugar and 2c.c. of thick sake yeast for 300 grms. of the mixture, and this was again digested at 30-50°C. for 12 days. In this case, the flavour was more agreeable and the taste not sour. The amount of lactic acid was only .044%, but that of soluble organic matter was 14.83%.

In the next experiment the following mixture was digested for 8 days at 30-35°C.

Germinated soja bean	50 grms.
Barley malt	25 grms.
Cane sugar	2 %
Thick sake yeast	1.5 cc.
Water	75 cc.

After the second day 12% of sodium chloride was added.[1] Here the flavour was radically different from that of soja sauce, and the taste was slightly sour ; small yeast cells and micrococci were visible and 15.12% of organic matter had become soluble. Then the following mixture was digested for one week at 30-35°C.

Germinated soja bean	50 grms.
Soja koji	25 grms.
Water	75 grms.
Sugar	2 %
Thick sake yeast	1.5 cc.

After the first day 12% of sodium chloride was added.

The amount of soluble organic matter was 14.4%.

(1) When to this mixture 12% of sodium chloride were added at the beginning, not only were there fewer bacteria observed, but also the enzyme action was much retarded.

I had also failed to develop the proper flavour and taste.

These experiments show that by the substitution for the *boiled* soja bean of *germinated* soja bean no real advantage is gained, but considerable gain results from well crushing of the materials of the wort and heating them to 35°C.

Some additional remarks with regard to the final treatment of the ripened soja sauce wort may not be out of place.

The thick wort is poured into numerous small flaxen bags and pressed.[1] On an average there is obtained :—

	Refuse.	Liquid.
By volume	27.3%	72.5%
By weight	31.4%	68.6%

The refuse[2] is used for the preparation of an inferior kind of soja sauce by adding salt solution and some fresh soja sauce wort. The refuse here remaining serves as food for cattle or as manure.

The sauce obtained is finally heated for 1-2 hours at 80-100°C. (sometimes boiled) in a large boiler, whereby some proteid is coagulated. After remaining 4-6 days in the settling vat[3] the clear liquid is fit for the market.

MICROSCOPICAL EXAMINATION.

Repeated microscopical examinations were made of the soja sauce wort at different stages, and it was found that although in the beginning the quantity of starch and galactan decreases considerably, there remain some starch granules even after the mixture has been standing for two years, while no trace of starch could be any longer recognized in wort of four years' growth.

In applying the iodine test I could not only distinguish the starch granules in wort two years old, but also the protein granules by the yellowish colour they hereby assumed.

Microscopical observation further demonstrated that the membranes of the cells of the wheat-endosperm and of the seeds of the soja bean, had been attacked and partially dissolved ; only

(1) This pressing is accomplished in a rather primitive way by large levers upon which many large stones are fastened.

(2) According to *T. Isono* a sample of such a refuse contained 14.01% starch, 4.88% nitrogen and 26.69% ash (mostly).

(3) The sedimentary matter is mixed again with ripening wort. By the heating 4 5-6.0% water is lost by evaporation.

the husk of the wheat had resisted completely. This action must be due to the powerful enzyme derived from the *Aspergillus oryzae* developed during the preparation of the koji.

Bacteria need not be taken into consideration, because my numerous investigations had shown that bacteria which occur during summer time to some extent on the surface of wort,[1] could never be found in the living state in the interior of the wort; a fact that will not surprise us when we consider the high percentage of salt.

Gelatin-plate cultures were made with great care in the usual way by inoculation with platinum wire from wort of different ages. The mycelium observed was mostly due to *Aspergillus* and *Penicillium*. The small elliptic yeast cells observed resembled *Saccharomyces exiguus* while the large kind of yeast resembled sake yeast. I have observed these yeasts also in the cold aqueous extract of soja koji. The following table shows the number and kind of colonies obtained :—

Time of observation.	Ages of the wort.	Colonies.		
		Yeast.	Mould fungi.	Bacteria.
24th Dec.	4 months.	1	3 [3]	0
(1895)	6 ,,	2 [2]	3	0
	1 year.	0	1	0
	,,	3	1	0
	18 months.	18	1	0
	2 years.	1	2	0
	4 years.	1	3	0
6th April.	1 year.	1	8	3[2]
(1896)	,,	5	many.	0

THE PRODUCTION OF THE FLAVOUR.

While the freshly prepared wort has a disagreeable mouldy odour derived from the *Aspergillus* in the koji, it gradually assumes altogether a different flavour. It is evidently the exceedingly slow development of the desired flavour which retards

(1) The small amount of lactic and acetic acid found in soja sauce may be due to their action.

(2) The gelatin became liquified.

the production of soja sauce so considerably. We have seen before that all the principal changes are going on during the first two months while the ripening of soja sauce takes one to two years

The question how this flavour is produced and whether its formation could not be hastened seemed to me of considerable interest.

I supposed that the gradual production of alcohol has some influence upon it and that this, together with those products formed by the roasting of the wheat, would contribute to the development of the flavour.

Indeed when I mixed crushed roasted wheat with some sake and digested the mixture for several weeks at 30°C., I observed a very similar flavour; the flavour was quite different when instead of roasted wheat boiled soja beans were used.

By roasting the wheat or barley there is produced some maltol (*Brand*) which might perhaps gradually yield an ether of the desired flavour.

SUGGESTION FOR THE IMPROVEMENT OF MANUFACTURE.

As in the present state of the manufacture so much time is required that a considerable loss of interest on capital is involved, the most important desideratum would be to shorten the time of manufacture. I have shown in the preceding pages that it is not so much the retarded action of the enzymes which cause the consumption of so much time, but principally the production of the flavour. I have further pointed out that the slow production of alcohol is evidently the cause of the slow development of flavour.

In the second place the materials of the wort should be crushed very finely to increase the surface and open the contents of the cells to the immediate action of the enzymes which have been prepared by the *Aspergillus oryzae* during the koji preparation.

In the third place, it has to be taken into account that during the 5 rather cold winter months the changes are almost completely at a stand still.

Therefore, the principal measures of the improvement I propose are: 1st, thorough milling of the roasted wheat and boiled soja beans; 2nd, application of a temperature of 35-40°C. and 3rd, direct addition of alcohol.

This adding of alcohol instead of permitting the yeast to prepare the wort has this advantage that instead of 20-25°C. much higher temperature can be applied. A temperature of 35-40°C. which, favourable as it is for the action of enzymes, would stop the alcoholic fermention altogether. I propose to add this alcohol in the form of sake or in the still cheaper form of *nigori*[1] which already has a certain agreeable flavour; 5-10% of it wlll be sufficient.

The expenses of milling and adding crude sake will surely be compensated by the much quicker utilization of capital, which may be turned over twelve times with my improvement to once by the old way of manufacture. I add here the result of an experiment which proves the correctness of my views. Common freshly prepared soja sauce wort was crushed very finely and with the addition of 2% of alcohol in the form of sake kept in a closed flask at 30-35°C. for 5 weeks. This mixture acquired a very agreeable odour and taste like that of common soja sauce; upon pressing, the sauce obtained had the following composition (*A*), to which I add for comparison the analysis of a commercial sample of soja sauce[2] (cf. above introduction) (*B*).

	(*A*)	(*B*)
Specific gravity (at 18°C.)	1.1612	1.185
Dry matter	32.63	37.907
Total nitrogen	1.052	1.484
Albuminoid nitrogen (peptone)	.137	—
Total acidity (as lactic acid)	.141	1.183
Glucose	2.91	2.696
Dextrin	.45	0.688
Total ash	16.24	18.476
Sodium chloride	15.13	16.032

In those cases in which the application of *sake* or *nigori* would be considered too expensive, I propose to add 1% of thick sake yeast to the fresh soja sauce wort and to apply in this

(1) *Nigori* is crude sake.

(2) The differences between the two samples are not greater than those sometimes found between two commercial samples.

case only a temperature of 20-25°C. I hope that the manucfature of soja sauce will be improved, however, not only by adopting the measure I propose, but also by introducing steam power and other modern appliances.

Contributions to the Chemistry of Sake Brewing.

BY

J. Okumura, *Nōgakushi.*

I. THE PRESENT MODE OF SAKE BREWING.

In order to become thoroughly acquainted with the preparation of *sake*, I have visited various factories at Noda, Nishinomiya, Sakai, Osaka, Kioto, Tsu, Muroyama, Yokkaichi, Handa, Kamezaki, Toyohashi, Fukui, etc. for longer or shorter periods and will here give for the convenience of the reader a short review of the various operations before I proceed to an account of my own experiments.[1]

The operations are carried on from the middle of November to the end of March in different factories and with varying details.

The main stages, however, are :—

1) The preparation of *tane-koji* and *koji*.
2) The preparation of *moto*-mash.
3) The preparation of *moromi* or chief process which is again subdivided into three operations : pressing, clarifying, and preserving.

(1) Tane-koji.

While the koji itself consists of rice grains covered with the mycelium of the fungus *Aspergillus Oryzae*, the *tane-koji*[2] contains besides this mycelium innumerable spores of that fungus. Another difference is that while *tane-koji* is prepared from only roughly whitened rice[3] (not so well cleaned as *koji* rice) the *koji*

(1) The descriptions by *Korschelt* and *Atkinson* are doubtless very detailed and especially the latter describes a series of interesting experiments. Nevertheless, the manufacture of sake still offers many points for further study.

(2) *Tane-koji* is not generally made in the *sake* factories, but its manufacture forms a special branch of industry.

(3) In some factories broken rice is used for brewing.

itself is made from whitened rice. In whitened rice[1] a certain amount of protein is removed with the bran; so the imperfectly whitened rice may be better suited for the production of the spores of the fungus. The *tane-koji* was analysed by *Sato*.[2] The rice is at first steeped in water for 12-18 hours, then steamed for about 2 hours, whereupon it is spread on straw mats. When the temperature has fallen to about 30°C., the rice is mixed with the ash of oak-leaves and the spores of *Aspergillus Oryzae*. The factories follow the old empirical rule that for about 200 litres of rice four litres of ash and 8 grams of spores are sufficient. In some factories spores are not added, as they abound in the air of the *koji* room. The rice is then spread in thin layers in open wooden boxes (*koji-buta*) about 50 cm. wide, 75 cm. long, 5 cm. deep, and placed in the *koji* room. After a few days kept at 25-30°C. the mycelium is well developed upon the grains, and 6-7 days later innumerable spores also.[3]

The addition of the ash of leaves is intended to accelerate the development of the fungus, and when we remember that the rice grains contain comparatively little ash and that this ash is distributed through the entire mass of the grain, while the fungus develops upon the *surface* of the grain, the beneficial action of ash will be understood as it contains all mineral matters necessary for the fungoid growth. *Tane-koji* is sold in small bags of 250 g.

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(1) Whitening or cleaning of the rice is separating the bran from the grain. *Kellner* made some researches about this point in conjunction with *Tanaka* and *Kobayashi*. (Bulletin I., No. 5.)

(2) We copy from *Sato's* results the following analyses:—

	Roughly whitened rice mixed with ash.	Tane-koji.
Crude protein	7.990	8.875
Ethereal extract	2.072	5.186
Crude fibre	0.770	1.860
Starch and non-nitrogenous extract	87.010	59.590
Dextrin	0.500	1.770
Glucose	trace.	18.760
Maltose	—	2.050
Ash	1.66	1.900

(3) The *tane-koji* makers mix some powdered malt with the steamed rice. Sometimes they also use a certain kind of fungus called *ina-koji* which attacks the rice fields. According to Prof. *Shirai's* reseaches the *ina-koji* fungus can produce yeast from its conidia.

(2) Koji.

Although the preparation of *koji* has been described by several authors as *Korschelt*,[1] *Atkinson*,[2] and *Kellner*,[3] some remarks may still be made here, as certain points require some further discussion. My own observations of the *koji* chamber at *Toyohashi* are the following. The air of this chamber, whose walls are constructed of two layers,[4] has a very mouldy smell and is saturated with moisture The temperature is kept at 23-28°C. while of that of the air ranges at that time of the year (December) from about 3° to 10°C. The higher temperature of the *koji* chamber is at first produced by wooden vats containing hot water,[5] but later on the respiration of the fungus produces so much heat that it suffices for the start of the next charge.

In the preparation of *koji* proper about 100 grams[6] of *tane-koji* to 200 litres of steamed rice are well mixed at 28-35°C. In some factories the rice is not immediately infected after it has cooled down to 28-35°C. but is at first placed in the *koji* room,[7] collected into a heap, and left to stand for 6 hours covered with 2 or 3 layers of mats before the infection takes place. The mixing is accomplished by turning over the rice and spreading it repeatedly. Thus the spores are not only well distributed, but also a most intimate contact of the rice grain with the rice straw mats is accomplished, which is very important. These straw mats, and also the air in the *koji* room and factory contain numerous yeast cells as I have ascertained by exposing a *Petri* dish containing sterilised nourishing gelatin to the air of the *koji* room for 10 minutes and also to the air of the factory.

(1) Mitthg. d. deutsch. Ges. Ostasiens Heft 16 (1878).

(2) Memoirs of the Science Department, Tokio Daigaku. 1881.

(3) Bulletin I., No. 5, Agricultural College, Imperial University. Tokio.

(4) The chambers are sometimes constructed entirely underground, generally, however, only the lower part is built into the earth. The walls and ceiling consist of 2 layers, viz., of rice straw and clay material. The inner wall consists of a layer of rice straw 3 c.m. thick which on the outside is covered with a layer of clay 2-3 c.m. thick. These chambers built of planks are mostly 2 m. high, 3-4 m. long and 2-3 m. wide, contain one small window and a door about 1 m. high and 70 cm. wide. The floor is covered with husks of rice upon which is a layer of rice straw (about 3 c. m.) and finally straw mats are spread over it.

(5) Such *koji* chambers as serve for the manufacture of *miso* are heated not by hot water but simply by a direct charcoal fire upon the paved floor.

(6) The quantities vary in different factories. In some factories instead of *tane koji* the spores alone (about 1-2 c c. to 200 litres of rice) are taken.

In the former case, I obtained 4 colonies of yeasts and 3 of mould fungi on the plate, while in the latter 27 yeast colonies and 12 mould fungi were found.

The spread out rice is again heaped up and covered with 2 or 3 layers of straw mats for about 14-17 hours.

Then the mixture is distributed upon wooden trays which are now placed beside and above each other in the *koji* cellar. When very cold weather sets in, these boxes are covered with straw mats. After 7-10 hours the mass is carefully mixed and heaped up again and at the same time the position of the boxes is changed, the upper ones being placed now at the bottom and vice versa, to procure an equal amount of heat for all the boxes. For the next 7-8 hours the temperature rises considerably as the development of the *koji* fungus proceeds, and the rice again becomes covered with white mycelium. The heaping and spreading and replacement of the trays are repeated from about six to seven hours. The *koji* is finally spread out on mats to cool, whereby any further development of the mycelium upon the grains is checked.

In the *Toyohashi* factory I have observed the following temperatures in the trays:

6 hours after infection	34°C.	34°C.	34°C.
12 ,, ,, ,,	39 ,,	40 ,,	35 ,,
18 ,, ,, ,,	46 ,,	47 ,,	44 ,,
24 ,, ,, ,,	43 ,,	43 ,,	40 ,,

(3) The Moto Process.

The principal object of this process is the *development of the yeast* for the following or *moromi* process.[1] There are only a few yeast cells in *koji* as I have observed by preparing a plate culture, but I have seen also numerous smaller globules (besides Aspergillus spores) sometimes 2 or 3 surrounded by a membrane, which

(1) Besides the development of yeast and alcoholic fermentation there proceeds also the saccharification of the rice starch by the enzyme of the *koji* fungus. The composition of *koji* was found by *Kellner*, *Mori*, and *Nagaoka* to be:

give the impression of ascospores. The main source of infection, however, is the *rice straw* as Mr. Yabe and myself have ascertained by experiments (cf. below Yabe's article). The *moto* process, however, yields not only a great deal of yeast but also much alcohol and may therefore be also considered as the first step in fermentation proper. The *koji* used in the moto-process must be prepared with great care; skilled workmen can easily distinguish, by the appearance and smell, whether the product is satisfactory or not. A bad product may lead sooner to the development of *bacteria* than to that of *yeast*. In some cases also

% In the dry matter.	Rice.		Barley.	
	Steamed grain and spores	*Koji.*	Steamed grain and spores	*Koji.*
Crude protein	7.81	8.97	10.79	12.92
Ether extract	2.23	7.21	1.19	4.74
Crude fibre	1.05	1.60	1.52	4.53
Starch, dextrin &c	87.97	70.97	84.63	61.62
Maltose	—	6.05	—	11.03
Glucose	trace	4.07	0.68	0.22
Ash	0.94	1.13	1.19	1.94
Total Nitrogen	1.249	1.436	1.726	2.067
Albuminoid „	1.227	1.246	1.621	1.768
Non albuminoid „	0.022	0.190	0.105	0.299
Substances solube in cold water.	3.63	38.52	6.50	39.92
Ammonia	—	0.020	—	0.024
Volatile acids (as acetic)	—	0.079	—	0.003
Fixed acids (as lactic)	—	0.351	—	0.516

Atkinson obtained the following result:

	Composition of koji dried at 100°C	
Dextrose	25.02%	58.10%
Dextrin	3.88	4.40
Soluble ash	0.52	0.54
Soluble albuminoids	8.34	6.40
Insoluble albuminoids	1.50	1.83
Insoluble ash	0.09	0.04
Starch	56.00	26.20
Cellulose	4.20	1.94
Fat.	0.43	0.50

a red yeast develops in the fermenting *moto*. In the preparation of the *moto mash*[1] 0.57 koku (0.0055 koku = 1 litre) of whitened rice are used to start with. The rice must be first well washed with water in order to carry away the fine meal which still adheres to the grains, whereupon steeping in water for about 10 hours and steaming takes place. After being allowed to cool by being spread upon mattings of *rice straw*, the mixture of *koji* and water is carefully prepared in the following proportions at *Toyohashi*:

Whitened rice	0.57 koku.
Whitened rice for *koji*.	0.23 ,,
Water	0.80 ,,

The cooled rice is divided into eight parts, placed in shallow tubs (*hangiri*) containing also the *koji* and water. After being well mixed and standing for two days the workmen commence to stir again with shovels called *kaburagai* or *yama-oroshigai*. By the repeated stirring the saccharification is considerably promoted. Occasional stirring continues for the following six days. The contents of the eight vessels are then poured into one vessel called *moto-oke* and left there for about two days. Now the temperature is gradually raised by closed wooden vessels containing hot water and the stirring is carried out 4 or 5 times a day[2] We observed in *Toyohashi* the following data :—

Before warming	5-9°C.
1st day of warming	5-13°
2nd ,, ,,	14-18°
3rd ,, ,,	19-24°
4th ,, ,,	20-25°
5th ,, ,,	28-32°
6th ,, ,,	33-36°
7th ,, ,,	34-36°

The heater is renewed twice a day. But some regard is paid to exceptionally cold or warm weather.

Lactic and acetic fermentation is sometimes observed in the mash. We visited one factory whose manager complained of great injury caused by alcoholic fermentation not setting in with pro-

(1) Experience has taught the manufacturers that it is advantageous to have this work carried on upon the first floor, perhaps because this can be kept cleaner than the basement story.

(2) The heater occupies $\frac{1}{6}$ of the volume of the moto-vessel.

per intensity, and the formation of much acid was noticed in the *moto* and *moromi* process. My opinion in that particular case was that proper cleanliness was disregarded.

As long as the temperature does not rise above 13° C. fermentation is hardly noticeable, but later on, at 18-20° foam forms and increases until it forms a stratum of 30-35 c. m. thickness. The *moto* is finished with the decrease of fermentation. Now the liquid of one vessel is divided into 5 or 6 smaller vessels, occasionally stirred and kept cool until the chief process commences. This treatment leads to a beneficial aeration of the yeast. I have repeatedly examined the moto mash under the microscope and observed in the first stage only very few yeast cells but numerous bacteria while in the last stages just the reverse is observed. The bacterial growth is evidently counteracted by the rapid development of yeast and by the intensity of the alcoholic fermentation.

(4) The Principal or Moromi Process.

In the *moromi* process not only alcoholic fermentation but also the continuation of the sacclarification goes on. In the same measure as the sugar decreases by alcoholic fermentation the *koji* glucase produces fresh sugar, as it is evidently more active when the sugar solution becomes diluted. We have here a very essential difference from the process of beer brewing, because in the latter case not any addition whatever is made during fermentation in order to increase the sugar.

The moromi process is divided into 3 operations:

1) *Soye.*
2) *Naka.*
3) *Tome or shimai.*

First the finished moto is brought down from the upper floor and put into a large fermenting vat called *sanjaku-oke.* To the moto is now added fresh *koji* and water; the mixture is well stirred and covered with a wooden plate. After 12 hours steamed rice is added and the mixture stirred every 2-4 hours, whereby not only are the rice grains crushed for a better exposure to the action of the *koji* glucase but also more air is brought into contact with the yeast, the multiplication of which is thus considerably promoted.

The temperature of the mixture rises gradually to 12°C. Within about 10 hours the fermentation sets in and is finished in 24-26 hours. The liquid is then divided into 2 parts, each portion is mixed with water and *koji* and after 2-3 hours with the steamed rice. This *naka* process takes 24 hours.

The mixture is now divided again into 2 equal portions and to each water, *koji*, and steamed rice is added. This process is the so called *tome* or *shimai* operation. The quantities of materials used in these processes are the following in the *Toyohashi* factory :—

(1) The quantities vary to some extent in the factories as it will be seen from the following table.

	Rice	Rice for Koji.	Water.
TOYOHASHI.			
Moto.	0.600*koku*	0.240*koku*	0.760*koku*
Soye.	1.000	0.360	1.000
Naka.	2.000	0.600	3.160
Tome.	4.160	1.200	6.104
HANDA.			
Moto	0.600	0.240	0.700
Soye.	1.000	0.401	1.000
Naka.	2.000	0.600	3.200
Tome.	4.000	1 200	6.300
KAMEZAKI.			
Moto.	0.500	0 200	0.640
Soye.	0.900	0.360	1.300
Naka.	1.800	0.540	2.400
Tome.	3.620	1.080	4.660
NADA.			
Moto	0.750	0.300	0.900
Soye.	1.590	0.495	1.620
Naka.	2.550	0.765	3.900
Tome.	5 445	1.605	7.000
ISE. I.			
Moto.	0.500	0 200	0.400
Soye.	1.100	0.400	1.100
Naka.	2.000	0.600	2.600
Tome.	4.000	1.200	5.600
ISE. II.			
Moto.	0.500	0.200	0.700
Soye.	1.400	0.360	1.300
Naka	1.860	0.540	2.400
Tome.	2.690	0.810	3 600
ISE. III.			
Moto.	0.540	0.2184	0.650
Soye.	1.300	0.500	1.500
Naka.	2.600	0.760	3.000
Tome.	4.630	1.300	7.080

	Rice	Rice for Koji.	Water.
TAHARA.			
Moto.	0.750*koku*	0.300*koku*	0.945*koku*
Soye.	1.200	0.360	1.200
Naka.	2.000	0.860	3.200
Tome.	3.480	1.050	6 6[illegible]
HANDA.			
Moto.	0.600	0.240	0.720
Soye.	1.000	0 400	0.900
Naka.	2.000	0.600	3.000
Tome.	3.960	1.200	6 180
YOKKAICHI.			
Moto	0.600	0.220	0.720
Soye.	1.000	0.400	1.000
Naka.	2.000	0 600	2.000
Tome.	4 000	1.200	5.550
NADA.			
Moto.	0.750	0.300	9.945
Soye.	1.500	0.480	1.700
Naka.	2 800	0.850	4.000
Tome.	5.570	1.700	8.979
KIOTO. I.			
Moto.	0.340	0.140	0.400
Soye.	0.720	0.160	0.900
Naka.	1.440	0.320	1.900
Tome.	2.090	0.450	2.750
KIOTO. II.			
Moto.	0.400	0.160	0.500
Soye.	0.700	0.200	0.950
Naka.	1 300	0.400	1.800
Tome	2.000	0.600	2.800
SAKAI.			
Moto.	1.000	0.400	1.400
Soye.	2.000	0.600	2.600
Naka.	4.300	0.900	5.600
Tome.	6.800	1.00[illegible]	8.800

	Rice.	Rice for Koji.	Water.
Soye.	1.000 koku	0.400 koku	1.000 koku.
Naka.	2.000 ,,	0.600 ,,	1.000 ,,
Tome.	4.000 ,,	1.200 ,,	6.700 ,,

The mixture is stirred again in from 2 to 7 hours. After 72 hours the contents of the four vats are collected into a large vessel called *rokushaku-oke* of about 4500-4600 litres capacity. Here the fermentation proceeds energetically for 5-6 days and the height of the froth reaches 40-50 c. m. The temperature during the *moromi* process which lasts from 17-20 days is as follows (observations at *Toyohashi*):

1st day	8-12°C.	9th day	23-26°C.
2nd ,,	10-14 ,,	10th ,,	21-22 ,,
3rd ,,	11-15 ,,	11th ,,	20-21 ,,
4th ,,	14-17 ,,	12th ,,	20-21 ,,
5th ,,	16-18 ,,	13th ,,	14-17 ,,
6th ,,	19-20 ,,	14th ,,	12-15 ,,
7th ,,	20-22 ,,	15th ,,	10-13 ,,
8th ,,	22-24 ,,	16th ,,	9-10 ,,

(5) Pressing and Clarifying.

On the 38th or 40th day the alcoholic liquid containing still particles of rice grains in suspension, is filled in linnen bags and pressed. From 300 to 800 bags, of 6 liters, are piled up in a box covered with a plate, carrying a heavy stone. In the clarifying vessels the liquid is now left to settle for about two weeks and finally it is heated in iron vessels for a short time to 60°C.[1] whereby the scum collecting at the surface is removed; the finished *sake* is kept in well closed vats.

A careful *Pasteurization* process and storing in sterilized vessels would of course be a desirable improvement. Sometimes small quantities of salicylic acid are added to preserve the liquid. As the residue from pressing still contains 5-6 % and sometimes even more alcohol, it is distilled after adding husk of rice in order to render the residue less compact. The distillate is called *shōchu* and used in the preparation of *mirin* (a sweet

(1) This heating is repeated several times during the hot season to avoid acetic fermentation.

liquor). The *shōchu* is consumed as a stimulant by the lower class. The residue serves also for vinegar manufacture.

It will be seen from this description that *sake* brewing is capable of considerable modern improvements. Above all it would be desirable to work with *pure cultures of sake yeast.* In the second place the *separation* of the *mashing* process from the *fermenting* process would render the proceeding much safer and avoid losses so often encountered. The time of the brewing process might also easily be shortened by one half, and by means of ice machines the manufacture made possible also in summer.

II. ON THE LOSS OF STARCH IN SAKE BREWING.

Before the whitened rice is cooked for consumption or is steamed for *sake* brewing it is usually washed with cold water to remove the fine particles of bran which are still attached to the grain, and which would impart an unpleasant taste to the product. It seemed to me of interest to determine the amount of starch which is thus lost, as it has a considerable value. This starch could be easily recovered by collecting the liquid in large tanks, and allowing it to settle for a day. In order to obtain a reliable estimate I washed 0.05 koku (7.45 kilos) of whitered or cleaned rice in cold water until the washings ceased to show a milky appearance. These washings were collected and digested with 1% KOH solution. After standing 24 hours the supernatant solution was poured off and the subsided starch was washed repeatedly and collected on a filter. This practically separable air dry starch amounted to 32.025 grams=0.469%.[1]

As in Japan 7.5 million hectoliters, i.e., 7% of the entire rice crop is used for *sake* brewing, this loss is very considerable.

(1) This amount only relates to the quantity of starch which could be recovered in a short time. In reality the total loss is much greater and was determined in this case to be 154.7 grams carbohydrate (principally starch) from 7.45 kilos of whitened rice.

(2) According to practical observations 87-95 parts of whitened rice are obtained from 100 parts of hulled grain by volume. The proportions are as follows :—

	Eijkman	*Tanaka*	*Kobayashi*
Whitened rice.	89.42	91.05	91.92
Broken grain.	1.30	1.69	0.50
Bran.	8.75	7.37	7.16
Loss.	0.53	—	0.30

Another source of loss is caused by the imperfert mashing, but the residue from filtering of the *moromi* containing this starch is utilized in various other ways, which however, are of less profit than *sake* would be.

III. OBSERVATIONS UPON THE PRINCIPAL ENZYME OF THE *KOJI* FUNGUS (*ASPERGILLUS ORYZAE.*)

The diastatic enzyme of this fungus was first studied by *Atkinson* who found that it not merely produces dextrin and maltose, but the action goes further until *dextrose* results. *Kellner*, *Mori* and *Nagaoka* observed the strong inverting power for cane sugar but it still remains undecided whether there is present only one ferment or a mixture of several.

It is of some interest to determine to what extent the amount of sugar and alcohol in the fermenting liquid would interfere with the action of the saccharifying enzyme. The *koji* enzyme was prepared by extracting several portions of *koji* one after another in the cold with the same diluted alcohol of 30% thus enriching the extract. From this filtrate the enzyme was precipitated with strong alcohol and ether ; after filtering, and washing with strong alcohol it was dissolved in a little water. This solution was left to stand for several days (a few drops of ether being added) to enable the ferment to saccharify dissolved dextrins completely, and then precipitated again with alcohol, and after being washed with alcohol, dissolved in 400 cc. water. Thus the enzyme was obtained free from dextrins.

100 cc. of this enzyne solution were distributed among 5 flasks which contained a mixture of 10 cc. of a 6% starch paste and cane sugar in different proportions, dissolved in 20 cc. water.

These mixtures were warmed to about 40°C. and frequently tested with iodine solution. The result was :

Cane sugar %	The starch was completely digested after:
0	2 hours 30 minutes.
5	4 ,, 15 ,,
15	8 ,, 15 ,,
25	11 ,, ———

The retarding influence of an increased amount of sugar upon the activity of the *Aspergillus*-diastase is (in analogy to malt diastase) quite evident.

In the same way an experiment with increasing quantities of alcohol[1] was made but even at 20% of it no such influence was noticed.

Influence of Organic Acids.

The peculiarity of the *moromi* process which combines the saccharification with alcoholic fermentation, and the frequent stirring which the *sake* yeast requires, is continually attended with the danger of acetic, lactic, and butyric fermentation setting and leading to considerable loss. As it is well known that for the most enzymes acids act noxiously, it was of some importance to find out to what extent the acids formed by bacterial action would interfere with the diastatic enzyme of *Aspergillus Oryzae*. As the noxious action of lactic acid was studied by *Kellner*, *Mori* and *Nagaoka*,[2] I tested only acetic and butyric acid. I prepared an aqueous extract of *koji* (1 part of water for 2 parts of *koji*) and precipitated the enzyme with strong alcohol and ether. The precipitate, after washing with some alcohol, was dissolved in a moderate quantity of water. 10 cc. of that solution were mixed with 90 cc. of water containing increasing quantities of acetic and butyric acid and 1.2% of starch in the form of paste. After standing for 24 hours the determination of sugar formed proved a very noxious action at 0.5—1.0% of these acids. Further experiments with formic and propionic acid proved for the former that 0.5% and for the latter 1% produce a highly noxious effect upon the saccharifying power.

(1) *Kellner* tested the influence of sodium chloride and found:

Sodium chloride in %	Reducing sugar, as dextrose.
0	0.444 %
2	0.223
4	0.155
10	0 054
15	0.040
20	0.033

(2) *Bulletin* Vol. I No. 5. Imperial College of Agriculture, Tokio. From their results we see that a proportion of about 0.05% of lactic acid had the best effect and that when the amount of acid is increased to 0.1% and more, the inverting power of *koji* extract is rapidly diminished, until at 0.6% and more it is suspended.

Influence of Mineral Acids and Caustic Potash.

The flasks which contained increasing quantities of sulphuric acid contained 10 cc. of aqueous solution of the enzyme. After standing for 20 hours, neutralising with sodium carbonate and adding 10 cc. of a 0.2 % solution of starch paste the mixture was digested at 40°C for one hour. *Fehling's* test showed then :

1 % SO_3	destroyed.
0.1 ,, ,,	destroyed.
0.01 ,, ,,	active.
1 % KOH	destroyed.
0.1 ,, ,,	destroyed.
0.01 ,, ,,	active.

In a second experiment carried out in the same way I obtained the following results :

0.02 % SO_3	active.
0.04 ,, ,,	active.
0.06 ,, ,,	active, but week.
0.08	
0.02 % KOH	active
0.04 ,, ,,	active.
0.06 ,, ,,	weakened.
0.08 ,; ,,	destroyed.

The sulphuric acid at 0.06 % is therefore less noxious than potassa in the same concentration.

Action of Heat.

Atkinson has found that at above 55°C. the activity of the glucace rapidly diminishes and that between 60 and 70°C. this activity is completely destroyed. But it seemed to me of interest also to determine exactly this point with the *pure enzyme solution* as the experiments of *Atkinson* were simply made with an aqueous extract of *koji* which had an *acid* reaction, that may have had an injurious influence. He observed that this extract turns very turbid upon heating to 60-70°C. which was due to the presence of coagulable albumin. I did not observe this phenomenon with the solution of the enzyme which I had prepared from the *koji*

extract with 30 % alcohol as above described. I took 10 cc. of this neutral solution for each experiment and warmed it in a large water bath to various degrees whereupon some starch paste was added. After digestion at 40°C. for 30 minutes *Fehling's* solution was applied.

At	60°	for	10m.	active.
,,	60°	,,	30m.	active.
,,	65°	,,	10m.	active.
,,	65°	,,	30m.	active.
,,	70°	,,	25m.	killed.

We observe here that this enzyme still remains active above 65°C., when the solution is *neutral.*

Acetate of phenlhydrazin produces in the enzyme solution after several days a small amount of amorphous sediment which increased upon the addition of a littte alcohol. This sediment was filtered and yielded *Millon's reaction.*

In another experiment I mixed a concentrated solution of the enzyme with a few drops of ammonical silver solution ; after 24 hours standing in darkness a brown colouration was observed.

Behaviour to Guaiacum Tincture.

Schönbein observed the interesting fact that diastase of malt yields a strong blue coloration when it comes in contact with tincture of guaiacum and peroxide of hydrogen. This coloration is due to the oxidation of guaiaconic acid caused by the action of enzyme and peroxide of hydrogen. However, the latter is not always necessary, as there exist enzymes which bring on this blue coloration also with the aid of common oxygen. *E. Schöne* has found that guaiacum tincture, if perfectly fresh, also yields this reaction wirh common diastase of malt, which I have compared with the enzyme of the *koji* fungus in this regard.

I dissolved the freshly precipitated *koji* enzyme in a moderate quantity of water and then added to 10 cc. this solution, one drop of guaiacum tincture, and a few drops of diluted peroxide of hydrogen, but only a slightly bluish coloration was obtained, while the control experiment with malt diastase yielded at once a very strong reaction, indicating a considerable difference also on this point between these two diastatic enzymes.

On the Origin of Sake Yeast (Saccharomyces Sake).

BY

K. Yabe, *Nōgakushi.*

The source of the *sake* yeast which rapidly develops during the first stage of *sake* manufacture, called *moto*, has repeatedly been a subject of discussion and even at the present day is considered an open question. *Korschelt* first propounded[1] the hypothesis that the mycelium of the same fungus that brings on the saccharification of the mash, is the source looked for, and believed that this case is analogous to that of Mucor racemosus. But *Atkinson*[2] soon afterwards expressed his doubts on this point. He says: "It is, of course, a matter of great difficulty to prove any preposition of this kind, but probability appears to my mind to be greatly in favour of the hypothesis that the germs have been either air-sown or were adherent to the grains of *koji* before use."

Indeed, a series of experiments which I have made, partly in conjunction with Prof. Kozai, have placed beyond doubt, that the mycelium fungus in question, *Aspergillus oryzae*, is entirely incapable of yielding yeast cells. I have prepared pure cultures in the usual way and cultivated the pure fungus under a series of very different conditions, in absence and in presence of air, of good and poor nutrients, but never could detect the formation of yeast cells.[3] Sometimes, however, the cells became somewhat deformed in absence of air (growth was never observed under this condition) and when thus kept in *Pasteur's* solution for 3-4 weeks showed small bright globules, which were neither fat nor glycogen, but very probably consisted of a peculiar proteid.

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(1) Mitthg. D. Ges. f. Ostasien, Tokyo 1878.

(2) The Chemistry of *Sake* Brewing, Tokyo 1881.

(3) The investigations of *Atkinson* and those of *Kellner*, *Nagaoka* and *Mori* have demonstrated the powerful action of the diastase and invertase of this fungus. I may here mention, however, that mannan prepared from the root of *Amorphophallus konjak* is not at all attacked by the enzymes of this fungus; although a rich vegetation of this fungus was in contact with that gelatinised carbohydrate for three weeks, no liquefaction, no formation of mannose was noticed.

The conclusion I reached was that the *Aspergillus* in question is incapable of transformation into yeast cells, and this has been confirmed recently by Klöckner and Skiönning.[1]

But nor can *Atkinson's* hypothesis be correct; the air could not be the carrier of the yeast germs in the manufacture of *sake*, as this would imply the frequent occurrence of *sake* yeast in the dust of the air of Japan. But my repeated investigations in this direction did not reveal its presence in the air. Thus in the Botanical Gardens at Komaba I once passed 60 liters of air on a bright clear day through a flask containing sterilized *Pasteur's* solution, kept somewhat acid by monopotassium phosphate. After several weeks mould fungi and yeast cells, besides bacteria, were developed, but among the yeast cells no *sake* yeast was discovered on further investigation, while much *Monilia* was observed.

The air in the *koji* cellar, however, contained the same yeast which plays the principal role in the fermentation of the *sake* mash. I exposed a sterile gelatine plate, of a diameter of 9 cm. for 30 minutes to this air and counted, after 76 days' standing at rather low temperatures, of colonies of Penicillium 207,
of Aspergillus 71,
of yeast 36.

This yeast agreed in size, and form, and energy of fermentation with *sake* yeast. How did this yeast reach these cellars? Certainly not through the boiled rice grains which serve to make *koji*, but through *rice straw*, which is used in the form of matting for spreading over the *koji*, and covering it. The following facts confirmed the probability of my supposition.

1. All the rice sent to the factories is packed in rice-straw, the dust on this straw is thus distributed through the whole factory

2. The boiled rice is never handled in wooden vessels, but always upon mats made of rice straw. The mats are never made of any other straw. Even the straw of upland rice is declared unsuitable by the manufacturers.

3. The steamed and cooled rice is rubbed upon these mats by hand, to avoid lumps and separate the grains.

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(1) Centralbl. für Bact. 1896. During my studies on the development of this *Aspergillus* under different conditions, I also applied solutions to which small quantities of ferrous sulphate were added, and observed that only in those solutions containing some iron spores were developed, which shows, in accordance with *Molish*, the important influence of this element on fungi

4. The sides and roofs of the *koji* cellars are covered with matting of rice straw.

5. In the preparation of moto the vessels are covered with this matting.

6. Every year new matting must be made of fresh rice-straw; the renewing of these mats even takes place several times during one and the same brewing season.

Indeed, yeast identical with sake yeast was obtained upon examination of the straw of the matting in the *koji* chamber of the fresh rice straw taken from the fields, and even of the soil of rice fields. Inoculations were made by transfering small chips of the straw into sterilized *Pasteur's* solution and preparing after some time a gelatine plate from the yeast sediment formed. The colonies of the *sake* yeast could easily be distinguished from those of *Saccharomyces mycoderma* and of a small kind of yeast somewhat resembling *S. exiguus*; colonies of mould-fungi and bacteria were also present. Of the *sake* yeast thus obtained a larger quantity was cultivated to enable exact comparisons to be made.[1]

It is an interesting fact that in *sake* manufacture *one kind of yeast* is principally observed although nop recaution is taken to avoid wild yeasts, as *Saccharomyces apiculatus*, *S. exiguus*, etc. In the first stage of the moto process there is generally found also a small kind of yeast, but later on this is no longer noticed to any notable extent. Also there occurs sometimes a development of red kinds of yeast, which however are harmless.

The *sake* yeast forms globular or slightly ellipsoidal cells of 5-9 μ in diameter, generally of 7 μ. In gemmation the cells separate very soon and never form a larger connecting group like the "top yeast" of the brewers. The yeast forms on gypsum-blocks (never in the fermenting liquid) 1-2 ascospores, rarely three and if so, the third is considerably smaller than the other two. A previous good nutrition in liquids not too poor in nitrogen is necessary to produce the spores.[2] I have cultivated this yeast, obtained in pure culture with the usual methods, under various conditions, e. g., upon sterilized potato and boiled rice with full

(1) The investigations of Omori show that this *sake* yeast is a product of a kind of *Ustilago* frequently present in the rice fields.

(2) I have, however, not proved that these spore-like formations develop into new yeast-cells.

access of sterilized air, but never observed anything like a mycelium; the cells preserved their form, whether they had been obtained from fermenting *moto* or directly from the rice straw.

The *sake* yeast still exhibits considerable fermenting energy in presence of 12 per cent. alcohol, but at 16 per cent it is very feeble. In a 10 per cent. sugar solution containing various proportions of alcohol, after six days only 0.1% sugar was found when alcohol amounted to 4%; 5.46% sugar at 12% alcohol, and 8.64% at 16% alcohol. In regard to the higher alcohols I observed that the development and fermentation is stopped by 5% propylic, 3% isobutylic, 1% amylic and 0.5% caprylic alcohol.

Cane sugar solutions can, in presence of some meat extract, be fermented by *sake* yeast, even in concentrations as high as 45 per cent., but the action sets in later. The presence of as much as 6 per cent. sodium chloride does not essentially interfere with the fermentation of a 10% cane sugar nourishing solution, while 10% sodium chloride depresses the fermenting energy by nearly one half and 22% stops it entirely.

In a mixture of 10% cane sugar and 4% tartaric acid, in which the so-called "wild" yeasts still show development, neither *sake* yeast from the *moto* mash nor that directly from the rice fields showed any sign of development within four weeks; this yeast behaves, therefore, like beer yeast, to which indeed it has a close resemblance.

In this connection it may be mentioned that in Japan some kinds of vegetable cheese, as *natto* and *tama-miso* are also ripened and influenced by microbes of rice straw. The fungi on the rice straw i.e. from swampy and heavily manured rice fields also play a role in the manufacture of arrac in Java. Crushed rice wrapped in rice straw for three days represents the so-called *ragi*, something similar to our *koji*. The diastase-yielding fungus, as well as the yeast, (*S. Vordermanni*) is also derived from the rice fields.

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(1) Cf. my investigation on Natto, Bullet. of the College of Agriculture II, No. 2.

Note on a Grape Wine Fermented by Sake Yeast.

BY

K. Negami.

According to recent investigations, the influence of the varieties of yeast upon the flavour and taste of wines is considerable,[1] although the kind of grape, and the soil and climate in which the grapes grow, also are essential factors. It has recently been proposed, in order to improve the wines of certain countries, to replace the accidental fermentation caused by the yeasts attached to the grapes, by pure cultures of such yeasts as are derived from the fermentation of highly valuable kinds of wine. I was, therefore, induced to test what quality of wine could be obtained by the application of a pure culture of that species of yeast, which plays such an important role in the preparation of *sake* in Japan.

Two litres of freshly prepared grape juice, improved by the method of *Chaptal*, and sterilized by boiling for one hour, were infected after cooling with a pure culture of *sake* yeast obtained in the usual way from one colony.

The flask was closed by a cotton plug and left to ferment for two months at a temperature varying from 5 to 20°C.

The clear filtered liquid yielded the following result:

Extract	1.78%
Acidity	0.572% (as tartaricacid)
Alcohol, vol %	10.30%

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(1). Also the energy of fermentation differs in these varieties.

The taste was that of an average white wine, but the flavour (bouquet) did not wholly correspond to our expectations. It was that of an inferior kind of wine. *Sake* yeast, therefore, can not favourably replace wine yeasts.

On the Behaviour of Yeast at a High Temperature.

BY

T. Nakamura, *Nōgakushi.*

It is a well-known fact that certain bacteria can be deprived of their fermenting power without their life being otherwise impaired ; though in this case they lead only an aerobic existence. It seemed to me of some interest to study closely also living yeast deprived of its fermenting power.

At the same time I wished to collect some imformation about the maximum of temperature which yeast can resist *for some time.* Numerous observations have been made on this point, but they do not agree well, as the *time* of exposure to the high temperature was not always taken into account, and pure-cultures free from ascospores were not selected for such experiments.

When the time of exposure is but short, the noxious effects will be less marked at the same high temperature than during a longer exposure. *Kayser* observed with some varieties of yeast a resisting power at 60° when heated (in the moist state) for only five minutes. In the dry state the cells were not even killed at 85°, some varieties resisted even 100°. Other authors state that ordinary beer-yeast loses its power of fermentation at 40° while the cells are killed at 70°. *Schützenberger*, again, states that the temperature of 53° is the highest that yeast can resist.

My own experiments were made with pure cultures obtained from a single colony on a sugar gelatine plate and with cells free from ascospores. From such yeast grown in a solution of 10% cane sugar with 0.5% meat extract, the supernatant liquid was decanted off, the sediment washed with sterilized distilled water to remove the nutrients and the alcohol produced, as these substances might perhaps have interfered with the result. The yeast so treated was suspended in some sterilized distilled water and 5 c.c. of this mixture, placed in a narrow sterilized test tube provided with a cotton plug, were exposed for several minutes to a constant temperature in a water bath.

It was thus found that the fermenting power was not destroyed even when the yeast was exposed for an hour and a half to 46°C., or for one hour to 48°C. However, at a temperature of 52°C. the fermenting power was wholly destroyed when the exposure was kept up for more than 20 minutes ; nor was any development on a gelation plate noticed.

In order to reach results as exactly as possible in regard to the *time* necessary to destroy the fermenting power at 50°C. I proceeded as follows : A number of test tubes containing pure-cultured yeast in sterilized distilled water were first placed in a vessel containing water of about 55°C., and the tubes were continuously well shaken ; one of these tubes containing only water was provided with a delicate thermometer. When a temperature of 50°C. was reached, all the tubes were placed in another vessel containing water of a constant temperature of 50°C. Every five minutes one of the tubes was removed, and after cooling 5 c.c. of sterilized *Pasteur's* solution of double the ordinary strength were added and the mixtures kept in an incubator at 16°—25°C. I then observed that a duration of 25 minutes had not destroyed the fermenting power, but that after 30° minutes the destruction was completely effected.

In order to determine the point *more precisely*, I repeated the same operation at intervals of only one minute between the 25—30 minutes.

The result was that even 29 minutes exposure to 50°C did not destroy the fermenting power, while in 30 minutes it was again completely done. Further no trace of development was noticed, when this yeast was transfered into well aerated nourishing solutions.

An observation was, however, made during all these experiments which may explain the contradictory statements of those observers who claimed that the fermenting power is destroyed by a temperature of 40°. I have found that yeast exposed to heat for some time never showed within such short time fermentation in *Pasteur's* solution as the control sample; sometimes the retardation amounted to 12 hours, sometimes to several days.

In some of the cases mentioned, viz., when yeast was heated for 27 or 29 minutes to 50°C. a weak fermentation was afterwards observed with these samples but after a few days it gradually stopped again, long before all the sugar of the solution was fermented. But those samples of yeast that had only been exposed for 25 minutes to 50°C., still preserved all their vital powers and were observed to develop well, when inoculated on nourishing gelatine, potato, or in 1% sugar and pepton solution. I, therefore, infer that for 25 minutes a temperature of 50° forms the limit beyond which not only the fermenting power but also all other life functions are destroyed.

It was my further object to test the influence of various compounds upon the resisting power of the yeast-cells against heat. The experiments were carried on in the same way as described above, but the yeast was here suspended in different solutions instead of in distilled water, while the liquid was heated. The temperature was 50° and the duration 30 minutes. The results were as follows:

Solution in which the yeast was heated.	Effect after the addition of aerilized Pasteur's solution.
Distilled water.	No fermentation.
Pasteur's solution[1]	Fermentation.
Cane sugar 10%	No fermentation.
Meat-extract 0.5%	Normal fermentation.
Sodium chloride 1.2.3.5.10%	Only fermentation at 3%.
Sodium nitrate ,, ,, ,,	Only fermentation at 2%.
Sodium sulphate ,, ,, ,,	No fermentation.
Di-sodium phosphate ,, ,,	No fermentation.

(1) Pasteur's solution in all cases here described consisted of 10% cane sugar and 0.5% meat-extract.

Only meat-extract, sodium chloride and sodium nitrate had effect in increasing the resistance towards heat. The effect of *Pasteur's* solution consisted only in the presence of meat-extract, not in that of the cane sugar.[1] The fact that sodium sulphate was not favourable shows that the conditions are here different from those of the enzymes which are more favourably influenced by sodium sulphate than by the chloride or nitrate as *Biernacki* has shown. A similar favourable influence was observed by *H. Buchner* with the protective proteids of the blood, the so-called alexines.

Addenda by Dr. O. Loew.

The difficulty encountered by *Mr. Nakamura* in obtaining living yeast cells deprived of their fermenting power might have been taken as an indication that the fermenting power is here more intimately connected with the living protoplasm than in the case of certain bacteria, but such a view is now untenable since *E. Buchner* has revealed the highly interesting fact that the fermentative power is connected with a soluble proteid that can be separated by expressing the yeast under a pressure of 4-500 atmospheres.[2] This albuminous body, called zymase, coagulates easily, and loses after a few days its active properties, also by heating to about 50°. This new observation must lead to a revision of certain points in the theory of the so-called *intermolecular res-*

(1) Very interesting experiments were carried on by *Davenport* and *Castle* on the increase of the resisting power of lower animals (tadpoles). Cf. the important work of *Charles B. Davenport*, *Experimental Morphology*, *New York* 1897, p. 253.

(2) Ber. D. Chem. Ges. *30*, 117.

piration, as it is not the protoplasm itself which, in absence of air, gains its energy by decomposition of sugar, but a soluble proteid, somewhat resembling the enzymes, steps in to provide this energy.[1]

The supposition that this proteid is connected intimately with the living *protoplasm* and is not merely dissolved in the liquid of the *vacuole* will probably be justified. It is an exceedingly labile proteid and perhaps closely related to the active proteids from which the yeast protoplam is built up. *E. Buchner* believes that the yeast cells *secrete the zymase through its walls* and thus the sugar would be decomposed *outside the cells* during the process of fermentation. But this supposition goes, I think, beyond the limits of the immediately admissible conclusions. It is true that *in certain cases* a secretion of this peculiar enzyme takes place, but the chief quantity will to all appearance remain *within the cells*, and there most of the sugar will be fermented.[2] This deduction would not only be in better accordance with the economy of living cells regarding energy but would follow also from the very small quantity of zymase secreted under normal conditions, and further from *Buchner's* own observations. He left, e. g., mixture of 150 cc. expressed yeast juice with 150 cc. sugar solution for three days in an ice box and although this mixture contained as much as 37% saccharose, not more than 2.1 gram alcohol was formed during this time. It will be of special interest to test whether the fermenting power of the zymase is easily destroyed by diamide. hydroxylamine, amidophenol, phenylhydrazine, prussic acid, and on the other hand by cyanogen, nitrous acid, formaldehyde, &c.

I have observed great differences of the enzymes in their behaviour to prussic acid, which in a concentration of 25% will easily destroy diastase, though not the proteolytic enzyme of the pancreas in twelve hours.[3] But in the behaviour to formaldehyde I observed *no essential differences* between various enzymes ;

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(1) Not sufficiently explained, however, is the fact that while yeast cells lose their fermenting power by the action of chloroform, zymase does not, according to *Buchner*.

(2) In the fermentation of beer-wort zymase can not be shown to exist dissolved in the liquid, neither in the coagulated condition in the sediment.

(3) *O. Loew*. Pflüg. Arch. 27, 208, foot-note.

all I tested were killed by the moderately diluted aldehyde even in perfectly neutral solution.[1] This observation, from which I infered that probably labile amido-groups are connected with the activity of the enzymes, was confirmed about four years later in the *Institut Pasteur* in *Paris.*

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(1) Journ f. prakt. Chem. 1888 p. 104.

On Two New Kinds of Red Yeast.

BY

K. Yabe, *Nigakushi.*

Species of red yeast occur very frequently in the air of Japan. In the *sake* factories, farther, a red colouration of *koji* and *moto* is not unfrequently observed, which I found also to be due to the cells of red yeast species. This fact induced me to look for the presence of red yeasts in the soil of the rice fields and on the surface of the rice straw. Indeed I soon discerned upon my sugar-gelatine plates two kinds of such yeasts, the one more intensely coloured than the other. Both kinds agree with *Saccharomyces rosaceous* in the principal point that they *do not form ascospores*, but they differ from it in other respects, leaving no doubt that they represent new species.

Saccharomyces Japonicus, nov. sp. The cells serving for my investigations were obtained in February 1896 by placing some rice straw in sterilized *Pasteur's* solution for five days and preparing with this culture in the usual way a plate, for which a nourishing gelatine served, containing besides the necessary mineral matters some cane sugar and ammonium tartrate. After eight days at a low temperature numerous colonies of mould-fungi and colourless yeast, and a few colonies of red yeast made their appearance with a tendency to grow upward above the surface of the plate. From one of the dark red colonies an inoculation was made again into *Pasteur's* solution and on potato, further into a solution containing 1% meat extract aud peptone.

The cells are *elliptic*, and approach more neary a globular form when well nourished with meat extract. Size in *Pasteur's* solution $=6\times3$ μ; in meat extract solutions 9.2×5.1 μ to 10.3×6.1 μ. This yeast grows very well on potatoes where it acquires a brillant red tint. That the full access of air promotes the formation of the red tint is therefore very probable, and this

influence may also be observed on cultivation in *Pasteur's* solution, in which those cells that grow attached to the sides of the vessel near the surface of the liquid, assume a fine red colour before the sediment has reached this intensity. The influence of light is not required, as the colour is just as well developed in perfect darkness.

This species is further incapable of forming alcohol from glucose or cane sugar ; neither could any development of gas bubbles in the liquid nor a trace of alcohol in the distillate be observed, when the yeast was left for some time in complete nourishing solutions containing those sugars.

Cane sugar and glucose proved to be better nutrients for this organism than milk sugar ; the fungoid mass grown in 10% milk sugar solutions containing 0.5% meat extract, weighed under equal conditions about half as much as when grown with glucose or cane sugar as nutrients. A retardation of the development is observed upon addition of 3% alcohol to the nourishing liquid, while 7% stops it altogether, which demonstrates a much greater sensibility to alcohol than beer or wine yeasts possess. A temperature of 40°C kept up for 15 minutes injures the cells to some extent, multiplication being retarded, but one of 45° acting for 15 minutes, kills the cells.

Stab-culture in sugar-gelatine even after weeks shows hardly a trace of development along the needle track, while on the surface a red film gradually develops, producing a concavity with gradual *liquefaction* of the gelatine. This shows the organism to be exquisite aërobic, which well agrees with its inability to produce alcohol from sugar.

I have paid special attention to the question whether this species would be capable of forming ascospores, and have subjected well nourished cells after transference upon moist gypsum blocks to close observation, but in no case did ascospores make their appearance. The only mode of propagation is *gemmation* which is, however, not only carried on in the usual way but also in another manner heretofore not observed, as far as is known to me. This peculiarity consists in the presence of a fine mycelial thread by which the young cell is attached to the mother cell. In gemmation many cells develop first a fine, not separated mycelial thread, at whose ends the young cells develop as shown in the following figure (1).

These mycelial formations may also branch and reach a length of 80 μ. without bearing any cells at their ends (2). In peptone solutions these phenomena very soon make their appearance.

This mycelium is evidently also the cause of the peculiarity of this species forming a *film* on the surface of the nourishing solutions; this film, when the culture is shaken, breaks into fragments and sinks to the bottom.

Some time ago a kind of red yeast was described by *Allan P. Swan* (Centr. Bl. f. Bakt. II. No. 1; 1896) of which this author remarks: "In cover glass cultures polymorphism is marked with a tendency to grow in chain form with septate hyphae like *Oidium* lactis." This condition has never been observed with the species here described, nor was the tendency to form the ascospore-like globular masses *Swan* mentioned and whose ascospore nature was not proved, as *Bay* has pointed out. Our species and *Swan's* red yeast however agree in the mode of growth of the colonies on gelatine and in liquefying gelatine, further in form and size. The power of liquefying gelatine however appears to be much more energetic in the species described by *Swan*.

Saccharomyces Keiskeana, nov. spec.

Cells of this kind of yeast were obtained from the same gelatine plate which yielded the former species. The pink coloured colonies differ considerably in intensity and shade of colour from those of the former species and from those of S. *rosaceus*. It forms neither ascospores nor mycelium, and only multiplies by the usual mode of gemmation. The young cells soon separate from the mother cells and do not form connections as the top yeast variety of *S. cerevisiae* does.

The cells are perfectly globular; usually of 5.1 μ. in diameter, but if well nourished reaching a diameter 9 μ.

In *Pasteur's* solution it forms a faintly pink deposit, but with no film on the surface ; on potato the tint becomes more vivid, probably under the direct influence of the free oxygen.

In stab-culture in sugar gelatine a moderate growth is observed along the needle track ; but these cells remain colourless, while those on the surface assume gradually a pink colour *liquefaction* of the gelatine does *not* take place.

A temperature of 45°C will not kill the cells within 15 minutes, but one of 50° will. Alcohol of 5% retards, of 7% stops, development in nourishing solutions.

The species is named in honour of the well known Japanese botanist *Keiske Ito.*

On Bromalbumin and its Behaviour to Microbes.

BY

O. Loew *and* **S. Takabayashi.**

Bromalbumin has recently been recommended for medical purposes. As it contains bromine organically bound, it seems to be better adapted than the combination of peptone with hydrobromic acid, whose therapeutical properties were studied by *Rosenthal*[1] but found not to differ essentially from those of potassium bromide.

Bromalbumin was first prepared by one of us[2] in the year 1885 by mixing finely powdered and well dried albumin (100g.) with bromine (50cc. or about 150 g.) and leaving the mixture to itself for about four weeks. Hereby only a very small quantity of hydrogen bromide becomes liberated and the albumin is gradually transformed into a thick semi-liquid mass, which, after well washing with water, retains a portion of losely bound bromine so obstinately, that primary sodium sulphite had to be

(1) Zeitschr. physiol. Chem. *22*, 227.
(2) *O. Loew*, Journ. f. prakt. Chem. *31*, 138.

applied to remove the last remnant and to obtain a colourless product. This contained 16.16% bromine but after dissolving it in ammonia and precipitating by acids only 13.10%.

This bromalbumin yielded no potasium sulphide on heating with a solution of caustic potassa, nor tyrosine on heating with hydrochloric acid, but it did then yield leucine. It gave further the biuret, but not the *Millon's* reaction. It was soluble in dilute alkalies and precipitated again by acids.

We have recently prepared bromalbumin again, but with the modification that equal weights of albumin and bromine were taken, and the mixture (cooled during preparation) heated for two days to about 60°C. After washing with water,[1] aqueous sulphurous acid was applied to remove the last traces of free bromine. It was then washed with a dilute solution of sodium carbonate, and treated with alcohol of 50%, until no more reaction for bromides was obtained in the filtrate ; finally with absolute alcohol. Dried at 100°, 0.640 g. yielded 0.1650 g. A g Br = 11.00% Br. 0.637 g. yielded 0.1565 g. Ag Br. = 10.64% Br. This product contained, therefore, less bromine than that obtained under the conditions described above.

In order to observe the behaviour to microbes 12 g. were dissolved in 150 cc. of a 2% solution of crystallised sodium carbonate, the solution diluted to 1200 cc. and finally 0.2% dipotassium phosphate and 0.02% magnesium sulphate added. To a part of this solution was then added 0.5% peptone, and to another 2% cane sugar. One half of each solution was infected with microbes from putrid meat, the other with anthrax bacilli, of course under all the necessary precautions of sterilization. Two divisions were further made to observe the effects of the presence and absence of air. In the latter case *Erlenmeyer* flasks were provided with sterilized india rubber stoppers carrying a bent tube filled with sterilized water and containing some

(1) This wash water removed a considerable portion of proteid-like bodies. Phospho-tungstic acid and mercuric nitrate give precipitates ; *Millon's* reaction fails. Saturation with ammonium sulphate yields a strong, with sodium sulphate a weaker, precipitate.

mercury to prevent the ingress of air. After 24 days standing in the dark at a temperature varying from 11-20°, the flasks were examined with the following result:

Microbes of Putrefaction.

	In presence of air.	In absence of air.
Bromalbumin 1%	Reaction neutral. Slight trace of ammonia. No putrid odour, although numerous cocci and bacilli present.	Reaction neutral, no ammonia, no turbidity, no putrid odour. Mere traces of cocci, but no bacilli.
Bromalbumin 1% and peptone 0.5%	Reaction alkaline, much ammonia, putrid odour, liquid very turbid, a rich vegetation of microbes present.	Result resembling that in presence of air, but bacterial vegetation less developed.
Bromalbumin 1% and cane sugar 2%	Smell and reaction acid. No ammonia. Rich bacterial vegetation present.	No odour, no fermentation. Only slight sediment of cocci, but no bacilli.

Bacilli of Anthrax.

	In presence of air.	In absence of air.
Bromalbamin 1%	Neutral, mere traces of development.	Neutral. Slight traces of development.
Bromalbumin 1% with peptone 0.5%	Considerable and characteristic development.	Some development.
Bromalbumin 1% with cane sugar 2%	Neutral; small traces of development.	Slight traces of development.

From these observations it follows that bromalbumin as such in absence of air and even in presence of sugar is not favourable for the development of microbes. However, it does not prevent

development when peptone is present. Further preliminary experiments with mice have shown us, that bromalbumin did not produce any immunity by subcutaneous injections in cases of anthrax and erysipelas.

On an Important Function of Leaves.

BY

U. Suzuki, *Nōgakushi.*

It has long since been known that nitrates absorbed by plants from the soil disappear rapidly in the leaves, while they are found stored up for a longer or shorter period in the stem and roots. It was therefore supposed by several authors that the nitrates can be reduced only in the leaves, yielding thereby proteids and amido-compounds. It was further asserted that direct sunlight would be necessary for the reduction, and one author went even so far as to assert that only the nascent carbobydrates in the chlorophyll bodies could bring on the assimilation of nitrates. But all these hypotheses evidently go too far and have not been verified. It can easily be shown that nitrates can be assimilated in darkness just as well as in daylight, as has been done by *Loew*.[1] He cultivated mould fungi in a dilute solution containing glycerol, sodium nitrate, monopotassium phosphate, sodium sulphate and magnesium sulphate, some of the flasks being kept in darkness, others in ordinary daylight, but no essential difference was observed in the weight of the fungoid mass, so that no favourable action of light upon the assimilation of nitrates was noticed. Indeed there are other causes which must have much influence upon the readiness to assimilate the nitrates, such as the intensity of respiration and the amount of glucose present, as well as the temperature. Thus we can easily understand why the nitrates are more quickly assimilated in the leaves, whose activity consists principally in the preparation of carbohydrates, and whose anatomical structure permits a very lively respiration which must naturally increase the energy of protoplasm in all the cells of the leaves. If it can be shown that under certain conditions amido-compounds present in roots and fruits are better sources of nitrogen for protein production than the nitrates, then an important function of the leaves in facilitating the protein production in all

(1) Biolog. Cent. Bl. *10*, No. 19.

parts of the plants would be evident. According to *Emmerling* amido-acids are formed in the leaves synthetically and are transported to the growing seeds. In the growing seeds or fruits themselves he found more amides (asparagine and glutamine) than amido-acids as leucine.[1] I am, however, of opinion that the amido-acids in the leaves are not formed directly by synthesis, as *Emmerling* and others suppose, but are the products of decomposition of proteids, only the amides such as asparagine and glutamine being the products of direct synthesis ; these are formed from ammonium salts or nitrates in all those cases, in which not all the conditions for the production of proteids are fulfilled.[2] Furthermore, the asparagine found in the growing fruits may either be the product of direct synthesis or, as *Loew* has surmised, a product of oxidation of other amido-acids, for which hypothesis I wished to adduce facts. I therefore paid attention to the following questions :

1st.—Are proteids decomposed in the leaves, and do the amido-products thus formed migrate into the other parts of the plants ?

2nd.—Is gradual oxidation of these amido-acids to asparagine observable ?

3rd.—Are amido-compounds, as leucine and asparagine, under certain conditions, a better source of nitrogen for protein production in fruits and roots than nitrates ?[3]

I. We know that proteids are protected to a certain degree by carbohydrates and that with the gradual disappearance of the carbohydrate, the proteids are more and more attacked by enzymes, as shown by *E. Schulze* who found that plants kept for a number of days in darkness, show an increase of asparagine and a decrease of proteids.[4]

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(1) The writers on the subjects do not make sufficient distinction between the amides and amido-acids. It has become, however, very clear that a different mode of formation and different functions have to be ascribed to asparagine (and perhaps also to glutamine) than those given to the amido-acids such as leucine and tyrosine. The amount of leucine is generally very much smaller than that of asparagine; thus, for instance, *E. Schulze* obtained from 7 kilo of *Vicia faba* six weeks old, grown in the field, only 0.5 gram leucine and neither tyrosine nor phenyl amido-propionic acid

(2) This Bull. II. No. 7.

(3) On these last two points I will communicate a later series of experiments.

(4) Asparagine, however, must not be considered as a direct product of proteid decomposition, but according to *Loew's* view, as the final product of metabolism, by which the previously formed leucine, tyrosine, arginine, lysine etc. are gradually oxidized whereby asparagine from the remaining fragments is formed.

But I thought that a decrease of proteids should take place in the leaves even in *one* night because we know that during every night a large portion of the carbohydrates in the leaves is transported into the other parts of the plants. This decrease of the protecting carbohydrates must naturally lead to an attack upon the reserve proteids formed in the leaves during the day, and, as the resulting amido-compounds would just as easily be transportable as sugar, a decrease of the proteids of the leaves during the night should be easy to prove. Thus far only one experiment in this direction has been made with the leaves of *Vitis vinifera*, by *Sapoznikow*[1] who infers as follows :—

"Aus der dritten Reihe von Versuchen mit, an den Pflanzen belassenen Blättern ergab sich, dass im Dunkeln das Eiweiss ebenso wie die Kohlenhydrate, wenn auch im geringerem Maase, aus den Blättern auswandert. Von einigen Blättern, wurde je eine Hälfte um 7 Uhr abends abgeschnitten, die andere verdunkelt an der Pflanze gelassen and um 8 Uhr morgens abgeschsuitten ; während dieser 13 Stunden verminderte sich der Eiweissgehalt pro q. m. um 0.281 gram ; in einem zweiten Versuche wurden die an der Pflanze balasenen Blatthälften fünf Tage lang Verdunkelt, die Verminderung des Eiweissgehaltes pro q. m. betrug 1.267 gram während der Gehalt an Kohlehydraten um 3.681 gram abnahm ; der gleichzeitig bestimmte Nicht-Eiweiss-Stikstoff nahm nur ganz unbedeutend zu."

But this one experiment is certainly not sufficient to show that this law holds good also for a great number of plants. I therefore carried on some more experiments with plants from different families, determining in the morning and in the evening not only the total nitrogen and albuminoid nitrogen, but also the aspragine nitrogen and the starch. The results are as follows :—

I. *Experiments with Leguminous Plants.*

A. Wistaria brachybotrys (Fuji).

400 leaves.	Dry weight.
Evening 6^h	20.089 grams
Morning 6^h	17.094 ,,

(1) Cent. Bl. d. Agr. Chem, 1896 p. 107.

Calculated to 100 leaves.	Dry weight.	Ratio of dry matter.
Evening	5.022	100.00
Morning	4.274	85.10

In 100 parts of dry matter.

	Evening.	Morning.
Total nitrogen	3.44	3.49
Albuminoid nitrogen	2.90	2.84
Asparagine nitrogen	0.10	0.14
Nitrogen in amides (without asp. nitr.)	0.44	0.51
Starch	9.65	6.11

Absolute quantity in 100 leaves.

	Evening.	Morning.	Ratio.
Total nitrogen	0.1725	0.1490	100 : 86.4
Albuminoid nitrogen	0.1457	0.1215	100 : 83.4
Asparagine nitrogen	0.0050	0.0058	100 : 116.
Nitrogen in amides (without asp. nitr.)	0.218	0.0217	100 : 100.
Starch	0.4848	0.2611	100 : 54.

Decrease of starch during the night = 0.2238 gram.
,, proteids ,, ,, = 0.1469 ,,

B. Phaseolus mungo.[1]

200 leaves.	Dry weight.	Ratio of dry matter.
Evening	30.389 grams.	100.00
Morning	26.468 ,,	87.30

In 100 parts of dry matter :

	Evening.	Morning.
Total nitrogen	5.37	5.49
Albuminoid nitrogen	4.35	4.50
Asparagine nitrogen	0.20	0.13
Nitrogen in amides (without asp. nitr.)	0.82	0.86
Starch	13.50	11.00

(1) This experiment was made on September 17th.

Absolute quantity in 100 leaves (in grams).

	Evening.	Morning.	Ratio.
Total nitrogen	0.8160	0.7270	100 : 89.1
Abuminoid introgen	0.6610	0.5955	100 : 90.1
Asparagine nitrogen	0.0300	0.0170	100 : 57.0
Nitrogen in amides (without asp. nitr.)	0.1250	0.1145	100 : 91.5
Starch	2.0520	1.4560	100 : 71.0

C. Phaseolus vulgaris[1]

50 leaves.	Dry weight.	Ratio of dry matter.
Evening	12.765	100.
Morning	12.222	95.7

In 100 parts of dry mitter.

	Evening.	Morning.
Total nitrogen	3.39	3.39
Albuminoid	2.75	2.56
Asparagine nitrogen	0.20	0.20
Nitrogen in amides (without asp. nitr.)	0.44	0.63
Starch	23.10	16.10

Absolute quantity in 100 leaves (in grams).

	Evening.	Morning.	Ratio.
Total nitrogen	0.8660	0.8290	100 : 95.7
Albuminoid nitrogen	0.7021	0.6260	100 : 89.1
Asparagine nitrogen	0.0510	0.0490	100 : 96.0
Nitrogen in amides (without asp. nitr.)	0.1129	0.1540	100:136.4
Starch	5.8970	3.9350	100 : 66.8

D. Pueralia Thumbergiana[2] (Kuzu)

50 leaves.	Dry weight.	Ratio of dry matter.
Evening	21.854	100.
Morning	21.099	96.5

(1) Experiment was made on Oct. 29th.

(2) Experiment was made on June 18th.

In 100 parts of dry matter.

	Evening.	Morning.
Total nitrogen	4.32	4.26
Abuminoid nitrogen	3.47	3.70
Asparagine nitrogen	0.26	0.27
Amido-nitrogen (without asp. nitr.)	0.63	0.29

Absolute quantity in 100 leaves (in grams).

	Evening.	Morning.	Ratio.
Total nitrogen	1.887	1.797	100 : 95.2
Albuminoid nitrogen[2]	1.516	1.559	100 : 103
Asparagine nitrogen	0.112	0.112	100 : 100
Amido-nitrogen (without asp. nitr.)	0.126	0.260	100 : 206

II. *Experiments with Solanaceae.*

A. Solanum tuberosum.[1]

220 leaves	Dry weight.
Evening (6 o'clock)	16.887 grams.
Morning (,,)	12.360 ,,

Calculated to 100 leaves	Dry weight.	Ratio of dry matter.
Evening	7.680	100.00
Morning	5.620	73.20

In 100 parts of dry matter.

	Evening.	Morning.
Total nitrogen	4.26	5.46
Albuminoid nitrogen	3.28	4.25
Asparagine nitrogen	0.30	0.29
Amido-nitrogen (without asp. nitr.)	0.68	0.92
Nitrate nitrogen	Trace	Trace
Starch	12.50	7.40

(1) This experiment was made on the 5th June.

Absolute quantity in 100 leaves (in grams).

	Evening.	Morning.	Ratio.
Total nitrogen	0.3350	0.3067	100 : 91.6
Albuminoid nitrogen	0.2517	0.2390	100 : 94.9
Asparagine nitrogen	0.0230	0.0163	100 : 67.0
Amido-nitrogen (without asp. nitr.)	0.0603	0.0514	100 : 85.2
Starch	0.9600	0.4134	100 : 43.1

B. Solanum tuberosum.[1]

200 leaves.	Dry weight.	Ratio of dry matter.
Evening (6 o'clock)	6.820	100.00
Morning (,,)	6.176	90.50

In 100 parts of dry matter.

	Evening.	Morning.
Total nitrogen	5.70	5.80
Albuminoid nitrogen	4.55	0.76
Asparagine nitrogen	0.38	0.76
Amido-nitrogen (without asp. nitr.)	0.77	0.46
Nitrate nitrogen	Trace	Trace

Absolute quantity in 100 leaves (in grams).

	Evening.	Morning.	Ratio.
Total nitrogen	0.1944	0.1791	100 : 92.1
Albuminoid nitrogen	0.1552	0.1414	100 : 91.1
Asparagine nitrogen	0.0130	0.0235	100 : 18.0
Amido-nitrogen (without asp. nitr.)	0.0260	0.0142	100 : 54

III. *Experiment with Convolvulaceae.*

Batatas edulis.[2]

100 leaves.	Dry weight.	Ratio of dry matter.
Evening	34.565	100.00
Morning	32.766	94.80

(1) This experiment was made on the 12th Oct.

(2) This experiment was made on the 18th Sept.

In 100 parts of dry matter.

	Evening.	Morning.
Total nitrogen	4.53	4.59
Albuminoid nitrogen	3.58	3.62
Asparagine nitrogen	0.44	0.64
Amido-nitrogen (without asp. nitr.)	0.51	0.33
Nitrates nitrogen	Trace.	Trace.

Absolute quantity in 100 leaves (in grams).

	Evening.	Morning.	Ratio
Total nitrogen	1.566	1.504	100 : 96.0
Albuminoid nitrogen	1.238	1.186	100 : 95.8
Asparagine nitrogen	0.152	0.210	100 : 138.0
Amido-nitrogen (without asp. nitr.)	0.176	0.108	100 : 61.0

IV. *Experiment with Polygonaceae.*

Polygonum fagopyrum.[1]

450 leaves.	Dry weight.	Ratio of dry matter.
Evening	18.185	100.00
Morning	16.091	88.40

In 100 parts of dry matter.

	Evening.	Morning.
Total nitrogen	4.45	4.62
Albuminoid nitrogen	3.84	4.02
Asparagine nitrongen	0.22	0.13
Amido-nitrogen (without asp. nitr.)	0.39	0.47
Nitrates nitrogen	0	0

Absolute quantity in 100 leaves (in grams).

	Evening.	Morning.	Ratio.
Total nitrogen	0.1798	0.1649	100 : 91.7
Albuminoid nitrogen	0.1551	0.1435	100 : 92.5
Asparagine nitrogen	0.0091	0.0048	100 : 53
Amido-nitrogen (without asp. nitr.)	0.0156	0.0166	100:106.4

(1) This experiment was made on the 26th Sept.

V. *Experiment with Compositae.*

Helianthus annuus.[1]

33 leaves.	Dry weight.	Ratio of dry matter.
Evening	27.427	100.00
Morning	24.266	88.50

In 100 parts of dry matter.

	Evening.	Morning.
Total nitrogen	4.78	4.88
Albuminoid nitrogen	3.60	4.08
Asparagine nitrogen	0.28	0.48
Amido-nitrogen (without asp. nitr.)	0.90	0.32
Starch	8.50	7.50

Absolute quantity in 100 leaves (in grams).

	Evening.	Morning.	Ratio.
Total nitrogen	3.976	3.590	100 : 90.3
Albuminoid nitrogen[2]	2.990	3.000	100 : 100.3
Asparagine nitrogen	0.226	0.344	100 : 152
Amido-nitrogen (without asp. nitr.)	0.760	0.246	100 : 32.4
Starch	7.066	5.535	100 : 78.3

We see from the above experiments that in most cases a considerable decrease of total and albuminoid nitrogen takes place during the night, and we observe also that the decrease of proteids is greater in those cases where the decrease of carbohydrates is greater. In the experiments with *Helianthus* and *Pueralia* (*kuzu*) the result differs from the other cases inasmuch as the albuminoid nitrogen was found not to decrease during the night. But this may be explained by the fact that the leaves gathered in the evening had not been dried immediately and therefore had remained alive during the night, still carrying on respiration. Thus, a splitting of proteids might have occurred with accumulation of amido-compounds. Hence leaves gathered

(1) This experiment was made on the 18th June.

in the evening and not killed immediately by drying or otherwise, may give rise to errors, inasmuch as the amount of proteid nitrogen may be found to be lower than it was at the time of gathering. The following experiments were made with the intention of furnishing further support to this view.

I. *Experiment with the Buckwheat Leaves* (*Polygonum fagopyrum*)

On the 8th of October the leaves of full-grown buckwheat plants were removed carefully, and divided into two portions; one portion was directly dried in the air bath, while the other portion was kept in the dark, the leaves being kept moist, and after twenty hours, dried and analyzed.

100 grams of fresh leaves became by direct drying 16.864 gram.

100 grams of fresh leaves after keeping moist for 20 hours 14.996 gram.

Ratio of dry matter.....100 : 88.9

In 100 parts of dry matter.

	Directly dried.	Kept moist.
Total nitrogen	3.90	4.43
Albuminoid nitrogen	3.55	3.54
Asparagine nitrogen	0.38	0.38
Amido-nitrogen (without asp. nitr.)	0.15	0.51
Nitrate nitrogen	0.08	0.08

In 100 parts of total nitrogen.

	Directly dried.	Kept moist	Ratio.
Total nitrogen	100.00	100.00	100 : 100
Albuminoid nitrogen	91.00	79.91	100 : 87.8
Asparagine nitrogen	5.24	8.58	100 : 163.7
Amido-nitrogen (without asp. nitr.)	1.66	9.71	100 : 585
Nitrates nitrogen	2.10	1.80	100 : 86

II. *Experiments with Phaseolus vulgaris.*

Leaves were gathered on the 29th Oct. at 1h. P.M.

100 grams of fresh leaves became by direct drying 16.689 gram.

100 grams of fresh leaves after keeping moist for 48 hours. 15.240 gram.

Ratio of dry matter.....100 : 91.3

In 100 parts of dry matter.

	Directly dried.	Kept moist.
Total nitrogen	3.70	4.00
Albuminoid nitrogen	2.61	2.53
Asparagine nitrogen	0.20	0.52
Amido-nitrogen (without asp. nitr.)	0.89	0.95
Nitrates nitrogen	0	0
Starch	12.9	8.5

In 100 parts of total nitrogen.

	Directly dried.	Kept moist.	Ratio
Total nitrogen	100	100	100 : 100
Albuminoid nitrogen	70.5	63.3	100 : 89.8
Asparagine nitrogen	5.5	13.0	100 : 236.3
Amido-nitrogen (without asp. nitr.)	24.0	23.7	100 : 99.0

These results show that by keeping the leaves moist and alive, the dry matter decreases considerably, and also the splitting of proteids takes place, forming thereby amido-compounds and asparagine.

Having thus arrived at a simple explanation of the apparently contradictory cases mentioned, the conclusion seems justified that reserve proteids in the leaves are decomposed into amido-compounds during the night, and the latter are transported from the leaves to the other parts of the plants. The migration of amido-compounds appears to proceed rapidly, as I have found no large quantity in the leaves gathered in the morning. Thus an important function of the leaves is positively established. This function consists in facilitating the formation of proteids in all

parts of the plants by the assimilation of nitrates, yielding thereby amido-compounds, which are in all probability better sources for proteid formation than nitrates, in organs poorer in sugar and with a less energetic respiration process. A great advantage is thus gained for the stems, roots and fruits, in which the conditions for nitrate assimilation are less favourable than in the leaves.[1] These amido-compounds produced are either asparagine, which, as I have shown in former article, can be formed synthetically from ammonium salts as well as from nitrates, or they are the decomposition products of proteids formed in the assimilation of nitrates. This leaf function will play an important part especially in plants of rapid growth (as many Leguminosae) or such plants as develope certain parts much more than others (as the turnip, melon, potato).[2]

Addendum.

After this investigation was finished, a recent publication of P. Kosutany[3] came to my knowledge, which also treats of the proteid formation in leaves. But I think that his observations cannot be regarded as conclusive in regard to those functions of leaves I have had under discussion. He collected the leaves between three and four o'clock in the afternoon and then again at three o'clock in the morning. Thus the leaves would not show differences as large as in my investigations, since I collected the leaves at six o'clock in the morning and six o'clock in the evening, which in September and October means in the latitude of Tokyo nearly twelve hours of daylight and twelve hours of darkness.

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(1) Cf. Nakamura's contribution, this Bulletin Vol. III. No. 7.

(2) In cases however of slow development, the proteids formed in the cells of the leaves may remain there stored up for a long time, as active albumin. Cf. *Daikuhara*, this Bulletin II. No. 2 and 4.

(3) Landw. Vers-Stat. *48*. 13.

On the Behaviour of Active Albumin as Reserve Material during Winter and Spring.

BY

U. Suzuki, *Nōgakushi.*

The well known fact that during winter time, much reserve material is stored up in the bark of trees, induced me to make the following investigation, in order to decide whether active albumin is also stored up in the bark of various plants, and whether it is consumed during the development of leaf-buds and flower-buds. *Daikuhara*[1] three years ago, examined many plants, late in autumn and found that the leaves of such plants as contain active albumin during summer time, contain it also late in autumn (October and November) although generally in a far smaller quantity.

I examined however the bark and buds in March before the buds had opened.

In regard to the reactions, I mention more in detail those observed with the bark of *Aesculus turbinata.*

Fresh sections of the bark of very young branches were treat-

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(1) This Bulletin II. No 2 and 4.

ed with a saturated caffeine solution, under the microscope. After ten minutes, I observed in a number of cells numerous little globules which gradually united to a lager one, while in cells, into which perhaps the caffeine entered more slowly, I observed a large globular formation formed at once, within which again small globules gradually made their appearance. After one hour's action, I treated the sections with 0.1% ammonia for about half an hour, when I observed that the smaller globules formed *directly* by the action of caffeine had become insoluble and in most cases vacuolised, as while such globules as were formed within the large globules, and after some time, disappeared by being dissolved. Some of these cells, however, were then still alive and remained transparent, others died off, and showed then dense granulations, evidently formed by the action of ammonia. The former produced the characteristic globules again by the action of caffeine, which proves that the *apparent solution by ammonia* was simply the effect of the extraction of caffeine which effect is produced also by water alone. Evidently two phenomena had taken place depending, perhaps, on the quicker or slower entrance of caffeine ; one phenomenon was the formation of *proteosomes* by the action of caffeine upon the active albumin in the vacuole, the other consisted in the formation of normal or anomalous *plasmolysis* in which case the proteosomes were afterwards produced much more slowly because the entrance of caffeine into the vacuole was retarded. In those cells into which the ammonia could enter more quickly than the caffeine previously applied was extracted, the proteosomes became solidified by the action of the dilute ammonia ; in such cases, however, in which the extraction of caffeine proceeded more quickly than the entrance of ammonia, the proteosomes disappeared again, as if the object had been treated with water, thus producing an apparently contradictory phenomenon.[1] The section treated with ammonia was now treated with absolute alcohol, whereby the *plasmolysis* disappeared at once, giving rise to irregular coagulated masses, whilst the *proteosomes* produced by caffeine and solidified by ammonia remained intact.

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(1) A much more characteristic result is obtained when we allow the caffeine solution to act for 8-10 hours before the treatment with ammonia. In this case all the proteosomes solidify, some also become hollow.

When a section treated with caffeine for several hours was *directly* treated with absolute alcohol, the globular formations of proteosomes disappeared at once, while with the plasmolized cells only irregular coagulated masses could be distinguished. As it seemed to me that the solution of the proteosomes was brought on in this case, by the caffeine being extracted more quickly than the alcohol could enter, I applied to another section treated with caffeine alcohol of 20% for about 15 minutes ; whereby the plasmolized cells remained partially alive and transparent, while the non-plasmolized cells containing the caffeine proteosomes showed then hollow or vacuolized globules, which *now* on treat ment with *absolute* alcohol remained *entirely unchanged*.[1]

If a section, treated for 24 hours with caffeine solution and showing both plasmolysis as well as proteosomes, is treated with a dilute aqueous solution of iodine in potassium iodide, we soon observe the vacuolization of all the proteosomes, while the vacuolized cells show irregular shaped contours of the coagulated cytoplasm.

Also it is characteristic that diluted solutions of acetic or nitric acid do *not dissolve* the caffeine proteosomes, when sufficient caffeine had entered into the cells.

The observations on the presence of active albumin in the bark and buds of various plants are embodied in the following table:—

Species	Object tested	Active albumin	Remarks.
Larix leptolepsis	Buds	Present	Much starch.
	Bark	Much present	,,
Ginko biloba	Buds	None	Very much starch.
	Bark	None	,, no soluble proteids, no tannin.
Rhus sylvestris	Buds	Much	Much starch.
	Bark	Very much	Little starch.
Prunus japonica (Thunb)	Buds	Very much	Little starch.
	Bark	Very much	,,
Prunus Grayana (Maxim)	Buds	Much	———
	Bark	Much	———
Morus alba	Buds	None	Much starch.
	Bark	None	,,

(1) In some cases, large proteosomes, commencing to develop vacuoles, considerably resemble plasmolized cells, in which small globules of caffeine proteosomes are developed. But a close observation will reveal the higher refractive power of the former.

Lindera praecox	Buds	Much	
	Bark	Very much	
Rhus semialata	Buds	Present	Very much starch.
	Bark	Present	,,
Prunus pseudocerasus Lindl	Buds	Very much	
	Bark	Very much	Much starch, no fat, little tannin.
Aesculus turbinata	Buds	Very much	
	Bark	Very much	Little starch, no fat, little tannin.
Prunus mume	Buds	Very much	
	Bark	Very much	
Ilex latifolia	Buds	Present	
	Bark	Much present	
Prunus persica var. necturina	Buds	Very much	———
	Bark	Very much	Little starch, no fat, little tannin.
Gleditschia japonica	Buds	None	Much starch, no fat.
	Bark	None	,, ,,
Magnolia hypoleuca	Buds	None	No starch, little fat.
	Bark	None	,, ,,
Sapindus mukurosi	Buds	None	Little starch, no fat.
	Bark	None	,, ,,
Quercus dentata	Buds	———	——— ———
	Bark	Very much	No starch, no fat, much tannin.
Acer pictum	Buds	Much	Little starch, no fat.
	Bark	Very much	,, ,, little tannin.
Hibiscus syriacus	Buds	None	Much starch, no fat, no tannin.
	Bark	None	,, ,, ,,
Alnus japonica	Buds	Present	Little starch.
	Bark	Present	,, little tannin.
Betula alba	Buds	Very much	,,
	Bark	Very much	,, little tannin.
Quercus grosseserrata	Buds	Little	No starch, no fat.
	Bark	Present	,, ,,
Diospyros kaki	Buds	———	——— ———
	Bark	None	Much starch, no fat, little tannin.
Akebia quinata	Buds	None	Much starch, no fat, little tannin.
	Bark	None	Little much ,, ,,
Ligustrum ibota	Buds	None	Much starch, no fat.
	Bark	None	,, ,,
Zanthoxylum piperitum	Buds	———	——— ———
	Bark	None	Very much starch, no fat, no tannin.

Prunus Armeniaca	Buds	———	——— ——— ———
	Bark	Very much	Little starch, no fat, little tannin.
Lycium chinense	Buds	———	——— ——— ———
	Bark	None	No starch, little fat, little tannin.
Mallotus japonica	Buds	None	Starch present, no fat, some tannin.
	Bark	None	„ „ „
Actinidia arguta	Bnds	Much	Much starch.
	Bark	Very much	„ „ some tannin.
Pirus Toringso	Buds	Much	Little starch, no fat, little tannin.
	Bark	Very much	„ „ „
Ficus erecta	Buds	None	Starch present, much fat, no tannin.
	Bark	Present	Very much starch, little fat, „
Juglans cordiformis	Buds	None	„ no fat little tannin.
	Bark	Much	„ „ „
Sterculia platanifolia	Buds	None	Starch present, no fat, no tannin.
	Bark	None	„ fat present, „
Helwingia rusciflora	Buds	None	Little starch some fat, little tannin.
	Bark	None	„ „ „
Mespilus sanguinea	Buds	Present	„ ——— „
	Bark	Much	„ ——— „
Albizzia Julibrissin	Buds		Much starch, no fat, „
	Bark	None	„ „ no tannin.
Corylopsis pauciflora	Buds	Little	Much starch, no fat.
	Bark	Present	„ „ „ little tannin.
Clethra barbinervis	Buds	None	Very much starch, little fat, much tannin.
	Bark	Present	Much starch, no fat, little tannin.
Acanthopanax spinosum	Buds	None	No starch, no fat. „
	Bark	None	„ , much fat, „
Rhus vernicifera	Buds	Present	Much starch, much tannin. „
	Bark	Much	„ „ „ „
Orixa japonica	Buds	None	Much starch, little tannin.
	Bark	None	„ , fat present, no tannin.
Ailanthus glandulosa	Buds	None (?)	Little starch, no fat, „
	Bark	None (?)	Very much starch „ „
Phellodendron amurense	Buds	None	Little starch and tannin.
	Bark	None	Much starch, no tannin.
Evodia rutaecarpa	Buds	None	Starch present, little fat, no tannin.
	Bark	None	„ „ „
Idesia polycarpa	Buds	None	Little starch, no tannin.
	Bark	None	Very little starch, „ „
Tilia Miqueliana	Buds	Very much	Little starch, no fat, trace tannin.
	Bark	Much	„ „ „
Liriodendron tulipifera	Buds	None	Much starch, much fat, little tannin.
	Bark	None	„ „ „ , very little tannin

We observe as a general result: of 48 species examined 25 contained active albumin and frequently there was contained more active albumin in the bark than in the buds. It behaves therefore in this respect like the other reserve materials.

On the Physiological Action of Neutral Sodium Sulphite upon Phænogams.

BY

K. Negami.

While neutral sulphites are poisonous to the higher animals, they prove to be either not so, or only very week poisons, for the lowest forms of animal and vegetable life.[1] In regard to phænogams, however, the action of neutral sulphites does not appear to have been investigated, though the action of free sulphurous acid on plants has repeatedly been studied.

The reason why I undertook some trials regarding this matter was that amido-sulphonic acid in the form of neutral salts was found to be poisonous to the phænogams,[2] while it is not poisonous to lower vegetable and animal life. This rendered the supposition possible that the specific action for phænogams might be due to the formation of sulphurous acid from that compound.

In my first experiment I prepared a 1% solution of neutral sodium sulphite[3] and mixed it with an equal volume of saturated

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(1) *O. Loew*, Natürl System der Giftwirkungen, p. 105.

(2) *O. Loew*. Journal of the College of Science, Tokyo, Vol. IX, 1896. Also: *N. Maeno*, Bull. College of Agric. Tokyo, Vol. II, No. 7.

(3) This salt was freshly recrystallized to free it entirely from sulphates.

gypsum solution. This solution was renewed every second day as an oxidation to sulphate takes place rather quickly. For control I prepared a corresponding solution of sodium sulphate mixed with an equal volume of saturated gypsum solution. Barley plants, however, showed in these solutions after 7 days no distinct signs of disease.

As I surmised that the oxidation of sulphite to sulphate might have been the cause of this result, I used in my next experiment a solution of double the former concentration, mixed with gypsum solution as above, and compared its effect with that of sodium sulphate under equal conditions and also with that of plain water. The sulphite solution was here renewed every day, as I had observed that the oxidation to sulphate proceeded much more quickly than I had surmised. The experiment was commenced with onions and barley plants on the 16th March.

Temperature : min. 8°C, max. 16°C.

I. *Experiments with Whole Plants.*

Experiment with Onions :

After two days a poisonous effect of the sulphite was plainly seen in one of the stems, which dried up on the tip and lost its turgor ; while all the control plants remained healthy.

On the fifth day the plants in the sulphite solution were dead, except the youngest branches which had still some turgor. Two days later all the parts of these plants were killed, while the control plants looked still well except that the tips of the leaves were drying up.

Experiment with Barley :

The plants kept in the sulphite solution showed after two days a poisonous action to a small extent, withering near the tips of the leaves, but on the fifth day some of the large leaves had completely dried up ; other leaves were also damaged, their upper parts having turned yellow, while the lower parts still appeared

healthy and green, as also did the plumula. Two days later I observed with these plants that every leaf was completely withered, while the control plants had still a healthy appearance, with the exception of the older leaves showing a yellow colouration.

The growth of the leaves is seen from the following table :—

Barley plants kept in	Length of Shoot		Percentage of increase
	At the beginning	After 5 days	
Sodium sulphite and gypsum.	24.0 cm.	242. cm.	0.83
Sodium sulphate and gypsum.	23.8 ,,	25.2 ,,	5.88
Water half saturated with gypsum.	24.0 ,,	25.8 ,,	7.50

II. *Experiments with Branches.*

On the 12th April, short branches about 20 cm. in length with many flower buds, of *Prunus Persica* and *Prunus triflora* were placed in 100 c.c. of a 1% solution of sodium sulphite and for control in a 1% solution of sodium sulphate and in plain water ; in these three cases the solutions were half saturated with calcium sulphate.

The result is seen from the following tables :

Prunus Persica.

	Sodium sulphite.	Sodium sulphate.	Water.
April 15th.	No buds opened.	Three buds opened.	Twelve buds opened.
April 20th.	Three buds opened, but two of them were withering ; six were half opened, but perfectly withered, the remaining five remained closed.	Eleven buds entirely opened, three nearly opened ; all healthy.	All thirteen buds opened and were of normal appearance.

Prunus triflora.

	Sodium sulphite.	Sodium sulphate.	Water.
April 17th.	Twenty four buds opened, but commenced to wither.	Twenty seven buds opened.	Thirty four buds opened.
April 20th.	All open buds were dying ; seventeen buds did not open at all.	Thirty buds opened, eleven were half opened, the remaining ten were not opened but healthy.	All forty two buds were opened and in healthy state.

Again, on the 14th April, young branches of *Brassica campestris* about 10 cm. long, bearing numerous flower buds were placed in the same solutions as above. The development of the youngest buds ceased here altogether under the influence of sodium sulphite, while three of the larger buds had opened, but had completely withered on the 20th April. In the two control cases all the larger buds had opened and only one on each case was withering, while the younger buds had increased more than double in size after six days. All the chlorophyll in the young leaves was destroyed by the sulphite, and also partially in the case of the sulphate, probably due to the effect of the solution concentrating in the leaves, while the control branches in gypsum water showed the full preservation of their chlorophyll.

III. *Experiments with Leaves.*

Isolated leaves of *Heliotropium Peruvianum* and *Vitis inconstans* were kept on the surface of a 1% solution of sodium sulphite as above. After six days they were found to be completely killed showing no trace of turgor at all, while the control leaves in sodium sulphate and in water were still in a quite healthy and normal state.

IV. *Experiments with Seeds.*

Seeds of soya bean, radish, and barley were soaked in the same solution as above mentioned, for 48 hours in well closed flasks; the sulphite solution was once renewed after 24 hours, and fifty seeds of each kind were left to germinate, the barley and radish in *Liebenberg's germination apparatus*, the soya bean on moist sea sand. The result is seen from the following table:—

		Number of germinating seeds.			
		After 2 days.	After 3 days.	After 5 days.	After 6 days.
Sodium sulphite.	Radish.	26	32	34	34
	Barley.	37	41	46	47
	Soya bean.	0	7	32	34
Sodium sulphate.	Radish.	34	36	37	37
	Barley.	25	31	44	45
	Soya bean.	31	35	49	49
Water.	Radish.	29	31	31	31
	Barley.	25	30	41	41
	Soya bean.	45	45	49	49

It appears, therefore, that no noxious effect was felt by the radish and barley seeds, but it was felt to some extent by the soya beans, where especially the retardation of germination was very striking.[1] Much depends in these cases upon the facility with which the poison can enter into the embryo.

(1) This might have been due to the absorption of the oxygen dissolved in the water absorbed by the seeds, whereby respiration could not set in as soon as in the control cases.

The poisonous action of the neutral sodium sulphite for phænogams is however quite evident with the *developed* plants. But whether this fact explains sufficiently well the noxious action also of amidosulphonates has to be decided by further experiments.

On the Poisonous Action of Ammonium Salts upon Plants.

BY

S. Takabayashi.

It has been observed that many plants show better development with nitrates as a source of nitrogen than with ammonium salts, further that the yield of a crop decreased in certain instances, when the ammonium salts were used in too high a concentration. Moreover, it is a fact that ammonium salts are never found stored up in plants, while nitrates can be stored to a considerable extent. Plants manured with ammonium salts contain only very small quantities of ammonia[1] while most of the ammonia absorbed in excess is converted into asparagine, as *Mr. Kinoshita* and *Mr. Suzuki* of this College have proved.

A noxious effect of ammonium salts upon the green plants when administered in excess, would probably induce the plants to transform the ammonia quickly into asparagine, which is a perfectly indifferent substance for them.[2]

The poisonous action of ammonium salts must naturally be much more rapid and more clearly exhibited on plants, whose store of carbohydrates is insufficient to transform all the absorbed ammonia within a certain time into asparagine.

A series of preliminary experiments showed that ammonium carbonate in a concentration of 0.5% easily kills various veget-

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(1) *E. Schulze* found with lupin shoots that the nitrogen present in the form of ammonia amounted only to 0.085% of the dry, or 0.0046% of the fresh substance. *U. Suzuki*, of this College found in 100 parts of fresh buck-wheat plants, kept for 9 days in 0.1% ammonium chloride solution, only 0.08 parts of ammonia. (This Bulletin II. No 7.)

(2) Ammonium salts also exert a poisonous action upon animals, that is, if more is administered than can be transformed within a certain time into urea, which, as *Nencki* has shown, is prepared in the liver by way of carbamate of ammonia. As soon as the liver is prevented from accomplishing this, ammonia will increase in the blood and lead to poisonous phenomena. (*Nencki*, *Pawlow* and *Zaleski*.)

able objects within a few days and, although more slowly, even in a dilution of 0.05%.[1] That it is not merely the alkaline reaction of such solution to which the noxious action must be ascribed, becomes evident when we compare the effect of 0.05% solutions of sodium and ammonium carbonate.

Further experiments have convinced me that it is impossible to counteract the noxious action of 0.5% solution of ammonium carbonate by administering at the same time cane sugar or glycerol in 1—2% solution, but on applying ammonium carbonate in a dilution of 0.05% I observed, in several cases at least, a retardation of the noxious action, but not a complete prevention. This result is evidently to be explained by the fact that the ammonium carbonate enters much more quickly by osmosis into the cells than the sugar or glycerol does. When the vegetable cells are provided with a sufficient quantity of glycerol or sugar *before* the ammonium carbonate enters, then the poisonous action of the latter may probably be better counter-balanced.

The phenomena of the poisonous actions of ammonium carbonate were principally the following :—the rootlets of the shoots were softened by loss of turgor, became more translucent, and assumed in many cases a brownish colouration ; isolated leaves placed in the solution gradually exhibited brown spots and lost their turgor, while the liquid assumed a yellowish colour due to organic matter no longer retained by the cells which had died off.

The objects which I used for these experiment were branches of *Polygonum fagopyrum*, *Polygonum tinctorium*, *Capsicum longum*, *Ginko biloba*, and *Quercus*, shoots of soya-beans, peas, beans, and potatoes, petals of sun-flowers and of roses, leaves of the mulberry tree and of the potato plant, and finally algæ, as *Spirogyra*.

These observations induced me to modify my further experiments in the following manner :—A part of the objects (A) was left in darkness for several days until most of the reserve material had been consumed by respiration ; the other part (B) was exposed to the direct sunlight and kept at the same time in a solution of 1% cane sugar. Then the proper experiments commenced by placing several plants of each portion in solutions containing 0.1% and 0.5% of the following salts, and kept in darkness :—

(1) Ammonium sulphate has a much weaker action than the carbonate.

1. Ammonium carbonate.
2. Ammonium sulphate,
3. Ammonium chloride.
4. Sodium carbonate. } for control.
5. Sodium sulphate
6. Water.

Experiment with Barley.

Time of exposure to darkness: seven days; Temperature of greenhouse: minimum 10°, maximum 19° C.

Two young plants 24—28 cm. high were placed in each vessel (March 3).

The noxious action upon the two starving plants (A), of ammonium carbonate in a dilution of 0.1% was very evident, when the plants were compared with the well nourished two control plants (B) in the same solution. The latter had not only numerous young rootlets but also five still healthy leaves which were only a little yellowish at their base, while there was not a single healthy leaf noticed in the other case; a yellowish colouration was seen all along the stems, and the leaves were more or less dried up from the tip downward.

The other control plants (A) kept in 0.1% sodium carbonate were still alive, although they had more or less yellowish leaves, while those in 0.5% sodium carbonate were much injured. However, there was a great difference noticed in the plants (B) placed in sodium carbonate compared with those kept in ammonium carbonate, both in 0.5% solutions, the former carbonate being by far less noxious than the latter, proving that it is not the alkaline reaction itself which exerts the noxious action.

Some etiolation was however noticed more or less in all the plants, and also the withering of some leaf-tips even with most of the plants (B), although this phenomenon was much more noticeable with the plants (A).

The following table shows the results of some of the observations:—

TABLE I.

	Condition.	Leaves.			Remarks.
0.1% Ammonium carbonate.	A	Green Partly yellow Yellow.	0 3 9	12.	No living leaves, no young rootlets, stem only green in a slight degree.
	B	Green Partly yellow Yellow.	2 8 3	13.	Numerous young rootlets.
0.1% Sodium carbonate.	A	Green Partly yellow Yellow.	1 3 6	10.	Young rootlets.
	B	Green Partly yellow Yellow.	2 4 3	9.	Young rootlets.
0.5% Ammonium carbonate.	A	Green Partly yellow Yellow.	0 1 11	12.	Leaves lost their turgor completely and turned yellow.
	B	Green Partly yellow Yellow.	0 7 6	13.	Young rootlets were formed at the beginning but later on were killed.
0.5% Sodium. carbonate.	A	Green Partly yellow Yellow.	0 1 7	8.	Some of the leaves lost their turgor.
	B	Green Partly yellow Yellow.	0 4 4	8.	Rootlets killed, some of the leaves withered.
0.1% Ammonium sulphate.	A	Green Partly yellow Yellow.	1 6 4	11.	Some leaves withered.
	B	Green Partly yellow Yellow.	3 5 4	12.	Young rootlets began to appear.
0.1% Sodium sulphate.	A	Green Partly yellow Yellow.	1 4 2	7.	Some of the old leaves dried up.
	B	Green Partly yellow Yellow.	1 4 2	7.	New rootlets appeared.
0.5% Ammonium ~~carbonate~~ sulphate.	A	Green Partly yellow Yellow.	0 4 11	15.	Rootlets killed.
	B	Green Partly yellow Yellow.	1 4 8	13.	,, ,,

Continued.

0.5% Sodium sulphate.	A	Green 0 Partly yellow 3 Yellow. 6	9.	Rootlets damaged.
	B	Green 0 Partly yellow 4 Yellow. 4	8.	,, ,,
0.1% Ammonium chloride.	A	Green 0 Partly yellow 6 Yellow. 6	12.	No young rootlet formed.
	B	Green 1 Partly yellow 9 Yellow. 3	13.	New rootlets appeared.
0.5% Ammonium chloride.	A	Green 0 Partly yellow 6 Yellow. 6	12.	No young rootlets developed.
	B	Green 0 Partly yellow 10 Yellow. 5	15.	,, ,,
Water.	A	Green 2 Partly yellow 6 Yellow. 5	13.	Some young rootlets developed.
	B	Green 5 Partly yellow 6 Yellow. 3	14.	Numerous young rootlets developed.

Second Experiment.

The experiment was repeated on March 16th with barley 25—30 cm. high and young onion plants, with the modification that only a 0.1% solution of ammoninm carbonate was applied and for comparison sodium carbonate, and further a 1% solution of ammonium sulphate and of sodium sulphate.

After 6 days great differences in the conditions of the plants were noticed. Some etiolation had taken place in all the plants. The ammonium sulphate (1%) had killed the barley plants (A), the sodium sulphate, however, had not done so. The roots and leaves of the plants (A) kept in 0.1% ammonium carbonate were much more damaged than those of the plants (B).

TABLE II.

Barley.

	Conditions	Leaves.		Remarks.
0.1% Ammonium carbonate.	A	Green 1 Partly yellow 3 Yellow 6	10.	Young rootlets were killed.
	B	Green 3 Partly yellow 4 Yellow 5	12.	New rootlets 2 cm.
0.1% Sodium carbonate.	A	Green 2 Partly yellow 4 Yellow 5	11.	No new rootlets.
	B	Green 3 Partly yellow 4 Yellow 3	10.	Numerous rootlets 4-5 cm. long.
1% Ammonium sulphate.	A	All the leaves turned yellow.		No new rootlets.
	B	Green 1 Partly yellow 3 Yellow 5	9.	No new rootlets.
1% Sodium sulphate.	A	Green 1 Partly yellow 3 Yellow 5	9.	Young rootlets appear, but shorter than at B.
	B	Green 2 Partly yellow 4 Yellow 5	11.	Young rootlets appeared.
Water.	A	Green 2 Partly yellow 3 Yellow 5	10.	New young rootlets.
	B	Green 5 Partly Yellow 4 Yellow 3	12.	New rootlets 6 cm. long.

Onion.

	Conditions.	Leaves.	Remarks.
0.1% Ammonium carbonate.	A	Two old leaves killed; tip dried.	Young leaflets 2 cm.
	B	,, ,,	Young leaflets 3 cm.

Continued.

0.1% Sodium carbonate.	A	The old leaves killed.	Young leaflets 1 cm.
	B	,, ,,	Young leaflets 3.5—8 cm.
1% Ammonium sulphate.	A	,, ,,	No young leaflets.
	B	,, ,,	Leaflets 1-4 cm.
Sodium 1% ~~Ammonium~~ sulphate.	A	,, ,,	Young leaflets 1-2 cm., tips of the leaves dried up.
	B	,, ,,	Young leaflets 2-10 cm., tip of the leaves dried up.
Water.	A	,, ,,	Leaflets appeared.
	B	,, ,,	Young leaflets 14 cm. long.

Third Experiment.

Young wheat and barley plants (A) 20—22 cm. high were this time (April 8th) subjected to a longer period of starvation than before, namely 7 days, kept in darkness at 10°—20°C., while the control plants (B) were kept in 1% cane sugar solution as before and in daylight, before the solutions were applied.

Then all the plants were placed in 0.2% and 0.1% solution of ammonium carbonate and for control in water and in 0.2% sodium carbonate. After 3 days it became evident that the plants (A) kept in ammonium carbonate were suffering very much, seven leaves having withered, while the plants (A) kept in water had merely some etiolated but still living leaves, and

showed only the first stages of withering, which proves again that it was not the degree of starvation itself which brought on the damage in the former case, but a decidedly poisonous action of the ammonium carbonate. Further, the plants (B) kept previously in sugar showed only one completely dried-up leaf and three partially dried up under the influence of ammonium carbonate ; further the chlorophyll with the barley plants was better preserved than with the wheat plants. Finally, the control plants kept in sodium carbonate in darkness showed a much better appearance than those in ammonium carbonate.

TABLE III.

Barley.

	Conditions.	Length.(1)		Leaves.	Remarks.
		April 14th.	April 19th.		
0.2% Ammonium carbonate.	A	32 cm.	33.5 cm.	All yellow ; two leaves dried up.	No rootlets ; roots translucent.
	B	32 cm.	35 cm.	All green, but the tips of 3 leaves turned yellow.	No new rootlets ; roots damaged.
0.2% Sodium carbonate.	A	30 cm.	32 cm.	Rather yellow ; two dried leaves.	No new rootlets.
	B	30 cm.	33 cm.	Two leaves partially yellow.	New rootlets.
0.1% Ammonium carbonate.	A	31 cm.	33.8 „	Green 2 Partially yellow 4 Dried up 3	No new rootlets.
	B	30 „	36 „	Almost all the leaves green.	New rootlets developing.
Water.	A	30 „	35.4 „	Green 4 Partially yellow 3 Dried up 1	New rootlets.
	B	29 „	28 „	The leaves green, only two of them partially yellow.	Numerous new rootlets.

(1) The length of the *longest* leaves was measured at the beginning (14 April) and at the close of the experiment (19 April).

Wheat.

	conditions.	Length. April 14th.	Length. April 19th.	Leaves.	Remarks.
0.2% Ammonium carbonate.	A	28-29 cm.	29-30.5 cm.	Yellow 4 Dried up 5	No new rootlets, lost turgor, leaves etiolated.
	B	28-30 cm.	30-33 "	Green 2 Partially yellow 5 Perfectly dried 2	No new rootlets
0.2% Sodium carbonate.	A	29 "	30 "	Almost all the leaves yellow, but still healthy.	Rootlets developing.
	B	30 "	34 "	Green 3 Partially yellow 1 Yellow 3	Rootlets developing.
0.1% Ammonium carbonate.	A	29 "	31 "	Yellow 5 Dried up 6	No new rootlets.
	B	28 "	32 "	Green 2 Partially yellow 5 Dried up 1	New rootlets somewhat formed
Water.	A	30 "	32 "	Green 2 Partially yellow 6 Dried up 3	New rootlets.
	B	28-31 "	31-35 "	Most of the leaves green ; dried up 2	Numerous new rootlets.

A fourth experiment with branches of *Cydonia japonica*, *Pyrus Toringo*, and *Brassica campestria*, covered with buds and partially with flowers, was carried on as before. Again, the noxious effect of ammonium carbonate in 0.1 and 0.2% solutions was quite evident after five days, when compared with the starving plants (A) kept only in water and with the previously well nourished plants (B) kept in ammonium carbonate. But in this case also sodium carbonate had caused some noxious effects with *Pyrus Toringo* (A) and *Brassica campestris* (A). All the blossoms of *Brassica campestris* (A) had withered under the action of ammonium carbonate.

From all the observations described it follows that ammonium salts have a noxious action upon phænogamous plants if there is not a sufficient quantity of sugar present in the plant. The sugar may convert the noxious ammonia into the indifferent asparagine, and therefore the noxious action is not noticed in well nourished plants.

The State of Cane Sugar Manufacture in Formosa.

BY

N. Yamasaki.

The island of Formosa (Longitude 120° 15′ E—122° 4′ E and Latitude 21° 53′ N—25° 16′ N) is possessed of a variety of climates, as it has extensive mountain regions reaching to considerable altitude.[1] While in the low country we find many kinds of tropical trees, the mountains abound in pine forests with a temperate zone vegetation. I mention the following meteorological average data :—

	Daihoku in the Northern part. 1896/97.		Takao[2] in the Southern part. 1883/84.	
	Average temp. °C.	Rain days.	Average temp. °C.	Rain days.
September.	26.8	13.	27.4	13.
October.	24.4	20.	25.5	0.
November.	20.4	19.	23.6	1.
December.	15.5	13.	19.8	0.
January.	15.1	22.	19.0	0.
February.	13.1	25.	17.8	2.
March.	17.3	22.	20.2	4.

(1) The summit of Mount Morison whose altitude has recently been determined by Professor *Honda* is 14,356 feet.

(2)

	1883.				
	April.	May.	June.	July.	August
Average temp. °C.	24.5	27.2	24.3	27.9	27.8
Rain days.	3.	3.	12.	16.	16.

The northern part of the island has a much greater rain fall than the southern part ; in the former the rainy season predominates in spring, in the latter in summer. Frost occurs but very rarely in the former and never in the latter, in which the cane harvest amounts to about 80% of that of the whole island.

There exist two regions of cane cultivation, one on the southern plain and the other in the river basins in the north. The soil is principally sandy with loam soil of the tertiary and quaternary ages.

After the ground has been ploughed and dug, seed cane (head of cane) is planted.[1] Afterwards ridges are formed at distances of from three to four and a half feet, and of a foot high.

Until the cane has reached a height of from two to three feet, the ground is weeded and furrowed two or three times, but no further attention is paid to the crop afterwards.

Irrigation is nowhere resorted to. When the cane shows signs of withering its growth will suffer, but even in that case the farmers do not resort to irrigation.

Seed Cane and Plantation.

The seed cane, planted once in three years, must always have three or four knots and large and healthy buds. They are first soaked for several days, until the buds begin to sprout, and then placed from 8 to 18 inches apart obliquely in holes made by hand or with a kind of sickle. The principal manures used are human and animal excrement, vegetable refuse, sometimes also oil cakes, and rarely bone dust. Mineral manure has not heretofore been applied.

Kinds and Crop of Sugar Cane.

There are cultivated three kinds called (a) bamboo cane, (b) red cane, and (c) wax cane or white cane with much broader leaves than the others.

On examining the three kinds from the same district I obtained the following results :—

	a).	b).	c)
Spec. gravity of juice.	1.064	1.071	1.071
Sucrose „ %	13.08	16.34	15.44
Glucose „ %	.32	.44	.46
Coefficient of purity.	84.	95.	86.
Fibre of cane.	13.46	11.42	11.75

(1) Between January and April.

Although red cane and wax cane are more profitable than bamboo cane for sugar manufacture, the latter serves almost exclusively for that purpose, probably on account of some other unfavourable properties of the former, as for instance the great brittleness of the stems.

The cane is raised in the first year from seed cane, but in the following two years from the roots. The harvest takes place between November and April; the amount varies between 20 and 40 tons per acre near Daihoku.

Attacks by insects and fungi occur usually to a certain extent. Of the former, a kind of *Hemiptera* and a larva of a kind of *Diptera* may be mentioned.[1] But more serious damage is caused by the larvae of *Diatraea strialis*, *Snell* (*Lepidoptera*), which corrode the pith of the cane. Diseases caused by fungi are not so frequent, and the *serch* disease so prevalent in Java seems to be unknown,[2] but some damage is done by a *Sclerotium* and *Cercospora Köpkei*, which latter causes red spots on the cane leaves.

Chemical Observations.

The sample of sugar cane (bamoo cane) that served for my investigations came from a plantation near Daihoku, I separated the juice merely by means of a small hand-roller, as is the usual practice in Formosa; hence the extraction was not complete. The juice of the knots and internodes of the cane were separately examined (equal weights) on the 24th February (a) and 5th March (b), with the following results:

		Sp. grav.	Sucrose.	Glucose.	Coeffts. of purity.
(a).	Knot.	1.050	9.79	.33	78.3
	Internode.	1.055	11.28	.42	86.5
(b).	Knot.	1.065	13.13	.19	87.6
	Internode.	1.070	14.39	.22	89.9

From this we observe that internodes contain much more sugar, and in a higher degree of purity, than knots; hence such cane as has many knots is not favourable. The low lands near Daihoku which are frequently inundated are very fertile, as may

(1) Also some kinds of *Coleoptera* occasionally do some damage.

(2) It has been recently asserted that this disease is not caused by fungi.

be judged by the following results obtained with manured cane (a) and unmanured cane (b) taken from the experimental field of the Government.

		Sp. grav.	Sucrose.	Glucose	Coeffts. of purity.
Febr. 28.	(a).	1.070	13.08	.15	79
	(b).	1.061	10.20	.13	73
March 5.	(a).	1.070	14.31	.20	87
	(b).	1.068	10.15	.23	63

The manure consisted of animal feces as well as their ash and ground-nut cake.

The relative amount of sugar in the top, middle, and lower part of the cane is seen from the following table :—[1]

	Sp. grav.	Sucrose.	Glucose.	Coeffts. of purity.
Top.	1.055	12.32	.38	92.3
Middle.	1.070	14.54	.27	89.7
Lower part	1.068	15.19	.25	94.9

Near the top, therefore, there is much more glucose or uncrystallzable sugar than near the base.

Also both healthy and diseased canes were examined, with the following results :

	Sp. grav.	Sucrose.	Glucose.	Coeffts. of purity.
Healthy.	1.055	12.19	.46	90.2
Diseased.	1.050	10.43	.66	80.0

The diseased cane had been attacked by insects, was injured by the wind, and was covered with fungi and worms. The yield of sugar was thus considerably decreased. Samples of juice from a manufactory of a Chinese were separatedly examined, the average result being as follows :

Sp. gr.	Sacharimeter Brix.	Sucrose.	Glucose.	Coeff. of purity.
1.061	15.6	13.48	.61	86.

In the south the quality of the juice is probably superior to this.

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(1) I divided the whole body into three equal parts and took equal weights of these parts.

Description of the Present Mode of Crude Sugar Manufacture.

Cane-crushing is effected in quite a primitive manner with granite rollers moved by buffaloes. The juice is collected into the receiving pan through a bamboo pipe. In the manufactory are eight or nine pans with wooden rims. The first of these receives the juice. The second is the clarifying pan, while the others serve for evaporation. After clarification with lime the juice is conveyed into the setting tank which is placed between the second and third pans, and is finally concentrated in the other pans to which fire is directly applied. When sufficiently concentrated the juice is conveyed to a large wooden box, about six feet and a half in length, six feet in width, and half a foot in height and after about ten minutes' cooling it is stirred with a kind of shovel, whereby the crystallisation is completed in from forty to fifty minutes.

On an average, about six or seven hundred pounds of sugar are daily manufactured in one factory; but only about six per cent of sugar is obtained from the cane, showing the very poor system still in vogue.

Samples of brown or crude sugar from the northern part of the country were examined with the following result :—

Regions.	Sucrose.	Glucose.
Santenpo (Daihoku)	81.05	5.16
Karioko (Shinchiku)	77.57	7.81
Getsubi (,,)	78.57	7.67
Suikioto (,,)	70.60	4.76
Taiko (Bioritsu)	60.86	9.60
Average.	73.79	7.00

The manufacture of *white* sugar is also carried on in an exceedingly primitive way. The crude sugar juice is poured into a conical percelain jar[1] provided with small holes at the bottom for the discharge of the molasses.

After about four days moist clay[2] is spread on the surface of the hardened syrup. After about ten days the clay becomes

(1) Each jar may contain about 120 lbs. of the crude sugar.

(2) Sometimes mud from sewers (!) is employed.

hard, and has by capillary attraction removed the coloured mother-liquor from between the crystals.

One third of the sugar present is thus decolourised. The resulting white sugar is removed, and new softened clay is placed upon the still brown part in the vessel which is thus decolourised in about twenty days. Therefore, the decolourisation of one jar is a work of about thirty days. This description shows the exceedingly primitive condition of the sugar manufacture in Formosa. My enterprising countrymen will certainly by application of modern systems change this state of things, so that Japan will be able to supply its own market entirely with home-made sugar.

According to the Custom House returns, the amount of sugar exported from Formosa to Japan proper and to China was

		Brown sugar.	White sugar.
in	1890	676.773 tan(1)	45.869 tan
,,	1893	480.529 "	29.391 "
,,	1895	570.966 "	59.483 "

If we take into account the quantity consumed by the native population, the total annual amount of sugar produced is about 1,600,000 tan or a hundred million kilos. The amount of brown sugar imported to Japan proper was

in	1890	344,945 tan	in	1893	180,934 tan
,,	1891	273,378 "	,,	1894	309,757 "
,,	1892	262,892 "	,,	1895	243 719 "

(1) One tan is equal to about 63 kilo.

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Über den Küstenschutzwald gegen Springfluthen.

VON

Dr. Seiroku Honda, *a. o. Professor der Forstwissenschaft an der Kaiserlichen Universität zu Tokyo.*

Es giebt kein grausameres Unglück als eine durch ein Meeresbeben hervorgerufene Hochfluth an der Küste. Eine solche kam, wie bekannt, am 15 Juni 1896 an der japanischen Nordostküste wieder vor. Der stille Ocean erhob sich plötzlich. Die haushohen Wellen brachen ein und überschwemmten mit Pfeilgeschwindigkeit einen ca. 150 englische Meilen langen Küstenstrich vollständig. In nur 18 Minuten * wurden 9381 Häuser und 6930 kleinere Schiffe und Boote zerstört oder weggeschwemmt und 21,909 Menschen vernichtet, 4398 sehr stark verwundet.

Die Wissenschaft ist bezüglich der Ursache der Hochfluthen oder Meeresbeben noch nicht im Klaren; noch weniger existiert irgend ein Vorschlag, wie man sich gegen eine solche Eventualität einiger Massen schutzen könnte.

Japan wird leider sehr häufig von solchen Unglücksfällen heimgesucht. Vor 184 Jahren war die nämliche Küstenstrecke überfluthet worden, was 1200 Menschen das Leben kostete. Weitere Hochfluthen suchten diese Küstenstrecke zwischen *Sendai* und *Aomori* vor 60 und vor 41 Jahren heim.

Die Frage, ob gar keine Vorkehrung möglich wäre, um die Wirkung der Hochfluthen abzuschwächen, ist daher umsomehr berechtigt, als nicht nur die oben erwähnte Küstenstrecke, sondern auch viele andere Strecken der japanischen Küste von solchen Hochfluthen heimgesucht werden. Die Statistik zeigt uns, dass im Durchschnitt von 6 aufeinander folgenden Perioden von je 50 Jahren 6 Hochfluthen an den verschiedenen Küstenteilen beobachtet worden sind. Herr *Ogashima* hat aus den älteren Berichten eine interessante statistische Zusammenstellung publiziert. Ich führe hier nur die in den letzten 300 Jahren beobachteten Hochfluthen an.

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* Grosse Fluthwellen brachen nur 3 mal mit je ca. 6 Minuten dauernder Pause ein.

Japanische Zeitrechnung.	Nach Christi Geburt.	Hochfluthen.
2251—2300	1592—1641	8
2301—2350	1642—1691	2
2351—2400	1692—1741	7
2401—2450	1742—1791	7
2451—2500	1792—1841	5
2501—2550	1842—1891	6
	In 300 Jahren :	35

Die Ursache des Meeresbebens : sei es „Erdsturtz des tiefen Tascarora Meers" „vulkanische Wirkung der tiefen Schichten" oder „eine tektonische Einwirkung des Erdkörpers" wollen wir hier nicht weiter erörtern, da diese Erklärungsversuche noch durchaus eines sicheren Bodens entbehren. Hier handelt es sich nur um die Frage, ob es durch irgend welche Vorkehrung möglich sei, den Schaden durch eine Hochfluth an der Küste zu verringern. Zu diesem Zwecke hat man entweder Verlegung der Wohnungen auf die Anhöhen oder eine verbesserte Bauart der Häuser vorgeschlagen, aber es hat sich, wie selbstredend, gezeigt, dass der erstere Vorschlag praktisch nicht gut durchführbar ist, und es liegt auf der Hand, dass der letztere Vorschlag wenig Aussicht bieten kann in Anbetracht der gewaltigen mechanischen Kraft, mit der eine Hochfluth in die Küste einbricht.

Indessen von den Thatsachen ausgehend, dass Wälder gegen heftige Winde, Flugsand und gegen Bodenrutschungen und dergleichen sichereren mächtigen Schutz verleihen, und dass die früheren *Daimyos* so viele Schutzwaldungen gegen Meereswinde an vielen Küstenstrichen angelegt haben, um hauptsächlich den Ackerbau zu beschützen und dieselben unter ziemlich drakonischen Gesetzen zu erhalten strebten, stellte ich mir die Fragen, ob es sich nicht von dem letzten grossen Meeresbeben constatieren lässt, dass Wälder irgend einen Schutz gegen die Fluth gewährt haben und, wenn dies der Fall ist, welche Baumarten dann am besten wiederstanden haben und was für eine Waldform sich als die sicherste gezeigt hat.

Um diese Fragen studieren zu können, reiste ich nach der Unglückstätte. Ich vermochte dort während meines zwei Wochen dauernden Streifzugs durch grössere Gebiete manches zu beobachten, was nicht ohne Interesse sein dürfte und im Folgenden dargestellt werden soll.

Auf diesen Excursionen durch diese Stätte grauenvoller Verwüstung wurde ich in meinem Streben durch Herrn Oberforstmeister *M. Hashiguchi* mit grosser Aufopferung unterstützt, wofür ich hier meinen herzlichsten Dank ausspreche.

I. Schutzwirkung des Waldes.

Der Schutz, den der Wald hier gewähren soll, ist natürlich lediglich ein mechanischer. Er soll die grosse Geschwindigkeit des vordringenden Wassers mässigen, was durch einen dichten Bestand sehr leicht zu geschehen scheint. Indem das Vordringen des Wassers sich verlangsamt, bleibt nicht nur Zeit genug zur Rettung der hinter dem Walde wohnenden Menschen, sondern der Wald verhindert auch das Abschwemmen der Holzhäuser ins Meer, weil auch diese Geschwindigkeit durch den Wald wesentlich verringert wird.

1. Die Fluthhöhe* betrug in Wirklichkeit nur 2-3 meter. Dieselbe wurde meistens nach der Meereshöhe des Landes abgeschätzt bis zu welcher das Wasser eingebrochen war, oder nach Höhen der steilen Küstenfelsen beurteilt, bis zu denen die Wellen emporgeschleudert wurden.

Wenn man aber die äusserst grosse Schnelligkeit der Fluthwellen in Betracht sieht, so wird es leicht begreiflich, dass das Wasser in den sich verengernden Thälern mit steilen Wänden zu einer ungeheueren Höhe aufstaute und weit höher hinauf geschleudert wurde als an den flachen Strecken der Küste, wenngleich die Fluthhöhe selbst nur eine mässige Grösse hatte. In der That fand ich bei solchen engen Thälern, dass Pflanzen bis zu einer Höhe von 15 Meter an den Abhängen abgestorben waren, eine Erscheinung, die ich niemals an den sanften Erhöhungen an der Meeresküste beobachtet habe. Hier fand ich immer solche Pflanzen nicht abgestorben, welche über 3 Meter hoch an den Abhängen gewachsen waren; auch die über 3 Meter Höhe befindlichen Baumtheile zeigten keine Spur des Meereswassers.

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* Einige Zeitungen berichten allerdings von einer 60-150 Fuss hohen Fluthhöhe und von dem Weggeschwemmen mancher Bäume. Solche Thatsachen lassen den Werth eines Schutzwaldes als ein Schutz gegen Überfluthung ganz illusorisch erscheinen. Allein diese exorbitanten Angaben beruhen offenbar auf der unstatthaften Identificirung der Fluthhöhe mit der Höhe der Fluthspuren, welche allerdings solche ungeheuere Hohen erreichen können.

Bei den in der Nacht vom 11 zum 12 October 1837 in Calcutta eintretenden Meeresbeben, welches 200 Häuser fortgerissen und 300,000 Menschenleben vernichtet hatte, betrug die Wasserhöhe nur 40 Fuss und bei der von 12 zum 17 November 1837 von den *Andamanen* nach *Coringa* gehenden Hochfluth, welche 700 Menschen zur See, 6,000 zu Land vernichtet hatte, nur 8 Fuss. Bei dem im Jahre 1876 bei Bengalbay in Indien beobachteten Meeresbeben, bei welchem 215,000 Menschen getödet wurden, war die Fluth 45 Fuss hoch. Ein Schiffskapitän *Fitzroy* beobachtete eine Hochfluth von 20 Fuss Höhe im Jahre 1835 an der mexikanischen Küste *Talcahuano.* Im Jahre 1755 wurden in Lissabon 60,000 Menschen durch eine Hochfluth getötet, deren Höhe nur 40 Fuss betrug, und im Jahre 1724 vernichtete eine Hochfluth von 24 m Höhe das ganze *Callao* in *Peru.** Obgleich die Fluthhöhe bei solchen älteren Angaben wie in dem vorliegenden Fall vielleicht viel zu hoch geschätzt sein mag, finde ich doch nirgends eine Höhe angegeben, welche 24 m überstiegen hätte. Dass ein Wald von ziemlich dichtem Bestand und aus 60-150 Fuss hohen Baumstämmen bestehend, wohl erheblichen Schutz gegen solche Überfluthung des Meeres zu gewähren vermag, welche die Küsten der Nordostprovinzen des Kaiserreiches verwüstet hat, ist desshalb anzunehmen.

2. Grosse dicke Kieferstämme sollen durch die Fluthen entwurzelt und in Reisfelder geschwemmt worden sein. Indem ich selbst solche Ortschaften (besonders bei *Ishihama* bei *Karakuwa*) besuchte, fand ich dort in der That einige Stämme in den Reisfeldern liegen. Allein es war hier kein Wald vorhanden gewesen, sondern nur eine einreihige Allee auf einem ungefähr 50 Meter langen und ca. 2 Meter hohen Damm, welcher das Meereswasser von den Reisfeldern abhalten sollte. Nun bestand dieser Damm aus lockerer Erde und erfuhr von jeher häufige Schädigung durch die eindringenden Meereswellen. Diesmal hatte die Fluth den Damm total ausgewaschen und die

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* Die angeführten Beispiele sind in den folgenden Werken erwähnt:

Hoernes: Erdbebenkunde, 1893.

Rudolf: Über submarine Erdbeben und Eruptionen, Zeitschrift für physikalische Erdkunde 1987-95.

Mungo Ponton: Earthquakes, Their History, Phenomena und Probable Causes, London 1888.

nahen Reisfelder ruiniert. Es war daher kein Wunder, dass starke Bäume weggeschwemmt worden sind. Auch in anderen Fällen konnte ich mich davon überzeugen, dass nur einzeln stehende schwächere Bäume aber nie solche in dichterem Bestande ausgerissen und weggeschwemmt sind. Grössere Bäume in der Nähe der Häuser erwiesen sich oft von grossem Nutzen, weil die Menschen sich oft hierauf retteten, während in der Umgebung sonst Alles nach dem Meere hingeschwemmt wurde. Wenn einzeln stehende Bäume schon Nutzen gestiftet haben, so ist dasselbe von einem dichten Bestande in noch höherem Grade zu erwarten. Sorgfältige zahlreiche Beobachtungen liessen mich unzweifelhaft den Schutz erkennen, welchen ein Wald an den Meeresküsten gegen die dahinter liegenden Ortschaften aus zu üben vermag. Man hat schon bei dem Meeresbeben von Bengalen eine oben angegebene Schutzwirkung des Waldes beobachtet: Blanford bemerkte: es seien beiläufig 100,000 Menschen ertränkt worden, allein die Häusergruppen sind hier in der Regel von Bäumen umringt, sonst wäre der Verlust noch weit grösser gewesen.* Ich teile hier auch einige Wahrnehmungen von den diesmaligen Hochfluthen in gleicher Hinsicht mit.

Schutzwald zu *Takata*.

Der zwischen den Städten *Takata* und *Imaisumi* liegende Küstenschutzwald ist vor ungefähr 250 Jahren von dem damaligen dortigen *Daimyo* begründet worden, hauptsächlich, um den Ackerbau gegen den Meereswind zu schützen. Als nun der Wald sich höher entwickelte, nahm man wahr, dass er nicht nur vortrefflichen Schutz dem Ackerland gegen Meereswind leistet, sondern auch, dass die Fische sich in der Nähe des Waldes bedeutend vermehrten, und liess dem Bestande eine besondere Pflege angedeihen. Als nun vor 62 Jahren ein Meeresbeben eintrat, und eine Hochfluth diese Küstengegend überschwemmte, starb der Bestand grösstenteils ab, allein er hatte den Stätten *Takata* und *Imaisumi* einen solchen Schutz gewährt, dass sie nur mit geringem Schaden davon kamen. Nach dieser Vernich-

* Hörnes: Erdbebenkunde, Seite 444.

tung begründete der *Daimyo* den gegenwärtigen Bestand, welcher 10,05 ha gross ist und hauptsächlich aus ca. 60 jährigen *Pinus Densiflora* mit Mischung von *P. Thumbergii*, *Zelkowa acuminata* und wenig *Cryptomeria japonica*, Juniperus=und Quercusarten besteht; Als Unterwuchs findet man zahlreiche und verschiedene Laubhölzer. Von *P. Densiflora* zählt man im ganzen ca 11.300 Stämme von Brusthöhendurchmesser 20-30 cm und Baumhöhe im Durchschnitt 20 m. Der ganze Bestand von ca 100 m Breite und 1,000 m Länge bildet einen langen Gürtel entlang der Meeresküste. Von diesem Gürtel bis nach *Takata* und *Imaisumi* dehnt sich eine gleichmässige Tiefebene hauptsächlich mit Reisfeldern und einigen kleinen sumpfigen Seeen aus, Während eine solche Anlage eigentlich am meisten von einer Hochfluth geschädigt werden sollte, trat bei der letzten Katastrophe fast gar keine Beschädigung ein, so dass man allgemein vermuthete die Hochfluth wäre in schräger Richtung in die Bucht *Takata-wan* eingebrochen, und hätte so mehrere Reflectionen erlitten, dass die Küste bei *Takata* nicht von der Hauptmasse des Wassers getroffen wurde, wie dieses durch die Pfeile auf Tafel IV angedeutet worden ist. Da aber solchen Vermuthungen jede wissenschaftliche Stütze fehlt und an anderen Stellen kein ähnlicher Fall sich auffinden liess, da ferner sogar drei nahe an der Küste aber ausserhalb des Bestandes vorhandene Häuser vollständig weggeschwemmt wurden, fällt jene vage Vermutnng in sich zusammen. Folgende Tabelle giebt die Schadenstatistik der Umgebung der *Takata*bucht an, wobei zu bemerken ist, dass die Dörfer *Shiwoya* und *Tatsu* keinen Schaden erlitten haben, weil sie hoch am Bergabhang liegen.

Die Tafel IV macht die Schadenverhältnisse in der Umgebung der *Takata*bucht augenscheinlich, die grünen Linien bedeuten Küstenschutzwald, die rothen parallen Linien die durch Hochfluth nur überschwemmte Landestheile, während die rothen Gitterlinien diejenigen Orte anzeigen, wo zahlreiche Menschen getötet und Häuser vernichtet wurden.

Ortsname.	Anzahl der Häuser vor dem Unglück.	durch Fluth beschudigte Häser.				Volkszahl vor dem Unglück.	Menschen.		
		weggeschwemmt.	völlig demolirt.	halb demolirt.	durchnässt.		getödtet.	stark Verwundet.	leicht verwundet.
Naga-saki.	43	10	0	7	5	311	49	1	12
Tako-no-ura.	67	38	5	2	1	459	87	3	7
Ishi-hama	25	7	0	1	1	144	35	3	3
Hoso-ura	90	75	0	1	9	364	319	5	31
Ko-hoso-ura.	25	5	0	2	2	191	28	1	3
Suisaki-tomari	97	51	3	2	2	580	251	8	9
Monno-hama	33	14	2	1	2	218	90	60	5
Oka-hara	32	9	0	3	2	183	43	4	0
Tada-ide	58	3	0	1	0	400	232	0	0
Naga-hora.	63	18	0	0	1	453	71	3	0
Ono	36	19	1	2	1	229	52	3	0
Taya	38	19	0	0	0	200	58	3	0
Mutsu-ura	17	6	0	1	1	104	11	1	0
Ne-saki.	52	12	0	2	0	252	88	0	0
Atsumari	11	10	0	0	0	80	77	1	0
Nagasa-hama	51	18	0	1	0	389	54	1	0
Tomari.	74	43	4	3	5	510	130	2	14
Ushiro-hama	17	6	0	0	0	91	8	2	6
Ōyō	51	7	0	0	0	371	20	0	1
Tano-ura Shiwoya	wegen ihrer hohen Lage erlitten diese keinen Schaden.								
Mikka-ichi	15	5	0	2	3	99	2	7	21
Rio-gai	27	0	0	19	2	139	1	0	0
Hamada	175	4	1	8	6	1.321	23	0	7
Waki-no-sawa	58	0	0	4	6	331	1	0	2
Numata	115	4	3	4	7	753	0	0	2
Naga-suna	92	2	0	0	14	586	1	0	0
Takata	Keine Häuser- und keine Menschenverluste.								
Imaisumi	Nur wenige Häuser etwas beschädigt.								
Kawa-guchi. Minato Koya Nagabe	253	28	11	17	11	1781	24	6	27

Indem ich die Fluthhöhe in diesem Walde nach der Höhe der welken Zweige mass, fand ich, dass sie nur 2 m hoch war.

Anderthalb Monate nach dem Unglückstage waren die jungen Exemplare bis zu 2 m hohen *P. densiflora* vollständig abgestorben und ältere Exemplare fingen meist an gelb zu werden, so dass die meisten Stämme des *P. densiflora* wohl nach und nach abgestorben sein mögen, während *P. Thumbergii* und *Juniperus*arten, so gut junge wie ältere Exemplare noch lebhaftes Wachsthum zeigten. Die *Cryptomeria* und fast alle Laubhölzer waren schon ganz verwelkt, nur einige entwickelten wieder neue Blätter.

Schutzwald der Umgebung der *Miyako*bucht.

Die Stadt *Miyako* an der *Miyako*bucht ist eine sehr bedeutende Hafenstadt in *Miyagi-ken*. In ihrer Umgebung, besonders an den Küstenstrecken der Bucht findet man sehr viele ziemlich stark bevölkerte Ortschaften, von denen die meisten mit Küstenschutzwäldern versehen waren; bei dem diesmaligen Meeresbeben ergab sich nun Folgendes (Siehe Tafel V):

a.) Schutzwald zu *Fujiwara*.

Die Waldfläche ist 1378 ha gross, ca 40 m breit und 330 m lang; sie dehnt sich unmittelbar an der Meeresküste von Ost nach Nord aus und bildet einen Gürtel zwischen der Küste und der Stadt *Fujiwara*, welche auf derselben Tiefebene steht wie die Waldfläche selbst.

Der Waldbestand besteht hauptsächlich aus grossen *P. Densiflora* vermischt mit *Cryptomeria japonica*, *Zelkowa acuminata* und *Gleditschia triacanthes*. Bei *P. densiflora* schätzte ich die Stammzahl auf ca 400 und das Alter auf ca 200 Jahre. Der Brusthöhendurchmesser hat im Durchschnitt ca 40 cm. und die mittlere Stammhöhe ca 45 m. von *Cryptomeria* findet man ca 20 Stämme von 15-30 Jahren, meist im Innern des Waldes ganz nahe bei der Stadt. *Zelkowa* und *Gleditschia* sind sehr hoch, aber nur durch 5-6 Stämme vertreten. Als Unterwuchs findet man zahlreiche kleine *Quercus*arten, *Zelkowa*, *Elaeagnus*, *Rosa* und andere verschiedene Straucharten mit einigen Bambus-Stämmen.

Die diesmalige Hochfluth erreichte im Innern des Bestandes eine Höhe von 1,2 m; sie strömte nachweislich einerseits direct

herein vom Meer, anderseits indirect von dem Fluss *Miyakogawa* vor. Der Bestand befand sich ungefähr 5 Stunden lang im Wasser, und wo die Waldstreu nicht die Sandfläche bedeckte, war eine bis ca 30 cm tiefe Erdschicht weggeschwemmt; doch wurde keiner der Baumstämme dadurch entwurzelt. Ein Monat später ist der Hauptbestand von Pinus langsam gelb geworden und nach zwei Monaten schrieb man mir von dort her, dass die grösseren *Pinus*stämme ganz abgestorben wären nud dass vielleicht die Hälfte der Stämme in dem ganzen Bestande Zeichen des Absterbens erkennen liessen. Die *Cryptomeria* und den Jungwuchs von *P. densiflora* fand ich auch nach 30 Tagen schon völlig abgestorben. Die Blätter der Laubbäume und Sträucher mit Ausnahme von *Rosa rugosa* waren nach ein paar Tagen meist schon schwärzlich und nach und nach abgefallen, allein ein Monat später entwickelten sie meist wieder junge Knospen.

Die Stadtheile, welche hinter dem Schutzbestand standen, hatten in keinem Hause Schaden erlitten und dort ist kein Menschenleben vernichtet worden, wenn gleich die ganze Stadt langsam überschwemmt wurde. Nur einige Häuser, welche direct am Fluss standen, wurden durch die Fluth zerstört. Der gegenüber der Stadt *Fujiwara* liegende Stadtheil *Kuwagasaki* war dagegen vollständig zerstört und an 100 Menschenleben vernichtet worden. Die dortige Bevölkerung erklärt *unumwunden*, dass der Wald allein diesen grossen Unterschied herbeigeführt habe.

b.) Schutzwald zu *Koshida* beim Dorf *Tsukei*.

Waldfläche 2,943 ha gross, ca 40 m breit 700 m lang. Der Waldgrund besteht aus Sandboden; die Umgebung ist eine gleichmässige Tiefebene, welche östlich an dem Meer, nördlich und südlich an Ackerboden, westlich aber an einer Reihe Häuser grenzt, welche das Dorf *Tsukei* bilden. Der Hauptbestand besteht hier aus *P. densiflora*; unter diesen waren ähnlich wie bei *a*) grosse 200 jährige Stämme ca 1000, 40 jährig ca 10 m hohe 10-12 cm dicke Stämme ungefähr 200 Stück. Auch 29 jährige ca 10 m hohe *Cryptomeria japonica* war durch 10 Stämme vertreten; ausserdem verschiedener Unterwuchs wie bei *a*).

Dieser Schutzwald ist von dem Schutzwald *a*) ca 200 m weit entfernt und hier waren Fluthöhe und Schadenverhältnisse

ganz ähnlich wie bei *a*). Das Verhalten der Laubbäume gegen Meereswasser war ganz wie bei *a*).

Nach der Hochfluth ist von der 40 jährigen *P. densiflora* beinahe 70 % ; *Cryptomeria japonica* ganz vollständig abgestorben; von 40 jähriger *P. densiflora* sind bis Septenber 1896 nur 40 Stämme verwelkt.

Durch diesen Schutzwald allein wurden sowohl Menschenleben als Häuser des Dorfes *Tsukei* von der Vernichtung bewahrt; auch blieb viel Ackerland verschont. Die dortige Bevölkerung schreibt diesen Schutz einzig und allein dem Umstande zu, dass dieser Wald viel dichter als bei *a*) war.

c.) Staatswald zu *Asukagata* beim Dorfe *Tsukei.*

Die Waldfläche 0,972 ha gross, ca 30 m breit 300 m lang, bedeckt gleichmässig einen tiefen Sandboden ; sie grenzt östlich an dem Meer, südlich an Grasflächen, westlich und nördlich aber an Dorfschaften.

Haupt- und Nebenbestand sind ziemlich ähnlich wie bei dem Schutzwald *b*), und zwar von 200 jährigen Stämmen sowohl wie von 50 jährigen sind ca je 100 Stück vorhanden. Seit den letzten zwei Jahren sind als Unterpflanzung 1700 Stück *Pinus densiflora* frisch angepflanzt worden. Diese wurden durch die Hochfluth vollständig getötet, ebenso von dem alten Bestand ca 90%. Das Verhalten der Laubhölzer war hier genau wie bei *a*). Nur die hinter dem Schutzwalde liegenden Strecken waren von der Hochfluth verschont geblieben, während die übrigen benachbarten Strecken eine fürchterliche Verwüstung erfuhren.

d.) Staatswald zu *Akamai* beim Dorfe *Tsugaruishi.*

Diese Waldfläche 4,312 ha gross ca 100 m breit 430 m lang, bedeckt einen ebenen tiefen humusreichen Sandboden und grenzt nördlich an dem Meer, östlich an Sandebenen, und Ackerland südlich aber an Reisfeldern, westlich befindet sich der ungefähr 60 m breite *Akamai*fluss.

Der Bestand besteht aus *Pinus densiflora* und *Quercus*arten, *Zelkowa acuminata* und anderen Laubhölzern. *P. densiflora* war 40 Jahre alt und 15 m hoch, während die Laubhölzer von sehr verschiedenen Alter und Grösse waren.

In diesem Walde stieg die Fluth vom Meer und von

Akamai-Fluss aus ca 1 m hoch, aber die hinter ihm liegenden Reisfelder waren weit weniger beschädigt als die der nicht geschützten Nachbarschaft. Von *P. densiflora* ist ca 90% abgestorben. Das Verhalten der Laubbäume gegen Meereswasser war hier ganz ähnlich wie bei *a*). Bei der vor 42 Jahren stattgefundenen Hochfluth war auf dieser Fläche ebenfalls ein alter *P. densiflora*-Bestand vorhanden, aber durch die damalige Hochfluth gänzlich getötet worden. Damals hat der Klanfürst wieder den gegenwärtigen Bestand anpflanzen lassen, ein Beleg dafür, dass man schon zu jener Zeit den grossen Werth eines Waldes als Schutz gegen Überfluthung erkannt hat.

Tafel V zeigt die Schadenverhältnisse der Umgebung der *Miyako*-bucht.

II. Verhalten verschiedener Holzarten gegen Meereswasser.

Vohergehende Darlegungen mögen genügen, uns zu überzeugen, dass der Küstenwald wohl den kräfligsten und zuverlässigsten Schutz gegen die Überfluthung des Meeres zu gewähren vermag. Es handelt sich darum zu untersuchen, welche Holzarten am besten zu diesem Zwecke geeignet sind. Zu dieser Untersuchung dürfte sich nicht leicht wieder so gute Gelegenheit darbieten als die diesmalige Überschwemmung, da bis jetzt niemals eine solche Meeresüberfluthung beobachtet worden ist, welche so tief in die Waldbestände eingedrungen wäre.

Da das Wetter bald nach dem Unglückstage sehr heiss und trocken war, so beobachtete ich, als ich fünf Wochen später dorthin reiste, bei den vom Fluthwasser erreichten Bäumen häufig Verwelken und von weitem erkennbare Schwärzung der Nadeln und Blätter. Gewisse Bäume blieben jedoch ausschlagfähig, einige aber waren gar nicht beschädigt. Ich war so im Stande leicht die empfindlichen von den wiederstandfähigen Baumarten zu unterscheiden.

Immergrüne Laubbäume sind im grossen Durchschnitt wiederstandfähiger gegen Hochfluthen als winterkahle. Laubbäume mit lederartigen Blättern sind ferner immer wiederstandfähiger als diejenigen, welche zart belaubt sind. Nadelbäume zeigen im Allgemeinen wohle ein späteres Verwelken als Laubbäume, allein Schäden bei den ersteren sind immer beträchtlicher als

bei den letzteren; bei den Laubbäumen werden meist nur die Blätter oder neue Triebe beschädigt, die Zweig- oder Stammteile bleiben ausschlagfähig, während einmal verwelkte Nadelbäume dem Tode unentrinnbar verfallen sind.

I. Klasse.

Vollkommen widerstandsfähige Holzarten, d. h. solche, die in allen vom Fluthwasser erreichten Beständen in verschiedenen Altern völlig intact geblieden waren:

	Japanischer Name.
Pinus Thumbergii, Parl	*Kuromatsu.*
Juniperus rigida, S. et Z.	*Muro.*
Juniperus chinensis, L.	*Byakushin.*
Juniperus chinensis, var. procumbens, Endl.	*Sonare.*
Rosa rugosa, Thumb.	*Hamanasu.*
(*Pittosporum Tobira, Ait.*)*	(*Tobera*).
(*Litsæ japonica. Iuss.*)	(*Hamabiwa*).
(*Pandanus odoratissimus, L.*)	(*Tako-no-ki*).
(*Euphorbia Tirucalli.*)	(*Ryoku-sango*).

II. Klasse.

Ziemlich widerstandsfähige Holzarten, d. h. solche, die nur am Blattrande oder deren neue Triebe verwelkt, deren Krone jedoch nicht abgestorben waren:

Celtis sinensis, Pers...	*Enoki.*
Zelkowa acuminata, Pl.	*Keyaki.*
Quercus glandulifera, Bl...	*Ko-nara.*
Diospyros Kaki, L. F.	*Kaki.*
Quercus dentata, Thumb...	*Kashiwa.*
Salix-Arten.	*Yanagi-Rui.*
Thea japonica, Nois...	*Tsubaki.*
Hamamelis japonica, S. et Z.	*Mansaku.*
Bambs-Arten.	*Take-Rui.*
Koelreuteria panisulata, Laxm.	*Mukugenji.*
Evonymus europaæ, L. var. Hamiltoniana, Maxim.	*Mayumi.*

* Die eingeklammerten Holzarten sind nicht solche, die bei diesmaliger Hochfluth beobachtet wurden, sondern sie sind an weiter südlich gelegener Meeresküste von Japan bei meiner Reise nach *Kiushu* und *Formosa* als gegen Meereswasser wiederstandsfähige Holzarten von mir beobachtet worden.

Evonymus japonica, Thumb. .. .. .. *Masaki.*

III. Klasse.

Mittelmässig wiederstandsfähige Holzarten, d. h. solche, deren vom Seewasser erreichten Blätter vollständig verwelkten, aber wieder neue Knospen trieben:

Castanæ vulgaris, Lam. var japonica, Dc. *Kuri.*
Magnolia hypoleuca, S. et Z. .. .. .. *Hō-no-ki.*
Zilia cordata Mill. var japonica, Miq. .. *Shina-no-ki.*
Picrasma quassioides, Benn. .. .. .. *Niga-ki.*
Carpinus japonica, Bl. .. .. *Kuma-shide.*
Carpinus yedoensis, Maxim. .. .. .. *Soro.*
Pourthiaæ villosa, Dcne. .. .. *Ushi-koroshi.*
Meliosma myriantha, S. et Z. .. .. .. *Awabuki.*
Acanthopanax spinosum, Miq. .. .. *Ukogi.*
Stewartia pseudo camellia, Maxim. .. *Shara.*
Albizzia Juribrissin, Boiv. .. .. .. *Nemu-no-ki.*
Elaægnus-Arten. .. .. *Gumi-Rui.*
Juglans cordiformis Maxim. .. .. .. *Hime-gurumi.*
Juglans Sieboldiana, Maxim... .. .. *Oni-gurumi.*
Ligastrum Ibota, Sieb. .. .. *Ibota-no-ki.*
Euonymus alatas, K. Koch. .. .. .. *Nishiki gi.*
Rosa multiflora Thumb. .. .. *No-ibara.*
Ligustrum japonicum Thumb... .. .. *Nezumi-mochi.*
Stachyurus præcox, S. et Z. . .. .. *Ki-fuji.*
Rhododendron indicum Sw. var. Kæmpferi, Maxim. .. .. *Tsutsuji.*
Nandina domestica, Thumb. .. .. .. *Nanten.*
Kraunhia floribunda, Taub. .. .. .. *Fuji.*

IV. Klasse.

Empfindliche Holzarten d. h. solche, deren sämmtliche Stammteile abstarben und bei denen Ausschlag nur vom Wurzelstocke aus statt fand:

Morus alba, L. (jüngere) .. .. *Kwa-Rui.*
Viburnum dilatatum Thumb. .. .. .. *Gamazumi.*
Picrasma quassioides Benn. .. .. .. *Niga-ki.*
Cephalotaxus drupacea, S. et Z. .. .. *Inu-gaya.*
Pæonia Moutan, Ait. .. .. *Botan.*

V. Klasse.

Sehr empfindliche, d. h. solche, deren ganzer Stamm und Wurzel vollständig abstarben:

Pinus densiflora, S. et Z.	*Aka-matsu.*
Cryptomeria japonica, Don.	*Sugi.*
Chamæcyparis pisifera, S. et Z.	*Sawara.*
Morus alba, L. (altere).	*Kuwa-Rui.*
Prunus Pseudo-cerasus, Lindl.	*Sakura.*
Pirus spestabilis, Ait.	*Kaidō.*
Cornus ignorata, C. et Koch.	*Sawa-miduki.*
Rhamnus japonicus, Maxim. var. genuina Maxim.	*Kuro-umemodoki.*
Callicarpa mollis, S. et Z.	*Yama-murasaki.*
Acanthopanax risinifolium, S. et Z. ..	*Bō-dara.*

Diese Klassification ist das Resultat der Besichtigung sehr verschiedener Bestände und zahlreicher Beobachtungen. Da in den beschädigten Gegenden die Bestandteile der Waldungen äusserst mannigfaltig sind und ein fast urwaldartig gemischter Bestand vorhanden ist, so war die Gelegenheit sehr günstig, zahlreiche Holz und Straucharten in ihrem Verhalten gegen Meereswasser in einem gleichen Bestande also unter gleichen Bedingungen gegenseitig vergleichen zu können. So war es höchst interessant zu beobachten wie bei einem jungen durch Naturbesamung entwickelten gemischten Bestande von *Pinus densiflora* und *P. Thumbergii* mit einigen *Zelkowa acuminata* und *Juniperus rigida*, nur *P. densiflora* gänzlich abgestorben war, *Zelkowa acuminata*, die alle Blätter verloren hatten, neue grüne Knospen trieben, während bei *P. Thumbergii* und *Juniperus rigida* kein einziges Nädelchen gelitten hatte.

Es ist hier noch zu bemerken, dass die eben aufgestellte Klassification lediglich dem Fall gilt, dass die ganze Pflanzen wenigstens einmal vom Fluthwasser völlig bespült worden sind. So war z. B. bei den zur *V Klasse* gehörigen Holzarten wie, bei *Pinus densiflora, Cryptomeria japonica* u. s. w. bei jungen bis zur Spitze nass gewordenen Beständen, alles welk geworden, aber bei älteren höheren Beständen nur die unteren durch die Fluth nass gewordenen Baumteile; indessen auf solchem Boden, der mehrere Stunden lang durch Fluthwasser überschwemmt war, war bei den zur *V Klasse* gehörigen Holzarten auch in sehr

alten hohen Beständen, welche nur im unteren Zehntel der Stammhöhe vom Fluthwasser erreicht wurden, allmähliches Gelbwerden der oberen Nadeln nach einigen Monaten zu beobachten, worauf ein langsames Absterben des ganzen Stammes erfolgte.

III. Begründung des Küstenschutzwaldes und seine Behandlung.

Im folgenden theile ich in Bezug auf die Begründung des Küstenschutzwaldes und seine Behandlung mit, was mir nach meinen Beobachtungen in den überflutheten Distrikten am meisten zweckmässig erscheint:

a.) *Grundidee:* Der Schutzwald soll vor allem den hinter ihm liegenden Geländen gegen Fluthwasser und auch gegen heftige Meereswinde thunlichst Schutz gewähren und in der diese Sicherheit gewährenden Gestalt dauernd erhalten werden. Es ist aber hier nicht zu vergessen, dass der Wald auch in soweit, als die Ausführung der Grundidee nicht gestört wird, auch der Forstbenutzung dienen kann.

b.) *Holzarten:* Zum Bestande des Küstenschutzwaldes sollen nur zur *I* und *II Klasse* gehörige Holzarten ausgewählt werden, da der Bestand ein gewisses Mass Bodendurchnässung durch Meereswasser und sogar zeitweise Überrieselung des Meereswassers ertragen muss. Um aber eine profitable Waldeinrichtung damit zugleich zu treffen, möchte ich vor allem als Hauptbestand empfehlen: *Pinus Thumbergii* und *Zelkowa acuminata;* als Nebenbestand würden vielleicht *Juniperus rigida*, *Juniperus chinensis*, *Juniperus littoralis* und *Quercus*-arten sich eignen. *P. Thumbergii* liefert ein im ganzen Küstenlande von Japan am meisten geschätztes Brenn- und Bauholz; diese Holzart ist ausserdem schnellwüchsig und lichtbedürftig; sie kann sehr lang 200-300 Jahre lang wachsen, so dass Stämme oft 30-48 m hoch und 2-3, 4 m stark werden. *Zelkowa acuminata* ist ebenfalls eine ähnliche grosse schnellwüchsige Lichtholzart, welche im ganzen Japan das werthvollste Nutzholz für Schiffe, Gebäude, Eisenbahnwagons und verschiedene Geräthe liefert.

c.) *Betrisbsarten:* Der Küstenschutzwald muss im Allgemeinen nur als Plenterwald behandelt werden, indem man in der Regel von der Innlandseite des Waldes gegen die

Küstenseite hin, mit ganz besonderer Vor- und Umsicht verfahrend, die älteren Stämme allmählich fällt, um dem etwa entstehenden oder durch Samenabfall zu erwartenden Jungwuchse Luft und Licht zu verschaffen und so allmählich die Verjüngung des Waldes herbeizuführen. Der Küstenschutzwald könnte auch wohl zuweilen als schmaler Saumschlagbetrieb behandelt werden, wenn der Wald nicht all zu geringe Breite hat, So z. B. könnte man den Wald der Meeresküste entlang in drei oder mehrere schmale Streifen einteilen und einzelne Streifen gegeneinander mit Kahlschlag oder Schirmschlag verjüngen. Bei allen Bewirthschaftungsformen müssen ferner selbstredend alle Fehlstellen durch Pflanzen oder Samen besetzt werden.

d.) *Waldfläche :* Es ist selbstverständlich, dass je breiter die Waldfläche ist, desto besser der Wald auch Schutz gewährt ; allein an den meisten schutzbedürftigen Küstenstrechen findet man meistens keine solche Fläche, um sehr grosse Wälder zu begründen, weil Ortschaften häufig ganz nahe an der Küste situirt sind. Man wird daher oft sich mit möglichst schmalen Schutzwald begnügen müssen.

Aus den Schadenverhältnissen bei der letzten Überfluthung glaube ich schliessen zu dürfen, das der Küstenschutzwald wenigstens 20 m breit sein müsste. Wo Örtschaften nicht hinderlich sind, halte ich es aber für sehr wünschenswerth, den Wald mindestens 40-60 m breit zu bauen.

Die Waldfläche muss entlang der Meeresküste ununterbrochen gelegt werden. Bei Flussmündungen ist der Wald so an den Flussufern zu begründen, dass er eine convexe Fläche gegen des Meer kehrt und desgleichen bei direct nach bis zum Meere durchgeführten Strassen (z. B. bei Hafenstädten).

e.) *Bestandsbegründung :* Um auf den Kahlflächen den Küstenschutzwald zu begründen, hat man vor Allem Pflanzen von *Pinus Thumbergii* anzupflanzen. Die Pflanzen sollen 2-3 jährig sein, die Pflanzweite dabei möglichst eng je nach den Standortsverhaltnissen ; im Allgemeinen aber wird ein Meter Weite im Dreiecksverband am passendesten sein. Da, wo lehmreicher tiefer Boden vorhanden ist, der nicht von den gewöhnlichen periodischen Fluthwässern durchnässt wird, hat man möglichst viel *Zelkowa acuminata* auf zu ziehen, da *dieses Holz viel werthvoller als das der P. Thumbergii ist.* In diesem Falle wäre es auch wünschenswert, immer unmittelbar an der Küsten

seite des Waldes wenigstens auf 10 Reihen *P. Thumbergii* und von da an nach dem Inneren *Zelkowa acuminata* zu bauen.

f.) *Bestandspflege :* Die bei den diesmaligen Springfluthen verwelkten Bestände sind möglichst bald nachzubauen, was nur durch Einpflanzung geschehen kann. Wo aber dem Bestand noch viele Bäume erhalten sind, so dass er einen Schutz ausüben kann, ist die Begründung auch vielleicht durch Besamung von *P. Thumbergii* oder *Zelkowa acuminata* möglich. Auf jeden Fall muss hier das Anzünden von Feuer und Grassnutzung in dem Bestande untersagt werden. Wenn der vorhandene Wald sehr alt und die Stämme zu hoch hinauf entästet sind, wie es beim Küstenwald oft der Fall ist, so muss ebenfalls das Anzünden von Feuer so wie Streunutzung streng unterbleiben, damit der natürliche Unterwuchs beschützt ist und weiter sich entwickeln kann. Wenn man den natürlichen Nachwuchs nicht mehr erwarten kann, so muss der Unterwuchs durch künstliche Besamung oder Pflanzung begründet werden. Man braucht hier nicht besorgt zu sein um die diesen beiden genannten lichtbedürftigen Hauptholzarten nöthige Licht- und Luftmenge unter dem alten Bestande, da die hier nur 20-60 m breiten saumartigen hohen Bestände von beiden freien Seiten her Licht- und Luft in genügender Menge zulassen.

g.) *Waldverwaltung :* Der Küstenschutzwald soll eigentlich von schutzbedürftigen Ortsgemeinden gebaut und verwaltet werden. Es ist aber nothwendig, dass die wichtigen Schutzwaldungen vom Staate aus begründet und controlliert werden, wo die zugehörigen Ortsgemeinden nicht in der Lage sind es zu thun. So in den neuerdings von Meerfluthen betroffenen Gegenden, wo die Gemeinden wegen der grossen Verluste nicht im Stande sind, selbst den Schutzwald zu bauen, ist es nothwendig von den Oberförstereien aus Schutzbestand zu begründen, oder wenigstens staatliche Hülfe den Gemeinden zu gewähren.

Zu einer umfassenden Begründung der Küstenschutzwälder auf den überflutheten Strecken wäre die Zeit jetzt eine höchst günstige, da jeder Privatgrund dort, dessen man zur Schutzwaldbegründung benöthigt wäre, noch unbebaut und brach, höchst billig zu kaufen ist, so dass es dem Staat oder auch den dortigen Gemeinden möglich ist, mit verhältnissmässig geringer Kosten die ganzen Küstenstrechen der Provinzen *Miagi*, *Iwate* und

Aomori mit einem Gürtel von Wald zu versehen, der sie gegen künftige Hochfluthen schützen könnte, ohne selbst dabei vernichtet zu werden.

BUII. AGRIC. COII. VOI. III Tafel IV.

UMGEBUNG DER TAKATA-BUCHT.

BULL. AGRIC. COLL. VOL. III Tafel V.

UMGEBUNG DER MIYAKO-BUCHT.

Über Schwinden und Quellen der Hölzer.

(*Mit 6 Holzstichen und Tafeln VI—XIV in Lichtdruck.*)

VON

Professor **Dr. Diro Kitao.**

Schwinden und Quellen sind durchaus relative Begriffe, insofern als der Begriff „Grünzustand" nicht an einen bestimmten Feuchtigkeitsgehalt eines Holzstücks gebunden ist. Ein frisch gefälltes Holz kann entweder gequellt, oder geschwunden erscheinen, je nach dem Feuchtigkeitsgehalt. Wird ein Stück Holz in Wasser gelegt und so gequellt, und dann der Luft ausgesetzt, so dass die eingesogene Feuchtigkeit verdampfen kann, so tritt Schwinden ein; allein das Holzstück wird immer noch gequellt sein, so lange seine Feuchtigkeit nicht die Grösse erreicht, bei der es zum Quellen gebracht worden war. Wenn man darum einen Feuchtigkeitszustand des Holzes als normal fixirt, so wird das Holz gequellt oder geschwunden sein, je nachdem seine Feuchtigkeit grösser oder kleiner ist, als jene.

Nun hat Laves* durch seine Quellversuche es höchst wahrscheinlich gemacht, dass die Quellung eines Holzstücks tangential am grössten, und longitudinal am kleinsten erfolgt, dass die im Grünzustand saftreichsten Hölzer bei der Tränkung im trockenen Zustand wieder mehr Wasser einsaugen und demgemäss eine grössere Volumenvergrösserung zeigen, als saftarme Hölzer, d. h. dass Quellung eines Holzstücks demselben Gesetz unterworfen ist, wie seine Schwindung. Nördlinger † hat sich an zwei identischen Scheiben von Cratægus punctata davon überzeugt, wie geringfügig der Einfluss des Wassers auf die Schwindungsgrösse des Hölzes ist und glaubte sich zu der Annahme berechtigt, dass bloss gequelltes, nicht sehr lange geflösstes Holz zu seinem ursprünglichen Gewicht und Volumen bei der Austrockenung zurückkehrt.

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* Laves: Mittheilungen des Hannöverschen Gewerbevereins. [12te Lieferung] pag. 300.

† Nördlinger. Die technischen Eigenschaften der Hölzer. Pag. 341.

Indem wir im Folgenden unternehmen, die Gleichgewichtsbedingung des Holzelementes in einem gequellten oder schwindenden Holzstück aufzufinden, wollen wir auch die Annahme machen, dass Schwinden und Quellen eines Holzstücks nur durch den Feuchtigkeitsgehalt bedingte und bestimmte Vorgänge seien, und dass ein Stück Holz, das einmal gequellt wurde, durch Abgabe einer gewissen Wassermenge dieselbe Schwindungsgrösse erreichen könne, in der es gequellt wurde, und umgekehrt, d. h. mit anderen Worten, dass Schwindung und Quellung eines Holzstücks eine und dieselbe Function des Feuchtigkeitsgehaltes seien.

In einem Holzstück vom Grünzustande ist der Splint bekanntlich immer feuchter als der Kern ; die Feuchtigkeit eines Hirnstücks muss darum von der Stammmitte aus nach der Rinde zu zunehmend betrachtet werden. Wird eine Holzscheibe zum Quellen oder zum Schwinden gebracht, so wird die Vertheilung der Feuchtigkeit nicht bloss durch die Vertheilung der Kern- und Splintzellen geregelt sein in Folge der verschiedenen Leichtigkeit, mit der das Wasser sich im Holz longitudinal, radial oder tangential fortpflanzt. Tränkung oder Verdampfung findet zuerst auf den Flächen statt, in denen die Holzzellen unmittelbar mit Wasser, respectiv mit der ungesättigten Luft in Berührung kommen. Von diesen Flächen aus schreitet die Tränkung oder Trockenung in das Innere der Holzmasse fort ; die Feuchtigkeit eines Holzelementes muss darum von Ort zu Ort variiren, und zwar so, dass die Fortpflanzung der Tränkung oder Trockenung schneller longitudinal vor sich geht als radial oder tangential. Die Feuchtigkeit eines Holzstücks kann demnach nicht nur davon abhängig sein, ob es ein Splintstück ist, oder ein Kernstück, sondern auch davon, ob in dem Holzstück der Hirn, oder Spiegel-oder Sehnenfläche vorherrscht.

Dem entsprechend kann die Grösse der Quellung oder Schwindung nicht bloss durch den Unterschied Kern und Splint bedingt und bestimmt sein, sondern auch durch die Flächen, in denen das Holzstück dem Wasser oder der ungesättigten Luft ausgesetzt wird und zwar in der Weise, dass sie um so schneller einer durch Maximal-Tränkung oder Trockenung bedingten Grösse zustrebt, je grössere Hirnfläche das Holzstück aufweist ; die Grösse der Quellung oder Schwindung ist darum von der

Gestalt des Holzstücks abhängig, nicht allein von der Vertheilung des Kern- und Splintholzes in dem Holzstück.

Schwindung und Quellung erfolgen in der Hirnfläche nicht gleichzeitig; sie pflanzen sich von der Rinde aus in's Innere fort. Einer der früheren Studenten des hiesigen Institutes Herr Koide hat an zwei Scheiben näher untersucht, wie die Schwindungsgrösse in der ganzen Hirnfläche vertheilt ist. Die Scheiben, von denen die eine dreieckig verarbeitet war, sind einem 22 jährigen kräftigen Quercus Grandulifera (Nara) entnommen. Die Jahresringe waren schön concentrisch. Die Methode war die Nördlingersche; auf jeder der Scheiben wurde ein Dreieck möglichst fein aufgetragen und jede der Seiten, die mit der Radialrichtung zusammenfallen, in gleiche Theile abgetheilt, und je zwei Theilpunkte wurden geradelinig verbunden. Wenn gleich die Rinde bei der Vollscheibe gelähmt wurde, wurd kein Sicherheitsspalt durch dieselbe gelegt*; um den Einfluss der Gestalt auf die Schwindungsgrösse ungetrübt zu erhalten.

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* Nördlinger: Die technischen Eigenschaften der Hölzer. Pag 294.

VOLLSCHEIBE.

Tangentialschwinden.

		1 Tag.	3 Tage.	11 Tage.	14 Tage.	24 Tage.
Splint	1	2.26 %	2.83	3.54	4.54	4.97
	2	1.87	2.6	3.04	4.21	5.04
	3	1.4	2.4	3.00	4.00	4.40
	4	0.5	1.5	1.75	2.50	4.00
Kern	5	0.77	2.17	2.43	3.43	3.76
	6	0	2.00	2.5	3.50	4.5
	7	0	2.00	2.0	4.00	6.00

Radialschwinden.

		1 Tag.	3 Tage.	11 Tage.	14 Tage.	24 Tage.
Splint	1	1.85	2.40	2.83	3.95	4.26
	2	1.04	2.21	2.71	4.04	4.71
	3	0.8	2.00	2.60	3.20	3.40
	4	0.25	1.25	1.50	2.00	2.00
Kern	5	0	1.10	1.77	2.77	3.43
	6	0	1.00	1.5	2.50	3.50
	7	0	1.00	1.00	2.00	5.00

Die Vollscheibe war ohne Riss geblieben. Es ist hierbei besonders zu bemerken, dass das Tangential- und Radial

schwinden in einer nicht anfreissenden Vollscheibe wenig von einander zu differiren pflegen, wie schon Nördlinger* darauf aufmerksam gemacht hat.

SCHEIBENDREIECK.

Tangentialschwinden.

		1	3 Tage.	6 Tage.	8 Tage.†	10 Tage.	12 Tage.	14 Tage
Splint	1	0.875	3.00	7.125	6.50	7.50	8.38	8.75
	2	0.96	1.57	7.12	6.83	7.54	8.30	9.12
	3	1.04	3.04	6.70	6.37	7.37	8.37	8.87
	4	1.0	3.00	5.40	4.80	5.6	6.00	4.80
Kern	5	0.5	1.00	4.00	3.75	3.75	4.00	4.50
	6	0.43	1.77	2.77	2.10	3.10	3.10	4.10
	7	0	1.77	2.00	2.00	2.50	2.50	3.50
	8	0	1.00	2.00	2.00	3.00	3.00	4.00

Radialschwinden.

		1	3 Tage.	6 Tage.	8 Tage.†	10 Tage.	12 Tage.	14 Tage.
Splint	1	0.5	1.00	2.00	2.00	2.25	2.25	2.50
	2	0.38	0.96	2.26	2.26	2.40	2.40	2.40
	3	0.38	1.04	1.21	1.21	1.54	1.54	1.77
	4	0.30	0.80	1.00	1.00	1.00	1.20	1.20
Kern	5	0	0.50	1.25	1.25	1.25	1.28	1.25
	6	0	0.43	0.75	0.77	0.77	1.10	1.10
	7	0	0	0.50	0.50	1.00	1.00	1.00
	8	0	0	0	0	1.00	1.00	1.00

* Nördlinger a. o. a. O. pag 301.

† An diesem Tage war es regnerisch.

Wie man sieht, pflanzt sich das Schwinden von Splint nach Kern fort und indem das Schwinden fortschreitet, nimmt der Schwund im Allgemeinen in allen Punkten zu. Bei der Vollscheibe nimmt der Tangentialschwund zuerst ungefähr im Verhältniss 2 : 1 zu dem Radialschwund zu, danns trebt er entschieden zu derselben Grenze zu, wie der Tangentialschwund. Bei dem Scheibendreieck ist das Verhältniss des Tangentialschwundes zu dem Radialschwund zuerst ungefähr 2 : 1; allein, indem das Schwinden die innerste Zone erreicht, wächst der Tangentialschwund in jeder Zone bei weitem schneller gegen gewisse Grenzwerthe, als der Radialschwund. Die Austrockenung erfolgt dabei bei dem Scheibendreieck schneller, als bei der Vollscheibe.

Wenn das Holz so viel Feuchtigkeit einbüsst, dass es anhebt, hygroskopisch zu werden, oder so viel Feuchtigkeit aufnimmt, dass seine Zellen nicht mehr Volumenvergrösserung erleiden, so hat das Schwinden oder Quellen das Maximum erreicht. Die Grösse dieses maximalen Schwindens oder Quellens kann indessen nicht durch die Vertheilung des Kern- und Splinthölzer in dem Holzstück allein bedingt sein. Wäre das Holz ein isotroper homogener Körper, so würde ein Holzelement unter Wasserabgabe, respectiv-Aufnahme sich so zusammen ziehen oder ausdehnen können, als befände es sich allein. Wäre des Holz ein zwar anisotroper, aber homogener Körper, so würde ein Element wenigstens in bestimmten Richtungen sich so zusammenziehen, oder ausdehnen, als befände es sich allein. Ein Stück Holz ist aber ein anisotroper, heterogener Körper, zusammengesetzt aus Elementen, welche in drei unterschiedlichen Richtungen sich verschieden zusammenziehen oder ausdehnen und je nach ihrer Lage in Bezug auf die Stammmitte im verschiedenen Grade befähigt sind, sich zusammenzuziehen, oder auszudehnen. In einem Stück Holz kann darum ein Element unmöglich so schwinden, oder quellen, wie es hätte bei der Feuchtigkeit, die es hat, thun müssen, insofern, als es unter dem Zwang der benachbarten, mit ihm im Massenzusammenhang stehenden Elemente steht. Unter diesem Zwang des Massenzusammenhanges muss die Schwindung oder Quellung eines Holzelementes der Grösse nach verschieden erfolgen, als der Fall gewesen wäre, wenn die Schwindung oder Quellung desselben frei vor sich gegangen wäre, d. h. wenn das Element

allein stünde, und sich zusammenziehen oder ausdehnen könnte nur gemäss der Feuchtigkeit, die es enthält.

Nördlinger* hat aus einer Scheibe schmahle Streifen in tangentialer und radialer Richtung ausgearbeit und nannte die so erhaltene Schwindungsgrösse „absolut." Er gelangte zu dem Satz, dass das Schwinden um so stärker auftritt, je unbehinderter, d. h. an je kleineren Stücken, sich dasselbe äussern kann. Herr Koide hat auch japanische Hölzer in Bezug auf das sogenannte absolute Schwinden näher untersucht und im allgemeinen den Nördlinger'schen Satz bestätigt gefunden. Er entnahm einer Holzart je drei identische Scheiben in den Stammshöhen 0.3^m 3.3^m 6.3^m 9.3^m 12.3^m, von denen die eine in tangentiale und radiale Streifen nach der Nördlinger'schen Vorschrift zersägt wurde, die zweite ein Scheibendreieck vom Winkel 90° bildet, und die dritte als Vollscheibe zum Austrockenen gebracht wurde. Die Messung geschah mittelst eingeschlagener Stecknadeln ; ihre Durchmesser wurden bei der Messung selbstredend eliminirt. Bei der Vollscheibe wurde ein Sicherheilsspalt nicht gelegt, weil es beabsichtigt wurde, zu ermitteln, wie die radiale und tangentiale Schwindung ausfallen würde, wenn eine Vollscheibe nicht aufreisst. Die Rinde wurde jedoch durch ein Paar Schnitte gelähmt, was nicht sonderlich die Wirkung derselben aufheben dürfte. Jede Scheibe wurde durch zwei Geraden in vier Quadrante getheilt, und in jedem Quadrant, ausgenommen den Quadrant, in dem ein Riss entstand, wurde die Schwindungsgrösse gemessen. Die folgende Tabelle giebt das Mittel der Schwindungsgrösse in den Quadranten. Die Dicke der Scheiben betrug constant 2^{cm}. Gefällt wurden die Bäume im Monate April in Kiyosumi, dem Versuchswald des hiesigen Institutes. Die Schwindung wurde als vollendet betrachtet, als die atmosphärische Feuchtigkeit Ende des Monates August die Schwindungsgrösse zu beeinflüssen begann. In der folgenden Tabelle bezeichnen.

AR die absolute radiale Schwindungs- oder Quellungsgrösse.

AT die absolute tangentiale Schwindungs- oder Quellungs grösse.

RD die radiale Schwindungs- oder Quellungsgrösse im Scheibendreieck.

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* Nördlinger : a. o. a. O. pag 295.

TD die tangentiale Schwindungs- oder Quellungsgrösse im Scheibendreieck.

RV die radiale Schwindungs- oder Quellungsgrösse in Vollscheibe.

TV die tangentiale Schwindungs- oder Quellungsgrösse in Vollscheibe.

Die römischen Ziffern bedeuten die Stammshöhen, denen die Scheiben entnommen worden sind, und zwar

$I = 0.3^m$, $II = 3.3^m$, $III = 6.3^m$, $IV = 9.3^m$, $V = 12.3^m$.

Kuromatsu (*Pinus Thumbergii*).

		AR	AT			RD	TD			RV	TV
I	Splint	2.41 %	4.87	I	Splint	2.45	4.29	...	...		...
	Kern	1.38	4.83		Kern	1.60	3.90	...	...	...	...
III	Splint	1.91	4.21	II	Splint	1.95	3.79	V	Splint	2.66	2.69
	Kern	1.51	3.84		Kern	1.68	3.76		Kern	2.37	2.76

Die Vollscheiben, I, II, III, IV wurden unbrauchbar in Folge vielfacher Risse. Die Scheibe V war ohne Riss geblieben; die radiale Schwindungsgrösse differirt wenig von der tangentialen und zwar in jedem der vier Quadrante.

Hinoki (*Chamæocyparis obtusa*).

		AR	AT			RD	TD			RV	TV
I	Splint	1.53	2.45	I	Splint	1.14	2.32	I	Splint	1.44	1.84
	Kern	1.29	1.88		Kern	1.48	2.11		Kern	1.45	1.85
III	Splint	1.34	2.90	II	Splint	1.00	2.29	II	Splint	1.53	1.56
	Kern	1.53	2.23		Kern	1.11	1.75		Kern	1.74	1.69
				III	Splint	1.14	2.54	III	Splint	1.49	1.48
					Kern	1.15	2.11		Kern	1.46	1.47

Die Vollscheibe I hat einen Riss bekommen, während die Scheiben II und III ganz geblieben waren.

Sawara (*Chamæocyparis pisifera*).

		AR	AT			RD	TD			RV	TV
I	Splint	0.90	3.25	I	Splint	1.05	2.99	I	Splint	1.05	1.91
	Kern	1.00	2.91		Kern	1.30	2.37		Kern	1.24	1.80
III	Splint	1.05	3.69	II	Splint	1.23	3.02	II	Splint	1.18	2.06
	Kern	0.91	2.70		Kern	1.21	2.44		Kern	1.25	2.01
				III	Splint	1.05	2.99	III	Splint	1.21	2.28
					Kern	1.13	2.51		Kern	1.55	2.06

Jede der Vollscheiben hat einen Riss bekommen.

Sugi (*Cryptomeria japonica*).

		AR	AT			RD	TD			RV	TV
I	Splint	0.90	1.82	I	Splint	0.91	1.47	I	Splint	1.20	1.18
	Kern	1.09	1.54		Kern	1.12	1.44		Kern	1.66	1.63
II	Splint	0.59	1.92	II	Splint	0.72	1.71	II	Splint	1.07	1.04
	Kern	0.68	1.19		Kern	0.70	1.00		Kern	1.32	1.31
III	Splint	0.79	2.03	III	Splint	0.89	1.98	III	Splint	1.36	1.31
	Kern	0.72	1.58		Kern	0.79	1.94		Kern	1.06	1.22
								IV	Splint	1.21	1.30
									Kern	1.30	1.33

Jede der Vollscheiben war ohne Riss gebleiben.

Kurokashi (*Quercus sessilifolia*).

		AR	AT			RD	TD			RV	TV
I	Splint	1.82	7.04	I	Splint	2.12	6.76	I	Splint	3.79	5.06
	Kern	2.34	8.14		Kern	2.57	7.81		Kern	7.87	8.70
II	Jung holz	1.97	6.03	II	Jung holz	1.86	6.17	II	Jung holz	5.62	5.94
	...	.....	.....		...	.....	.....		...	...	...

Die Vollscheibe I riss stark auf.

Momi (*Abies firma*).

		AR	AT			RD	TD			RV	TV
I	Äusser. Holz	1.51	2.61	I	Äusser.	1.27	2.67	I	Äusser.	1.16	2.14
	Inner. Holz	1.19	3.36		Inner.	1.41	2.77		Inner.	1.18	2.15
II	Äusser.	1.45	3.65	II	Äusser.	1.20	3.22	II	Äusser.	1.74	1.87
	Inner.	1.47	3.41		Inner.	0.88	2.76		Inner.	1.42	1.70
III	Äusser.	1.17	3.53	III	Äusser.	1.62	3.27	III	Äusser.	1.77	1.80
	Inner.	1.39	3.32		Inner.	1.28	3.08		Inner.	1.55	1.60
								IV	Äusser.	1.03	1.85
									Inner.	0.68	1.50

Die Scheiben I und IV sind aufgerissen.

Keyaki (*Zelkowa Keaki*).

		AR	AT			RD	TD			RV	TV
I	Splint	2.39	4.81	I	Splint	2.34	4.76	I	Splint	3.92	3.83
	Kern	2.12	3.40		Kern	1.60	3.15		Kern	3.56	3.61
II	Splint	2.36	5.75	II	Splint	2.93	5.46	II	Splint	4.38	4.45
	Kern	1.48	3.16		Kern	1.90	3.97		Kern	3.30	3.46
				III	Splint	2.82	5.56	III	Splint	4.03	4.20
					Kern	1.14	4.00		Kern	3.52	3.77

Die Vollscheiben sind ohne jeden Riss geblieben.

Sakura (*Prunus pseudocerasus*).

		AR	AT			RD	TV			RV	TV
I	Splint	2.61	9.03	I	Splint	1.60	6.00	I	Splint	3.82	3.67
	Kern	2.40	3.77		Kern	1.03	3.50		Kern	2.85	2.90
II	Splint	2.39	7.39	II	Splint	1.93	5.30	II	Splint	4.07	4.06
	Kern	1.67	3.67		Kern	1.15	3.76		Kern	3.47	3.47
								III	Splint	4.58	4.67
									Kern	4.64	4.77

Die sämmtlichen Vollscheiben sind ganz geblichen.

Uri-Kayede (*Acer rufinerve*).

		AR	AT			RD	TD			RV	TV
I	Splint	3.32	6.59	I	Splint	4.27	5.73	I	Splint	6.22	6.11
	Kern	3.77	7.23		Kern	4.50	6.61		Kern	7.88	7.43
II	Splint	3.39	6.76	II	Splint	4.02	5.53	II	Splint	4.04	6.27
	Kern	3.80	7.51		Kern	4.32	6.25		Kern	4.23	6.46
III	Splint	3.02	6.54					III	Splint	5.43	5.43
	Kern	3.15	6.36						Kern	5.92	6.86

Die Jahresringe sind sehr excentrisch. Die Scheibe II erhielte einen klaffenden Riss.

Herr Koide hat dieselben Holzarten auch in Bezug auf die Quellung näher untersucht, indem er diesen Winter dieselben völlig lufttrocken gewordenen Scheiben in's Wasser brachte und sie völlig aufquellen liess. Ich bemerke noch, dass die unten mitgetheilten Zahlen die Ausdehnung der Längeneinheit geben von dem Zustand der Lufttrockenheit bis zu dem Zustand, wo die Ausdehnung ein Maximum geworden zu sein scheint, dass nicht jede Holzart dieselbe Dimension, wie in dem Grünzustande zurückerlangt hat, trotz ihres 2-3 wöchentlichen Aufenthaltes im Wasser.

Kuromatsu (*Pinus Thumbergii*).

		A. R.	A. T.			R. D.	T. D.			R. V.	T. V.
I	Splint	2.10	4.87	I	Sp.	2.43	4.78	V	Sp.	2.76	2.93
	Kern	1.87	5.08		m	2.12	4.73		m	2.84	3.06
III	Splint	1.78	4.38		Kr.	1.37	3.75		Kr.	3.35	4.14
	Kern	1.53	4.27	III	Sp.	1.81	4.03				
					Kr.	1.56	3.74				

m bedeutet die Mittelregion zwischen Splint und Kern.

Hinoki (*Chamæocyparis obtusa*).

		A. R.	A. T.			R. D.	T. D.			R. V.	T. V.
I	Splint	1.55	2.42	I	Sp.	1.31	1.11	I	Sp.	1.53	2.00
	Kern	1.75	2.30		m	1.18	1.12		m	1.48	1.94
III	Splint	1.36	2.99		Kr.	1.37	1.19		Kr.	1.60	2.01
	Kern	1.17	2.66	II	Sp.	1.01	0.89	II	Sp.	1.49	1.50
					m	0.97	0.81		m	1.57	1.58
					Kr.	1.12	1.02		Kr.	1.82	1.77
				III	Sp.	1.19	1.16	III	Sp.	1.58	1.43
					Kr.	1.22	2.29		Kr.	1.70	1.78

Sawara (*Chamæocyparis pisifera*).

		A. R.	A. T.
I	Splint	0.71	3.46
	Kern	0.80	3.00
III	Splint	1.06	3.56
	Kern	0.91	3.06

		R. D.	T. D.
I	Sp.	1.00	3.02
	m	1.06	2.60
	Kr.	1.10	2.57
II	Sp.	1.09	3.05
	m	1.04	2.84
	Kr.	1.11	2.64
III	Sp.	0.95	3.08
	m	1.04	2.93
	Kr.	1.15	2.58

		R. V.	T. V.
I	Sp.	1.13	2.03
	m	1.27	1.95
	m	1.36	2.00
	Kr.	1.67	1.95
II	Sp.	1.05	1.99
	m	1.05	1.71
	Kr.	1.16	2.14
III	Sp.	1.16	2.30
	m	1.11	2.28
	Kr.	1.30	2.17

Sugi (*Cryptomeria japonica*).

		A. R.	A. T.
I	Splint	0.80	1.77
	Kern	0.91	1.22
II	Splint	0.45	1.81
	Kern	0.34	1.20
III	Splint	0.64	2.94
	Kern	0.72	1.94

		R. D.	T. D.
I	Sp.	0.78	1.49
	m	0.73	1.29
	Kr.	0.89	1.46
II	Sp.	0.50	1.64
	m	0.55	1.38
	Kr.	0.55	1.26
III	Sp.	0.82	2.14
	Kr.	0.80	1.98

		R. V.	T. V.
I	Sp.	1.11	1.07
	m	1.13	1.14
	Kr.	1.38	1.52
II	Sp.	0.97	1.03
	m	0.87	0.88
	Kr.	0.96	1.06
III	Sp.	1.19	1.19
	Kr.	1.07	1.22
IV	Sp.	1.22	1.26
	Kr.	1.09	1.21

Kurokashi (*Quercus sessilifolia*).

										R. V.	T. V.
								I	Sp.	3.24	4.51
									Kr.	1.59	7.74
								II		5.28	5.04

Momi (*Abies firma*).

		A. R.	A. T.			R. D.	T. D.			R. V.	T. V.
I	Äus.	1.30	2.65	I	Äu.	1.17	2.87	I	Äu.	1.10	1.15
	Inn.	1.20	3.30		m	1.13	2.87		m	1.12	2.29
II	Äus.	1.35	3.81		In.	1.25	2.88		In.	1.11	2.20
	Inn.	1.19	3.78	II	Äu.	1.16	3.33	II	Äu.	1.70	1.84
III	Äus.	1.18	3.80		m	0.88	2.39		m	1.64	1.76
	Inn.	0.84	3.46		In.	1.04	2.83		In.	1.36	1.89
				III	Äu.	1.22	3.48	III	Äu.	1.69	1.56
					In.	0.95	3.17		In.	1.46	1.62
								IV	Äu.	1.02	1.89
									In.	0.65	1.52

Keyaki (*Zelkowa Keaki*).

		A. R.	A. T.			R. D.	T. D.			R. V.	T. V.
I	Splint	1.94	4.08	I	Sp.	1.93	4.00	I	Sp.	3.43	3.51
	Kern	1.45	3.19		Kr.	1.23	2.49		Kr.	3.02	3.49
II	Splint	2.05	4.67	II	Sp.	2.47	4.39	II	Sp.	3.62	3.67
	Kern	1.50	2.85		Kr.	1.59	3.62		Kr.	2.63	2.41
				III	Sp.	2.46	4.55	III	Sp.	3.24	3.45
					Kr.	0.70	3.47		Kr.	2.77	2.94

Sakura (*Prunus pseudocerasus*).

		A. R.	A. T.			R. D.	T. D.			R. V.	T. V.
I	Splint	2.15	5.90	I	Sp.	1.44	4.66	I	Sp.	2.86	3.03
	Kern	1.47	2.53		Kr.	0.86	2.69		Kr.	1.67	1.99
II	Splint	1.98	6.72	II	Sp.	1.79	4.67	II	Sp.	3.99	3.50
	Kern	1.28	3.33		Kr.	0.99	3.41		Kr.	2.66	2.79
								III	Sp.	3.94	4.38
									Kr.	3.80	4.06

Uri-Kayede (*Acer rufinerve*).

		A. R.	A. T.			R. D.	T. D.			R. V.	T. V.
I	Äus.	3.06	6.30	I	Äus.	3.95	5.48	I	Äus.	5.76	5.64
	Inn.	3.40	7.15		Inn.	4.03	6.47		m	6.21	6.05
II	Äus.	3.38	6.59	II	Äus.	3.84	5.41		Inn.	7.42	7.07
	Inn.	3.95	7.16		Inn.	4.13	6.15	III	Äus.	5.77	5.12
III	Äus.	2.83	6.36						Inn.	5.51	5.59
	Inn.	2.61	6.31								

Wie man aus diesen Zahlen ersieht, bestätigt sich der Nördlinger'sche Satz, den man auch auf die Quellung ausdehnen könnte. Die Schwindungs- und Quellungsgrösse in's besondere die tangentiale an einem Scheibendreieck sind fast ohne Ausnahme kleiner, als die sogenannte absolute.

Was das Schwinden bei Vollscheiben anbelangt, springt die Thatsache in die Augen, dass die Schwindungsgrösse in erster Linie davon abhängt, ob die Scheibe radial aufreisst oder nicht; dass die Schwindungsgrösse, falls die Scheibe nicht aufreisst, tangential und radial ziemlich denselben Werth zeigen, und wenn hingegen die Scheibe aufreisst, tangential und radial Werth hat, der der Schwindungsgrösse bei Scheibendreiecknahe gleich kommt, aber fast ohne Ausnahme kleiner ist, als die absolute. Die Schwindungsgrösse bei einer nicht aufgerissenen Vollscheibe kann radial diejenige bei einem

Scheibendreiecke, je die absolute überflügeln; dafür wird die tangentiale Schwindungsgrösse der Vollscheibe bedeutend deprimirt, gleichsam als fände bei einer Vollscheibe, die nicht aufreisst, ein Ausgleich zwischen dem radialen und tangentialen Schwinden statt, und zwar in dem Sinne, dass die Summe der radialen und tangentialen Schwindungsgrösse sogut für ein Scheibendreieck wie für eine Vollscheibe einer Constante gleich ist, was auch in der That roh angenährt der Fall ist.

Es kann somit als ausgemacht betrachtet werden, dass die Schwindungsgrösse von der Grösse und Gestalt des Holzstücks abhängt, dass die Druckkräfte, welche ein Holzstück beim Schwinden, oder Quellen deformiren, nicht bloss durch die Feuchtigkeit bestimmt werden, sondern auch durch die Grösse und Gestalt des Holzstücks in Bezug auf die Mitte des Stammes, welchem es entnommen ist. Wir können uns den Vorgang des Schwindens, oder Quellens, wie folgt, vorstellen. Jedes Element eines Holzstücks zieht sich zusammen, oder dehnt sich aus, sobald seine Feuchtigkeit ab- oder zunimmt, und zwar mit einer Kraft, welche von der Strukturbeschaffenheit der Holzzellen abhängig ist, und darum nicht nur im Splint und Kern, sondern auch in drei unterschiedlichen Richtungen longitudinal, radial und tangential verschieden sein dürfte. Indem die anderen Elemente sich zusammenziehen, oder ausdehnen, und dabei streben, im Massenzusammenhang zu bleiben, resultirt eine Druckkraft auf der Oberfläche des in Rede stehenden Elementes, welche je nach der Gestalt des Holzstücks bald in demselben, bald im entgegengesetzten Sinne wirkt, wie die Druckkraft, welche in Folge der Feuchtigkeitsänderung in dem Elemente wirkt, und es zusammenzudrücken, oder auszudehnen strebt. Die Druckcomponenten, die in dem Elemente wirken, sind theils normal zur Oberfläche des Elementes, theils tangential dazu, und bewirken die Deformation des Elementes, und somit des ganzen Holzstücks, als hätten Druckkräfte auf die Oberfläche desselben gewirkt, und so die Deformation des Elementes hervorgerufen. Wir können uns somit an der Vorstellung festhalten, dass *jedes Element in einem Holzstück, in dem die Feuchtigkeit von Ort zu Ort variirt, sich in einem Spannungszustand befindet, wie das Element eines elastischen Körpers, auf dessen Oberfläche Druckkräfte wirken; dass*

wir ein Holzstück, das zum Schwinden oder Quellen gebracht wird, als einen elastischen Körper betrachten dürfen, auf dessen Element Druckkräfte wirken, die es nach allen Seiten hin zusammenzudrücken, oder auszudehnen streben, und zwar mit einer Intensität, die so wohl mit der Gestalt des Holzstücks, mit den Richtungen im Holzstück, wie mit dem Ort des Elementes in Bezug auf die Stammmitte variirt.

Indem wir die Bedingungen für das Gleichgewicht des Elementes eines solchen Körpers aufsuchen, wollen wir nicht von irgend einer Annahme über die Structur der Holzzelle ausgehen; wir wollen uns nur mit der Annahme begnügen, dass ein Holztheilchen, dessen Verrückung und Deformation wir untersuchen, continuirlich mit Massentheilchen erfüllt sei, welche mit der Fähigkeit begabt sind, Wasser zu verdampfen, respectiv aufzunehmen, und so sich zusammenzuziehen, respectiv auszudehnen. Wir denken uns in dem Holzstück ein rechtwinkliges Coordinatensystem, und parallel seinen Axen ein unendlich kleines Parallelopipedon. Die Druckcomponenten, die auf dieses Parallelopipedon in Folge des Schwindens oder Quellens wirken, wirken theils normal, theils tangential. Es seien

$$\bar{X}_x \quad \bar{Y}_y \quad \bar{Z}_z$$
$$\bar{X}_z = \bar{Z}_x \quad \bar{Z}_y = \bar{Y}_z \quad \bar{Y}_x = \bar{X}_y$$

die Componenten der Druckkräfte, welche in Folge der Feuchtigkeitsabnahme- oder zunahme in dem Holzstück auf das Parallelopipedon wirken, und daher von der Gestalt des Holzstücks abhängen, und Functionen der Coordinaten sein sollen, welche die Lage des Parallelopipedons bestimmen.

Es seien ferner

$$X_x \quad Y_y \quad Z_z$$
$$X_z = Z_x \quad Z_y = Y_z \quad Y_x = X_y$$

die Componenten der Druckkräfte, welche unter dem Zwang des Massenzusammenhanges die Deformation des nämlichen Parallelopipedons hervorrufen, d. h. die Componenten der Druckkräfte in dem Holzelemente bei gezwungenem Schwinden oder Quellen, welche wohl mit den elastischen Druckkräften des Holzes identificirt werden dürfen. Die Differenzen

$$\overline{X}_x - X_x = X_x' \quad \overline{Y}_y - Y_y = Y_y' \quad \overline{Z}_z - Z_z = Z_z'$$
$$\overline{Y}_z - Y_z = Y_z' = Z_y' \quad \overline{Z}_x - Z_x = Z_x' = X_z' \quad \overline{X}_y - X_y = X_y' = Y_x'$$

sind die Druckcomponenten, welche in jedem Holzelemente wirken, um sein Gleichgewicht herzustellen. Wir denken uns diese 12 Grössen $\overline{X}_x$ X_x etc., und mithin auch X_x' etc. als überall in der ganzen Ausdehnung der Holzmasse endlich und stetig und ein unendlich kleines Tetraeder in dem Parallelopipedon gelegt. Bezeichnen wir ferner mit n die Normale an der Tetraederfläche, welche von den drei Coordinatenaxen durchsetzt wird, so sind

$$X_x' \cos(nx) + X_y' \cos(ny) + X_z' \cos(nz)$$
$$Y_x' \cos(nx) + Y_y' \cos(ny) + Y_z' \cos(nz)$$
$$Z_x' \cos(nx) + Z_y' \cos(ny) + Z_z' \cos(nz)$$

die Componenten der Druckkraft, welche auf diese Tetraederfläche wirkt. Es sei $d\sigma$ ein Element der Tetraederfläche, und $d\tau$ ein Volumenelement des Tetraeders. Wenn wir das Integral

$$\int \left(X_x' \cos(nx) + X_y' \cos(ny) + X_z' \cos(nz)\right) d\sigma$$

bilden, und uns dabei der Formel erinnern

$$\int V \cos(nx) d\sigma = -\int \frac{\partial V}{\partial x} d\tau$$

so kommt

$$\int \left(X_x' \cos(nx) + X_y' \cos(ny) + X_z \cos(nz)\right) d\sigma$$
$$= -\int \left(\frac{\partial X_x'}{\partial x} + \frac{\partial X_y'}{\partial y} + \frac{\partial X_z'}{\partial z}\right) d\tau$$

wo die Integration über die ganze Holzmasse auszudehnen ist. Insofern man aber die Grenzen der Integration in Folge der Möglichkeit, beliebig gestalteten Raum aus unendlich kleinen Tetraeder zusammenzusetzen, beliebig erweitern oder verengern kann, so müssen die unter dem Integralzeichen stehenden Ausdrücke im Fall des Gleichgewichtes

überall verschwinden, da kein äusserer Druck auf die Oberfläche der Holzmasse einwirken soll. Man erhält somit für das Gleichgewicht eines Holzelementes

$$\frac{\partial X_x'}{\partial x}+\frac{\partial X_y'}{\partial y}+\frac{\partial X_z'}{\partial z}=0$$

$$\frac{\partial Y_x'}{\partial x}+\frac{\partial Y_y'}{\partial y}+\frac{\partial Y_z'}{\partial z}=0 \qquad (1)$$

$$\frac{\partial Z_x'}{\partial x}+\frac{\partial Z_y'}{\partial y}+\frac{\partial Z_z'}{\partial z}=0$$

und als Grenzbedingung

$$X_x' \cos(nx)+X_y' \cos(ny)+X_z' \cos(nz)=0$$
$$Y_x' \cos(nx)+Y_y' \cos(ny)+Y_z' \cos(nz)=0$$
$$Z_z' \cos(nx)+Z_y' \cos(ny)+Z' \cos(nz)=0$$

Nun können die drei Cosinusse auf keine Weise gleichzeitig verschwinden, in Folge der Relation

$$\cos^2(nx)+\cos^2(ny)+\cos^2(nz)=1$$

und die Determinante

$$\begin{vmatrix} X_x' & X_y' & X_z' \\ Y_x' & Y_y' & Y_z' \\ Z_x' & Z_y' & Z_z' \end{vmatrix}$$

verschwindet im Allgemeinen nicht, wenn nicht je zwei Parallelreihen einander gleich werden. Es müssen daher an der Grenzfläche

$$X_x'=0 \qquad Y_y'=0 \qquad Z_z'=0$$
$$Z_y'=Y_z=0 \qquad X_z'=Z_x'=0 \qquad X_y'=Y_x'=0$$

Dieses entspricht dem Fall, wo das Gleichgewicht eines elastischen Körpers gesucht wird, auf den keine äussere Kraft, auf dessen Oberfläche kein äusserer Druck wirkt. In einem solchen Fall giebt es nur eine einzige Lösung der Gleichungen (1); sie ist

$$X_x'=0 \qquad Y_y'=0 \qquad Z_z'=0$$
$$Z_y'=Y_z'=0 \qquad X_z'=Z_x'=0 \qquad X_y'=Y_z'=0$$

die Bedingung für das Gleichgewicht eines Holzelementes lautet demnach

$$\begin{array}{lll} \overline{X}_x = X_x & \overline{Y}_y = Y_y & \overline{Z}_z = Z_z \\ \overline{Z}_y = Z_y & \overline{X}_z = X_z & \overline{Y}_x = Y_x \end{array} \qquad (2)$$

Wir gelangen somit zu der Erkenntniss, dass *ein jedes Element der Holzmasse nur dann im Gleichgewicht* ist, *wenn der elastische Druck in ihm gleich wird, dem Druck, welchen es von den anderen sämmtichen Elementen des Holzstücks erleidet.*

Hat eine der Druckcomponenten solche Grösse erreicht, dass sie die Festigkeit des Holzes in dieser Richtung überschreitet, so muss die Holzmasse in dieser Richtung anfreissen.

Die Druckcomponenten X_x etc. sind Functionen der Deformationen des Elementes $x\ y\ z$. Wenn wir die Verrückungscomponenten des Elementes $u\ v\ w$ nennen, so erhalten wir under der Vorausselzung, dass zwei Punkte in dem Elemente, die einander unendlich nah geradlinig verbunden waren, immer unendlich nah geradlinig verbunden bleiben, als Deformationen dieses Elementes

$$x_x = \frac{\partial u}{\partial x} \qquad y_y = \frac{\partial v}{\partial y} \qquad z_z = \frac{\partial w}{\partial z}$$

$$z_y = y_z = \frac{\partial w}{\partial y} + \frac{\partial v}{\partial z} \qquad x_z = z_x = \frac{\partial u}{\partial z} + \frac{\partial w}{\partial x} \qquad x_y = y_x = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}$$

Indem wir diese 6 Grössen als unendlich klein vorstellen können wir die Druckcomponenten X_x etc. als lineare Functionen dieser 6 Argumente darstellen. Die Anzahl der Coefficienten ist im Allgemeinen 36. Wenn gleich es keine Schwierigkeit hat, die vorgenommene Rechnung mit dieser Coefficientenanzahl durchzuführen, wollen wir die Annahme machen, dass die Druckkräfte ein Potential P haben, und dass das Holz, so weit seine Masse in Betracht kommt, drei Symmetrieebenen darbietet, welche senkrecht auf einander durch die Stammmitte gehen. Dann hat man

$$P = b_{11}x_x^2 + b_{22}y_y^2 + b_{33}z_z^2 + b_{13}(2x_xz_z + x_z^2)$$
$$+ b_{12}(2x_xy_y + x_y^2) + b_{23}(2y_yz_z + y_z^2)$$

indem wir die Z-Axe in die Linie der Stammmitte legen. b_{11} b_{12} etc. die elastischen Coefficienten des Holzes sind aller Wahrscheinlichkeit nach mit der Lage des Holzelementes veränderlich, schon wegen der Verschiedenheit der Feuchtigkeit im Splint und Kern. Wenn gleich die Rechnung auch b_{11} b_{12} etc. als Functionen von xyz durchgeführt werden kann, sollen sie die Feuchtigkeit nicht enthalten, also reine Constanten des Holzstoffes, welche nur das Verhältniss geben zwischen den Deformationen eines Holzelementes, und den Druckkräften, die sie hervorrufen. Ihre Anzahl reducirt sich noch weiter, wenn wir uns die Structur der Holzmasse rundum die Z-Axe symmetrisch denken, dass P denselben Werth erhält, wie die Axen x und y um die in der Stammmitte festgelegte Z-Axe gedreht werden mögen. Wir führen ein nenes Coordinatensystem ein, das so definirt ist

$$x = x'\alpha - y'\beta \qquad \alpha = \cos\chi \qquad \beta = \sin\chi$$
$$y = x'\beta + y'\alpha \qquad \alpha^2 + \beta^2 = 1$$
$$z = z'$$

Es ist zunächst

$$u = u'\alpha - v'\beta$$
$$v = u'\beta + v'\alpha$$
$$w = w'$$

Setzt man

$$x_x' = \frac{\partial u'}{\partial x'} \qquad y_y' = \frac{\partial v'}{\partial y'} \qquad z_z' = \frac{\partial w'}{\partial z'}$$

$$x_y' = \frac{\partial u'}{\partial y'} + \frac{\partial v'}{\partial x'} \qquad z_x' = \frac{\partial u'}{\partial z'} + \frac{\partial w'}{\partial x'} \qquad y_z' = \frac{\partial v'}{\partial z'} + \frac{\partial u'}{\partial y'}$$

so erhält man

$$x_x = x_x'\alpha^2 + y_y'\beta^2 - y_x'\alpha\beta$$
$$y_y = x_x'\beta^2 + y_y'\beta^2 + y_x'\alpha\beta$$
$$z_z = z_z'$$
$$y_x = 2(x_x' - y_y')\alpha\beta + y_x'(\alpha^2 - \beta^2)$$
$$z_y = z_y'\alpha + x_z'\beta$$
$$x_z = x_z'\alpha - x_y'\beta.$$

Es ist nun

$$X_x' = \frac{\partial P}{\partial x_x}\frac{\partial x_x}{\partial x_x'} + \frac{\partial P}{\partial y_y}\frac{\partial y_y}{\partial y_y'} + \frac{\partial P}{\partial z_z}\frac{\partial z_z}{\partial z_z'} + \frac{\partial P}{\partial x_y}\frac{\partial x_y}{\partial x_y'}$$
$$+ \frac{\partial P}{\partial y_z}\frac{\partial y_z}{\partial y_z'} + \frac{\partial P}{\partial z_x}\frac{\partial z_x}{\partial z_x'}$$

und dabei

$$\frac{\partial x_x}{\partial x_x'} = \alpha^2 \qquad \frac{\partial y_y}{\partial y_y'} = \beta^2 \qquad \frac{\partial z_z}{\partial x_x'} = 0 \qquad \frac{\partial y_z}{\partial x_x'} = 0 \qquad \frac{\partial z_x}{\partial x_x'} = 0$$
$$\frac{\partial x_y}{\partial x_x'} = \frac{\partial y_x}{\partial x_x'} = 2\alpha\beta$$

so folgt

$$X_x' = X_x\alpha^2 + Y_y\beta^2 + 2Y_x\alpha\beta$$

Auf dieselbe Weise findet man

$$Y_y' = X_x\beta^2 + Y_y\alpha^2 - 2\alpha\beta Y_x$$
$$Z_z' = Z_z$$
$$X_y = (Y_y - X_x)\alpha\beta + X_y(\alpha^2 - \beta^2)$$
$$Y_z' = -X_z\beta + Y_z\alpha$$
$$Z_x' = X_z\alpha + Y_z\beta$$

Indem wir X_x etc. bilden, und die Ausdrück (3) einführen, erhalten wir

$$\frac{X_x'}{2} = x_x'(\alpha^4 b_{11} + \beta^4 b_{22} + 6\alpha^2\beta^2 b_{12})$$
$$+ y_y'\Big(\alpha^2\beta^2(b_{11} + b_{22}) + (\alpha^4 + \beta^4)b_{12} - 4\alpha^2\beta^2 b_{12}\Big)$$
$$+ z_z'(\alpha^2 b_{13} + \beta^2 b_{22}) + y_x'\Big(2b_{12}(\alpha^2 - \beta^2) - \alpha^2(b_{11} - b_{12})\Big)\alpha\beta$$
$$\frac{Y_y'}{2} = x_x'\Big(\alpha^2\beta^2(b_{11} + b_{22}) + (\alpha^4 + \beta^4)b_{12} - 4\alpha^2\beta^2 b_{12}\Big)$$
$$+ y_y'(\beta^4 b_{11} + \alpha^4 b_{22} + 6\alpha^2\beta^2 b_{12})$$
$$+ z_z'(\beta^2 b_{13} + \alpha^2 b_{12})$$
$$+ y_x'\Big(\alpha^2(b_{22} - b_{12}) - \beta^2(b_{11} - b_{12}) - 2(\alpha^2 - \beta^2)b_{12}\Big)\alpha\beta$$
$$\frac{Z_z'}{2} = x_x'(\alpha^2 b_{13} + \beta^2 b_{23}) + y_y'(\beta^2 b_{13} + \alpha^2 b_{23})$$
$$+ y_x'\alpha\beta(b_{23} - b_{13}) + b_{33}z_z'$$

$$\frac{Z_y'}{2} = \alpha\beta x_z'(b_{23} - b_{13}) + z_y'(\alpha^2 b_{23} + \beta^2 b_{13})$$

$$\frac{X_z'}{2} = x_z'(\alpha^2 b_{13} + \beta^2 b_{23}) + z_y'\alpha\beta(b_{23} - b_{13})$$

$$\begin{aligned}\frac{Y_x'}{2} = {} & \alpha\beta x_x'\Big(\beta^2 b_{22} - \alpha^2 b_{11} + b_{12}(\alpha^2 - \beta^2) + 2b_{12}(\alpha^2 - \beta^2)\Big) \\ & + \alpha\beta y_y'\Big(\alpha^2 b_{22} - \beta^2 b_{11} + b_{12}(\beta^2 - \alpha^2) - 2b_{12}(\alpha^2 - \beta^2)\Big) \\ & + \alpha\beta z_z'(b_{23} - b_{13}) \\ & + y_x'\Big(\alpha^2\beta^2(b_{22} - b_{12}) + \alpha^2\beta^2(b_{11} - b_{12}) + b_{12}(\alpha^2 - \beta^2)^2\Big)\end{aligned}$$

Nun soll der Körper so gebaut sein, dass die Druckcomponenten völlig unabhängig von dem Winkel χ sind, so dass sie nach wie vor von der Form sind

$$\frac{X_x'}{2} = b_{11} z_x' + b_{12} y_y' + b_{13} z_z' \qquad \frac{\ _y'}{2} = b_{12} x_x' + b_{22} y_y' + b_{23} z_z'$$

$$\frac{Z_z'}{2} = b_{13} x_x' + b_{23} y_y' + b_{33} z_z'$$

$$\frac{X_y'}{2} = b_{12} y_x' \qquad \frac{Y_z'}{2} = b_{23} z_y' \qquad \frac{Z_x}{2} = b_{13} x_z'$$

so müssen die folgenden 11 Gleichungen erfüllt werden

$$\begin{aligned}
&\alpha^4 b_{11} + \beta^4 b_{22} + 6b_{12}\alpha^2\beta^2 = b_{11} \\
&\alpha^2\beta^2(b_{11} + b_{22}) + b_{12}(\alpha^4 + \beta^4) - 4b_{12}\alpha^2\beta^2 = b_{12} \\
&\alpha^2 b_{13} + \beta^2 b_{23} = b_{13} \\
&\beta^2(b_{22} - b_{12}) - \alpha^2(b_{11} - b_{12}) + 2b_{12}(\alpha^2 - \beta^2) = 0 \\
&\beta^4 b_{11} + \alpha^4 b_{22} + 6b_{12}\alpha^2\beta^2 = b_{22} \\
&\beta^2 b_{13} + \alpha^2 b_{23} = b_{13} \\
&-\beta^2(b_{11} - b_{12}) + \alpha^2(b_{22} - b_{12}) - 2b_{12}(\alpha^2 - \beta^2) = 0 \\
&b_{13} - b_{23} = 0 \\
&\beta^2 b_{22} - \alpha^2 b_{11} + b_{12}(\alpha^2 - \beta^2) + 2b_{12}(\alpha^2 - \beta^2) = 0 \\
&\alpha^2 b_{22} - \beta^2 b_{11} - b_{12}(\alpha^2 - \beta^2) - 2b_{12}(\alpha^2 - \beta^2) = 0 \\
&\alpha^2\beta^2(b_{22} - b_{12}) + \alpha^2\beta^2(b_{11} - b_{12}) + b_{12}(\alpha^2 - \beta^2)^2 = b_{12}
\end{aligned}$$

Man befriedigt diese 11 Gleichungen mit Rücksicht auf die Relation $\alpha^2 + \beta^2 = 1$ durch die Annahme

$$b_{13}=b_{23} \qquad b_{11}=b_{22}=3b_{12}$$

Somit erhalten wir für Holz, in so weit als die Z-Axe in der Stammmitte fixirt und das Holz rings um diese Axe vollkommen symmetrisch gebaut ist,

$$P=3b_{12}(x_x^2+y_y^2)+b_{12}(2x_xy_y+y_x^2)$$
$$+b_{13}(x_z^2+z_y^2+2x_xz_z+2y_yz_z)+b_{33}z_z^2$$

ganz wie für einen Krystall aus dem hexagonalen System.

Wir wollen jetzt gewisse Grössen statt der Verrückungs componenten $u\ v\ w$ einführen. Es seien $x\ y\ z$ die Coordinaten eines Punktes bei der Feuchtigkeit F. Indem F sich verändert, erleidet der Punkt eine Verrückung, deren Componenten

$$u=x'-x \qquad v=y'-y \qquad w=z'-z.$$

Wir führen die Cylindercoordinaten

$$x=r\cos\varphi \qquad y=r\sin\varphi \qquad z=z$$

ein, und setzen fest, dass

$$\begin{aligned} x'&=(r+\rho)\cos(\varphi+\delta\varphi) \\ y'&=(r+\rho)\sin(\varphi+\delta\varphi) \end{aligned} \qquad z'=z+w$$

Indem wir uns die Verrückung des Punktes unendlich klein denken, können wir schreiben

$$u=\rho\cos\varphi-\delta\varphi(\rho+r)\sin\varphi$$
$$v=\rho\sin\varphi+\delta\varphi(\rho+r)\cos\varphi$$

ρ ist nichts anderes, als die radiale Verrückung des Punktes unb $\delta\varphi(\rho+r)$ nichts anderes, als die tangentiale Verrückung. Wir setzen

$$\delta\varphi(\rho+r)=\tau$$

und bilden $\frac{\partial u}{\partial x}$, $\frac{\partial v}{\partial y}$ etc. Es ist

$$\frac{\partial u}{\partial x}=\frac{\partial u}{\partial r}\frac{\partial r}{\partial x}+\frac{\partial u}{\partial\varphi}\frac{\partial\varphi}{\partial x} \qquad \frac{\partial v}{\partial y}=\frac{\partial u}{\partial r}\frac{\partial r}{\partial y}+\frac{\partial v}{\partial\varphi}\frac{\partial\varphi}{\partial y}$$

da aber

$$\frac{\partial \varphi}{\partial x} = -\frac{\sin \varphi}{r} \quad \frac{\partial \varphi}{\partial y} = \frac{\cos \varphi}{r} \quad \frac{\partial r}{\partial x} = \cos \varphi \quad \frac{\partial r}{\partial y} = \sin \varphi$$

ist

$$\frac{\partial u}{\partial x} = \frac{\partial u}{\partial r} \cos \varphi - \frac{\partial u}{\partial \varphi} \frac{\sin \varphi}{r}$$

$$\frac{\partial v}{\partial y} = \frac{\partial v}{\partial r} \sin \varphi + \frac{\partial v}{\partial \varphi} \frac{\cos \varphi}{r}$$

Indem wir hierin setzen

$$u = \rho \cos \varphi - \tau \sin \varphi$$

$$v = \rho \sin \varphi + \tau \cos \varphi$$

erhalten wir

$$x_x = \cos^2 \varphi \frac{\partial \rho}{\partial r} + \frac{\sin^2 \varphi}{r} \left(\rho + \frac{\partial \tau}{\partial \varphi} \right) - \sin \varphi \cos \varphi \left(\frac{\partial \tau}{\partial r} + \frac{1}{r} \frac{\partial \rho}{\partial \varphi} - \frac{\tau}{r} \right)$$

$$y_y = \sin^2 \varphi \frac{\partial \rho}{\partial r} + \frac{\cos^2 \varphi}{r} \left(\rho + \frac{\partial \tau}{\partial \varphi} \right) + \sin \varphi \cos \varphi \left(\frac{\partial \tau}{\partial r} + \frac{1}{r} \frac{\partial \rho}{\partial \varphi} - \frac{\tau}{r} \right)$$

Auf ganz dieselbe Weise erhalten wir weiter

$$x_y = 2 \sin \varphi \cos \varphi \left(\frac{\partial \rho}{\partial r} - \frac{\rho}{r} - \frac{1}{r} \frac{\partial \tau}{\partial \varphi} \right) + (\cos^2 \varphi - \sin^2 \varphi) \left(\frac{\partial \tau}{\partial r} + \frac{1}{r} \frac{\partial \rho}{\partial \varphi} - \frac{\tau}{r} \right)$$

$$z_x = \cos \varphi \left(\frac{\partial \rho}{\partial z} + \frac{\partial w}{\partial r} \right) - \sin \varphi \left(\frac{\partial \tau}{\partial z} + \frac{\partial w}{r \partial \varphi} \right)$$

$$y_z = \sin \varphi \left(\frac{\partial \rho}{\partial z} + \frac{\partial w}{\partial r} \right) + \cos \varphi \left(\frac{\partial \tau}{\partial z} + \frac{\partial w}{r \partial \varphi} \right)$$

Die Functionen

$$\frac{\partial \rho}{\partial r}, \qquad \frac{1}{r} \left(\rho + \frac{\partial \tau}{\partial \varphi} \right) \qquad \frac{\partial \tau}{\partial r} + \frac{1}{r} \frac{\partial \rho}{\partial \varphi} - \frac{\tau}{r}$$

$$\frac{\partial \rho}{\partial z} + \frac{\partial w}{\partial r} \qquad \frac{\partial \tau}{\partial z} + \frac{\partial w}{r \partial \varphi}$$

die hier charakteristisch auftreten, haben mechanische Bedeutung, wie x_x y_y etc, sie bestimmen die Deformation eines aus

dr, $rd\varphi$, dz construirten Elementes, $\frac{\partial \rho}{\partial r}$ und $\frac{1}{r}\left(\rho+\frac{\partial \tau}{\partial \phi}\right)$ sind die radiale und tangentiale Schwindungs- oder Quellungsgrösse in dem Punkt ρ, φ, τ, die Grösse $\frac{\partial \tau}{\partial r}+\frac{1}{r}\frac{\partial \rho}{\partial \psi}-\frac{\tau}{r}$ bestimmt den Winkel zwischen den Seiten dr und $rd\varphi$, die Grösse $\frac{\partial w}{\partial r}+\frac{\partial \rho}{\partial z}$ den Winkel zwischen dz and dr, und die Grösse $\frac{\partial \tau}{\partial z}+\frac{\partial w}{r\partial \varphi}$ schliesslich den Winkel zwischen dz und $rd\varphi$.

Wenn wir die oben stehenden Gleichungen nach $\frac{\partial \rho}{\partial r}$ etc. auflösen, so finden wir

$$\frac{\partial \rho}{\partial r}=x_x \cos^2\varphi+y_y \sin^2\varphi+\sin\varphi\cos\varphi x_y$$

$$\frac{1}{r}\left(\rho+\frac{\partial \tau}{\partial \varphi}\right)=x_x \sin^2\varphi+y_y \cos^2\varphi-\sin\varphi\cos\varphi x_y \qquad (2a)$$

$$\frac{\partial v}{\partial r}+\frac{1}{r}\frac{\partial \rho}{\partial \varphi}-\frac{\tau}{r}=x_y(\cos^2\varphi-\sin^2\varphi)-2\sin\varphi\cos\varphi(x_x-y_y)$$

$$\frac{\partial \rho}{\partial z}+\frac{\partial w}{\partial r}=z_x\cos\varphi+y_z\sin\varphi$$

$$\frac{\partial \tau}{\partial z}+\frac{\partial w}{r\partial \varphi}=y_z\cos\varphi-z_x\sin\varphi$$

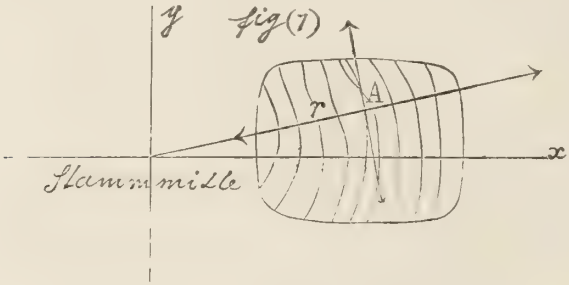
Bezeichnat man die Volumendilatation mit σ, so hat man

$$\sigma=\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=\frac{\partial \rho}{\partial r}+\frac{1}{r}\left(\rho+\frac{\partial \tau}{\partial \varphi}\right)+\frac{\partial w}{\partial z}$$

Es seien R_r Φ_φ Z_r R_r Φ_z die Druckcomponenten im System der Cylindercoordinaten. Da nun X_x, Y_y Z_z etc. lineare functionen von $x_x y_y$ etc sind, können wir setzen

$$R_r=X_x\cos^2\varphi+Y_y\sin^2\varphi+\sin\varphi\cos\varphi X_y$$
$$\Phi_\phi=X_x\sin^2\varphi+Y_y\cos^2\varphi-\sin\varphi\cos\varphi X_y$$
$$Z_z=Z_z$$
$$R_\phi=X_y(\cos^2\varphi-\sin^2\varphi)-2\sin\varphi\cos\varphi(X_x-Y_y)$$
$$Z_r=X_x=Z_w\cos\varphi+Y_z\sin\varphi$$
$$\Phi_z=Y_z\cos\varphi-Z_x\sin\varphi$$

Es handelt sich jetzt darum, die Functionen $\overline{X}_x$ $\overline{Y}_y$ etc. darzustellen, und zwar in ihrer Abhängigkeit von der gegebenen Gestalt des Holzstücks, indem wir annehmen, dass die Druckcomponenten, mit denen jedes Element sich zusammenzieht, oder ausdehnt, gegeben seien. Es sei R die Druckcomponente in radialer Richtung, Φ diejenige in tangentialer Richtung, und Z diejenige in longitudinaler Richtnng. Hinsichtlich der Natur der zu bildenden Functionen schicken wir Folgendes als Bedingung voraus. Da das Holzstück als Ganzes keine Verrückung erleidet, so muss es einen Punkt in dem Holzstück geben, dessen Dilatation verschwindet, d. h. einen Punkt, in dem die Druckcomponenten gleichzeitig verschwinden. Demgemäss müssen $\overline{R}_r$ $\overline{\Phi}_\varphi$ $\overline{Z}_z$ so gebildet werden, dass sie in drei Flächen verschwinden, welche in dem Holzstück liegen, und einander senkrecht schneiden. Es sind dies die Bedingungen dafür, dass das Holzstück als Ganzes weder radial, noch tangential, noch longitudinal verrückt wird, indem es schwindet oder quillt. Wir fassen zunächst



ein Holzstück in's Auge, welches die Stammmitte nicht enthält, [fig (1)] und denken uns durch den Punkt A, dessen Lage in Bezug auf die Stammmitte durch r φ z bestimmt ist, einen Kreiscylinder mit dem Radius r gelegt. Das Integral

$$\iint R r d\varphi dz$$

ausgedehnt über die Cylinderfläche, so weit sie in dem Holzstück liegt, ist die Summe der Druckkräfte entlang der Cylinderfläche, welche jeden Punkt dieser Cylinderfläche radial zu verschieben streben. Wenn wir das Integral

$$\int\left[\int\int Rrd\varphi dz\right]dr$$

einmal über den Theil des Holzstücks bilden, der innerhalb der Cylinderfläche $r=\text{const}$ liegt, und das andere Mal über den Theil, der ausserhalb der Cylinderfläche liegt, so erhalten wir Druckkräfte, welche die durch die Cylinderfläche geschiedenen Theile des Holzstücks in entgegengesetzter Richtung auf diese Cylinderfläche ausüben. Bezeichnet man den kleinsten und grössten Werth von r in dem Holzstück mit r_1 und r_2, so ist

$$\int_{r_1}^{r}\left[\int\int Rrd\varphi dz\right]dr-\int_{r}^{r_2}\left[\int\int Rrd\varphi dz\right]dr$$

die Druckkraft, welche das Holzstück in der Cylinderfläche $r=\text{const}$ aufzureissen strebt, und auf diese radial wirkt. Dividiert man diesen Ausdruck mit dem Volumen des Holzstücks

$$V=\int\int\int rdrd\varphi dz$$

so erhält man die Druckkraft pro Flächeneinheit, und man darf wohl annehmen, dass

$$\overline{R}_r=\frac{1}{V}\left(\int_{r_1}^{r}\left[\int\int Rrd\varphi dz\right]dr-\int_{r}^{r_2}\left[\int\int Rrd\varphi dz\right]dr\right)$$

Ich bemerke hierbei, dass diese Annahme uns zwingt, der Function $\overline{R}_r$ Eigenschaften zuzuschreiben, welche näherer experimenteller Begründung bedürfen. R_r ist zunächst in der dargestellten Form eine Function von r allein, und verschwindet bei einem gewissen Werth von r; in dem Holzstück müsste eine gewisse cylindersche Fläche existieren, in der jeder Punkt von beiden Seiten der Fläche her denselben radialen Druck in entgegengesetzter Richtung erleidet und darum keine Verrückung in radialer Richtung zeigt. Ferner wirken in den Punkten $r=r_1$ und $r=r_2$ entgegengesetzte Druckkräfte, welche absolut genommen von gleichen Intensität sind. Ist darum R positiv d. h. quillt das Holzstück, so ist R_r positiv

ausselhalb der cylindrischen Fläche, in der R_r verschwindet, und negativ innerhalb derselben; der dem Herz fernere Theil des Holzstücks entfernt sich von dem Herz, während der nähere Theil sich demselben nähert. Das sind Eigenschaften der Function $\overline{R}_r$, welche vielleicht in der Wirklichkeit bestätigt werden.

Wir denken uns von der Stammmitte aus durch den Punkt A eine Ebene $\varphi=\text{const}$ gelegt. Das Integral

$$\int\int \Phi dr dz$$

ausgedehnt über diese Ebene, so weit sie in dem Holzstück liegt, ist nichts anderes, als die Summe der Druckkräfte, welche in tangentialer Richtung auf diese Ebene wirken. Bildet man das Integral

$$\int\left[\int\int \Phi dr dz\right] r d\varphi$$

einmal über den Theil des Holzstücks, der auf einer Seite der Ebene $\varphi=\text{const.}$ liegt, und das andere Mal über den Theil, der auf der anderen Seit der Ebene liegt; bezeichnet man ferner den grössten und kleinsten Werth von φ in dem Holzstück mit φ_2 und φ_1, so ist

$$\int_{\varphi_1}^{\varphi}\left[\int\int \Phi dr dz\right] r d\varphi - \int_{\varphi}^{\varphi_2}\left[\int\int \Phi dr dz\right] r d\varphi$$

die Druckkraft, welche auf die Ebene $\varphi=\text{const}$ normal wirkt, und das Holzstück in dieser Ebene d. h. tangential aufzureissen strebt. Man kann dann setzen

$$\overline{\Phi}_\varphi=\frac{1}{V}\left(\int_{\varphi_1}^{\varphi}\left[\int\int \Phi dr dz\right] r d\varphi - \int_{\varphi}^{\varphi_2}\left[\int\int \Phi dr dz\right] r d\varphi\right) \qquad (2b)$$

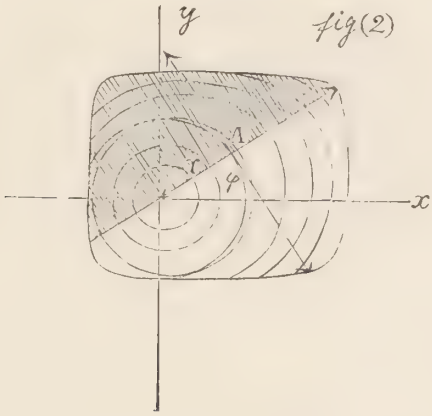
Ganz dieselbe Überlegung führt zu dem Ausdruck

$$\overline{Z}_z=\frac{1}{V}\left(\int_{z_1}^{z}\left[\int\int Z r dr d\varphi\right] dz - \int_{z}^{z_2}\left[\int\int Z r dr d\varphi\right] dz\right)$$

wo z_1 z_2 den kleinsten und grössten Werth von z in dem Holzstück bedeutet.

Diese Annahme über die Natur der Druckcomponenten $\overline{\Phi}_\varphi$ und $\overline{Z}_z$ führt zu denselben Consequenzen, wie bei der Componente $\overline{R}_r$, welche noch durch Versuche geprüft werden müssen. $\overline{\Phi}_\varphi$ ist eine Function von φ allein, und $\overline{Z}_z$ eine von z allein; es giebt zwei senkrechte Ebenen, in denen jeder Punkt keine Verrückung in tangentialer respectiv longitudinaler Richtung erleidet, und durch welche hindurch $\overline{\Phi}_\varphi$ und $\overline{Z}_z$ ihr Vorzeichen ändern.

Wenn das Holzstück die Stammmitte enthält, [fig (2)], so gilt $\overline{Z}_z$ in unveränderter Form, während $\overline{R}_r$ und $\overline{\Phi}_\varphi$ sich in etwas verändern. In diesem Fall ist der kleinste Werth von r in



dem Ausdruck für $\overline{R}_r$ Null; in der Stammmitte müsste von allen Seiten her die Druckkraft wirken, deren Intensität

$$= -\frac{1}{V}\int_0^{r_2}\left[\iint R r d\varphi dz\right]dr$$

ist. Soll die Stammmitte keinerlei Verrückung erleiden, so muss $\overline{R}_r$ für $r=0$ verschwinden d. h.

$$\overline{R}_r = \frac{1}{V}\left(\int_0^{r_2}\left[\iint R r d\varphi dz\right]dr + \int_0^{r}\left[\iint R r d\varphi dz\right]dr - \int_r^{r_2}\left[\iint R r d\varphi dz\right]dr\right)$$

oder da

$$\int_0^{r_2} = \int_0^{r} + \int_r^{r_2}$$

ist,

$$\overline{R_r} = \frac{2}{V} \int_0^{r} \left[\iint R r d\varphi dz \right] dr$$

Die Druckkraft, welche auf die Ebene φ=const. normal wirken, ist nach wie vor

$$\iint \Phi dr dz$$

Der Werth dieses Integrals ist veränderlich mit φ, und zwar so, dass je grösser der Qnerschnitt des Holzstücks durch die Ebene φ=const, desto grösser der Werth des Integrals ist. Ist Φ positiv, d. h. quillt das Holzstück, so müsste jeder Punkt in dem kleineren Querschnitt Compression erleiden durch jeden Punkt im grösseren Querschnitt, so dass jedes Element in dem kleineren Querschnitte scheinbar schwindet. Um einen Ausdruck hierfür zu erhalten, setzen wir statt φ $\varphi + \psi$ und bilden

$$\int_0^{\pi} \left[\iint \Phi dr dz \right]_{\varphi+\psi} r d\psi$$

Es ist die Druckkraft, welche von dem schattirten Theil des Holzstücks her auf die Ebene φ=const einwirkt. Das Integral

$$-\int_0^{\pi} \left[\iint \Phi dr dz \right]_{\psi-\varphi} r d\psi$$

ist dem entsprechend die Druckkraft, welche von dem nicht schattirten Theil her auf dieselbe Ebene wirkt. Die Differenz

$$\int_0^{\pi} \left[\iint \Phi dr dz \right]_{\psi+\varphi} r d\Psi - \int_0^{\pi} \left[\iint \Phi dr dz \right]_{\psi-\varphi} r d\psi$$

ist die Druckkraft, welche das Holzstück in der Ebene $\varphi = \text{const}$ aufzureissen, und die Ebene $\varphi + \pi$ zu comprimiren strebt. Die Druckkraft welche die Ebene $\varphi + \pi$ aufzureissen, und die Ebene $\varphi = \text{const}$ zu comprimiren strebt, ist dagegen

$$\int_0^\pi \left[\iint \Phi dr dz \right]_{\psi+\pi+\varphi} r d\psi - \int_0^\pi \left[\iint \Phi dr dz \right]_{\psi-\pi-\varphi} r d\psi$$

Die Druckkraft, welche in der That auf die Ebene $\varphi = \text{const}$ wirkt, und jeden Punkt derselben tangential verschiebt, muss darum von der Form sein

$$\int_0^\pi \left(\left[\iint \Phi dr dz \right]_{\psi+\varphi} - \left[\iint \Phi dr dz \right]_{\psi-\varphi} \right) r d\psi$$

$$- \int_0^\pi \left(\left[\iint \Phi dr dz \right]_{\psi+\pi+\varphi} - \left[\iint \Phi dr dz \right]_{\psi+\pi+\varphi} \right) r d\psi$$

Man kann dann setzen

$$\overline{\Phi}_\phi = \frac{1}{V} \left\{ \int_0^\pi \left(\left[\iint \Phi dr dz \right]_{\psi+\varphi} - \left[\iint \Phi dr dz \right]_{\psi-\varphi} \right) r d\psi \right. \tag{2c}$$

$$\left. - \int_0^\pi \left(\left[\iint \Phi dr dz \right]_{\psi+\pi+\varphi} - \left[\iint \Phi dr dz \right]_{\psi-\pi-\varphi} \right) r d\psi \right\}$$

In diesem Fall giebt es keine Ebene mehr, in der jeder Punkt keinen einseitigen tangentialen Druck erleidet, wenn gleich $\overline{\Phi}_\phi$ nach wie vor eine Function von φ allein ist. $\overline{\Phi}_\phi$ verschwindet dagegen, wenn Φ von φ unabhängig d. h. das Holz symmetrisch um die Stammmitte, und das Holzstück eine Kreisscheibe von constanten Dicke ist, oder, wenn Φ mit wachsendem r sein Vorzeichen so ändert, dass jedes Glied in dem Ausdruck Φ_ϕ verschwindet, was eintreten kann, wenn eine Vollscheibe eine starke Rinde hat, welche gar nicht quillt oder schwindet. In der Ebene $\varphi + \pi$ wirkt eine Druckkraft, welche bei derselben Intensität in entgegengesetzter Richtung wirkt, wie diejeinge in der Ebene $\varphi = \text{const.}$, da ja

$$\left[\int\int\Phi drdz\right]_{\psi+2\pi+\varphi} rd\psi = \left[\int\int\Phi drdz\right]_{\psi+\varphi} rd\psi$$

$$\left[\int\int\Phi drdz\right]_{\psi-2\pi-\varphi} rd\psi = \left[\int\int\Phi drdz\right]_{\psi-\varphi} rd\psi$$

ist. Ist daher Φ negativ d. h. schwindet das Holzstück, so wirkt in dem kleineren Querschnitt eine Druckkraft von derselben Intensität, wie im grösseren Querschnitt aber aufreissend; das Holzstück müsste mit Vorliebe im kleinsten Querschnitt radial aufreissen; eine Schlussfolgerung, welche in der That oft bei in Bezug auf das Herz exentrisch bearbeiteten Holzstücken beobachtet wird.

So sind die normalen Druckcomponenten $\overline{R}_r\ \overline{\Phi}_\varphi\ \overline{Z}_z$ bestimmt, wenn $R\ \Phi\ Z$ bekannt sind. Was die tangierenden Druckcomponenten $\overline{R}_\varphi\ \overline{\Phi}_z\ \overline{Z}_r$ anbelangt, hängen diese von $R\ \Phi\ Z$ und von der Gestalt des Holzstücks auf eine gewisse Weise ab. Die Bedingungen für das Gleichgewicht eines Holzelementes im System der Cylindercoordinaten sind

$$R_r = \overline{R}_r \quad \Phi_\varphi = \overline{\Phi}_\varphi \quad Z_z = \overline{Z}_z \quad R_\varphi = \overline{R}_\varphi \quad \Phi_z = \overline{\Phi}_z \quad Z_r = \overline{Z}_r$$

Die drei ersteren Gleichungen bestimmen $\rho\ \tau\ w$ vollständig, bis auf drei willkürliche Functionen, welche je zwei von den drei Variabeln $r\ \varphi\ z$ enthalten. Da indessen, die Verrückungscomponenten $\rho\ \tau\ w$ mit den Druckcomponenten $\overline{R}_r\ \overline{\Phi}_\varphi\ \overline{Z}_z$ gleichzeitig verschwinden müssen, so folgt, dass die drei willkürliche Functionen $=0$ zu setzen sind, da sonst die Verrückungscomponenten nicht verschwinden würden, wenn auch die Druckcomponenten, die sie hervorbringen, verschwinden. Die Functionen $\overline{R}_\varphi\ \overline{\Phi}_z\ \overline{Z}_r$ können dann nicht willkürlich gegeben sein, da die linker Hand stehenden Grössen der letzten drei Gleichungen lediglich durch die Differentiation der Functionen $\rho\ \tau\ w$ abgeleitet werden können. Es bleibt denn nichts übrig, als anzunehmen, dass die tangentialen Druckcomponenten $\overline{R}_\varphi\ \overline{\Phi}_z\ \overline{Z}_r$ im Fall des Gleichgewichtes überall die Werthe erhalten, welche entstehen, wenn wir in die drei letzteren der oben stehenden Gleichgewichtsbedigungen die durch die drei ersteren bestimmbaren Functionswerthe für $\rho\ \tau\ w$ einführen.

Die Functionen $\overline{X}_x$ $\overline{Y}_y$ $\overline{Z}_z$ lassen sich, wie folgt, ableiten Es ist

$$R_r = X_x \cos^2 \varphi + Y_y \sin^2 \varphi + \sin \varphi \cos \varphi \, X_y$$

Da vermöge der Gleichgewichtsbedingungen $R_r = \overline{R}_r$ $X_x = \overline{X}_x$ $Y_y = \overline{Y}_y$ $Z_y = \overline{Z}_y$ ist, so muss

$$\overline{R}_r = \overline{X}_x \cos^2\varphi + \overline{Y}_y \sin^2\varphi + \sin\varphi \cos \varphi \overline{X}_y$$

sein. Aus demselben Grund müssen

$$\overline{\Phi}_\varphi = \overline{X}_x \sin^2\varphi + \overline{Y}_y \sin^2\varphi - \sin \varphi \cos\varphi \overline{X}_y$$
$$\overline{R}_\varphi = \overline{\Phi}_r = X_y(\cos^2\varphi - \sin^2\varphi) - 2 \sin \varphi \cos \varphi \, (\overline{X}_x - \overline{Y}_y)$$
$$\overline{Z}_r = \overline{R}_z = \overline{Z}_x \cos \varphi + \overline{Y}_z \sin \varphi$$
$$\overline{\Phi}_z = \overline{Z}_\varphi = \overline{Y}_z \cos \varphi - \overline{Z}_x \sin \varphi$$

Hieraus findet man

$$\overline{X}_x = \overline{R}_r \cos^2 \varphi + \overline{\Phi}_\varphi \sin^2\varphi - \sin \varphi \cos \varphi \, \overline{R}_\varphi$$
$$\overline{Y}_y = \overline{R}_r \sin^2\varphi + \overline{\Phi}_\varphi \cos^2\varphi + \sin \varphi \cos \varphi \, \overline{R}_\varphi$$
$$\overline{X}_y = 2 \sin \varphi \cos \varphi(\overline{R}_r - \overline{\Phi}_\varphi) + (\cos^2\varphi - \sin^2\varphi) R_\varphi$$
$$\overline{Z}_x = \overline{R}_z \cos \varphi - \overline{\Phi}_z \sin \varphi$$
$$\overline{Y}_z = \overline{R}_z \sin \varphi + \overline{\Phi}_z \cos \varphi$$

Wenn wir in die rechte Seite einführen

$$r^2 = x^2 + y^2 \quad \varphi = \text{arct.} \frac{y}{x} \quad \cos \varphi = \frac{x}{\sqrt{x^2+y^2}} \quad \sin \varphi = \frac{y}{\sqrt{x^2+y^2}}$$

so sind die sämmtlichen Druckcomponenten im System der rechtwinkelingen Coordinaten $x\,y\,z$ bestimmt.

Wir betrachten zunächst Schwinden oder Quellen eines Holzstücks im System der rechtwinkeligen Coordinaten, indem wir keinerlei Annahmen über die Functionen $\overline{X}_x$ etc. machen, sondern sie uns nur vorstellen, als Functionen von $x\,y\,z$, welche mit wachsendem Werth von x und y im Allgemeinen wachsen d. h. je weiter das Holzelement, das wir betrachten, sich von dem Herz entfernt.

Die Gleichgewichtsbedingung (2) ergiebt

$$b_{11}\frac{\partial u}{\partial x}+b_{12}\frac{\partial v}{\partial y}+b_{13}\frac{\partial w}{\partial z}=\overline{X}_x$$

$$b_{21}\frac{\partial u}{\partial x}+b_{22}\frac{\partial v}{\partial y}+b_{23}\frac{\partial w}{\partial z}=\overline{Y}_y \qquad (3)$$

$$b_{31}\frac{\partial u}{\partial x}+b_{32}\frac{\partial v}{\partial y}+b_{33}\frac{\partial w}{\partial z}=\overline{Z}_z$$

$$b_{12}\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)=\overline{X}_y \qquad b_{23}\left(\frac{\partial v}{\partial z}+\frac{\partial w}{\partial y}\right)=\overline{Y}_z$$

$$b_{13}\left(\frac{\partial w}{\partial x}+\frac{\partial u}{\partial z}\right)=\overline{Z}_x$$

Setzt man

$$\Delta=\begin{vmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{vmatrix}$$

und weiter

$$a_{11}=\frac{1}{\Delta}\begin{vmatrix} b_{22} & b_{32} \\ b_{23} & b_{33} \end{vmatrix} \qquad a_{12}=\frac{1}{\Delta}\begin{vmatrix} b_{23} & b_{33} \\ b_{21} & b_{31} \end{vmatrix}$$

$$a_{13}=\frac{1}{\Delta}\begin{vmatrix} b_{21} & b_{31} \\ b_{23} & b_{33} \end{vmatrix}$$

$$a_{21}=\frac{1}{\Delta}\begin{vmatrix} b_{13} & b_{33} \\ b_{12} & b_{32} \end{vmatrix} \qquad a_{22}=\frac{1}{\Delta}\begin{vmatrix} b_{11} & b_{31} \\ b_{13} & b_{33} \end{vmatrix}$$

$$a_{23}=\frac{1}{\Delta}\begin{vmatrix} b_{12} & b_{32} \\ b_{11} & b_{31} \end{vmatrix}$$

$$a_{31}=\frac{1}{\Delta}\begin{vmatrix} b_{12} & b_{22} \\ b_{13} & b_{23} \end{vmatrix} \qquad a_{32}=\frac{1}{\Delta}\begin{vmatrix} b_{13} & b_{23} \\ b_{11} & b_{21} \end{vmatrix}$$

$$a_{33}=\frac{1}{\Delta}\begin{vmatrix} b_{11} & b_{21} \\ b_{12} & b_{22} \end{vmatrix}$$

dann erhält man die Gleichungen

$$\frac{\partial u}{\partial x} = a_{11}\overline{X}_x + a_{12}\overline{Y}_y + a_{13}\overline{Z}_z$$

$$\frac{\partial v}{\partial y} = a_{21}\overline{X}_x + a_{22}\overline{Y}_y + a_{23}\overline{Z}_z \qquad (4)$$

$$\frac{\partial w}{\partial z} = a_{31}\overline{X}_x + a_{32}\overline{Y}_y + a_{33}\overline{Z}_z$$

Keine der 9 Constanten verschwindet, wenn wir auch die Struktur des Holzes vollkommen symmetrisch in Bezug auf die Z-Axe annehmen, und setzen

$$b_{23} = b_{13} \qquad b_{11} = b_{22} = 3b_{12}$$

Unter diesem Umstand wird

$$\Delta = 4b_{12}(2b_{12}b_{33} - b_{13}^2)$$

was nur eine positive endlich Grösse sein kann, insofern, als die longitudinale Dilatation eine sehr kleine ist und $2b_{33}$ daher eine sehr grosse Zahl sein muss. Es werden ferner

$$a_{11} = \frac{1}{\Delta}(3b_{12}b_{33} - b_{13}^2) \qquad a_{12} = \frac{1}{\Delta}(b_{13}^2 - b_{33}\,b_{12})$$

$$a_{13} = \frac{1}{\Delta}(b_{12}\,b_{33} - b_{13}^2)$$

$$a_{21} = -\frac{1}{\Delta}(b_{12}\,b_{33} - b_{13}^2) \qquad a_{22} = \frac{1}{\Delta}(3b_{12}\,b_{33} - b_{13}^2)$$

$$a_{23} = -\frac{2}{\Delta}\,b_{13}\,b_{12}$$

$$a_{31} = -\frac{2}{\Delta}\,b_{13}\,b_{12} \qquad a_{32} = -\frac{2}{\Delta}\,b_{13}\,b_{12}$$

$$a_{33} = \frac{8}{\Delta}\,b_{12}^2$$

Wir wollen indessen eine solche Struktursymmetrie nicht annehmen, sondern nur, dass die 9 Constanten ausreichen, Schwinden und Quellen darzustellen und die Gleichungen (4) auf einige specielle Fälle anwenden.

Wir fassen eine unendlich dünne Platte in s'Auge, welche parallel der $z\ x$ Ebene aus dem Stamm geschnitten sein möge und zwar in der Sehne. Für eine solche Platte ist

$$u = a_{11} \int \overline{X}_x \, dx + a_{12} \int \overline{Y}_y \, dx + a_{13} \int \overline{Z}_z \, dx$$

$$v = a_{21} \int \overline{X}_x \, dy + a_{22} \int \overline{Y}_y \, dy + a_{23} \int \overline{Z}_z \, dy$$

$$w = a_{31} \int \overline{X}_x \, dz + a_{32} \int \overline{Y}_y \, dz + a_{33} \int \overline{Z}_z \, dz$$

Willkürliche Functionen, die hier eigentlich auftreten, sind $=0$ zu setzen, weil $u\ v\ w$ mit $\overline{X}_x\ \overline{Y}_y\ \overline{Z}_z$ gleichzeitig verschwinden müssen. Da nun in einer solchen Sehnenplatte $\overline{Y}_y$ als constant in Bezug auf y angesehen werden kann, so folgt

$$u = a_{11} \int \overline{X}_x \, dx + a_{12} \int \overline{Y}_y \, dx + a_{13} \int \overline{Z}_z \, dx$$

$$v = (a_{21}\ \overline{X}_x \quad + a_{22}\ \overline{Y}_y \quad + a_{23}\ \overline{Z}_z)\ y$$

$$w = a_{31} \int \overline{X}_x \, dx + a_{23} \int \overline{Y}_y \, dz + a_{33} \int \overline{Z}_z \, dz$$

Insofern wir uns die Functionen $\overline{X}_x\ \overline{Y}_y\ \overline{Z}_z$ im Allgemeinen als zunehmend mit wachsendem x (d. h. vom Kern nach dem Splint) zu denken haben, so sieht man, dass die Sehnenplatte sich aus der $x\ z$ Ebene heraus krümmt, und so zwar concav gegen dieselbe, wenn $a_{21}\ a_{23}$ negativ, und $\overline{X}_x\ \overline{Y}_y\ \overline{Z}_z$ positiv sind., d. h. die Platte quillt. Mit der Spiegelplatte verhält es sich anderes. Bei einer solchen können wir uns $\overline{X}_x\ \overline{Y}_y\ \overline{Z}_z$ als symmetrische Functionen in Bezug auf y denken. Es lässt sich dann immer eine Fläche finden, in Bezug auf welche

$$\int \overline{X}_x \, dy = \int \overline{Z}_z \, dy = 0$$

ist, d. h.

$$v = 0$$

sobald die Platte symmetrisch auf die Stammmitte ausgearbeitet ist. Eine Spiegelplatte wirft sich nicht.

Haben wir einen longitudinalen Stab entnommen ausserhalb der Stammmitte, so haben wir noch $\overline{X}_x\ \overline{Y}_y\ \overline{Z}_z$ als constant in Bezug auf x zunehmen, so dass

$$u=(a_{11}\,X_x+a_{12}\,Y_y+a_{13}\,Z_z)\,x$$

$$v=(a_{21}\,X_x+a_{22}\,Y_y+a_{23}\,Z_z)\,y$$

$$w=a_{31}\int X_x\,d_z+a_{23}\int Y_y\,d_z+a_{33}\int Z_z\,dz$$

Die Stab krümmt sich aus der xz und zy Ebene heraus.

Für einen longitudinalen der Stammmitte entnommenen Stab ist $\overline{Z}_z$ symmetrisch in Bezug auf x und y. Sobald der Stab symmetrisch in Bezug auf die Stammmitte ausgearbeit ist, so lässt sich eine Linie finden, in Bezug auf welche

$$\int \overline{Z}_z\,dx=\int \overline{Z}_z\,dy=0$$

ist, d. h.

$$u=v=0$$

der Stab krümmt sich gar nicht; er schwindet oder quillt nur longitudinal.

Ist der Stab dadurch entstanden, dass man eine Sehnen- oder Spiegelplatte senkrecht zur longitudinalen Richtung zersägt, so dass z sich zwischen kleinen Grenzen bewegt, dann kann man $\overline{Z}_z$ $\overline{X}_x$ $\overline{Y}_y$ als constant in Bezug auf z annehmen. Man hat somit

$$u=a_{11}\int \overline{X}_x\,dx+a_{12}\int \overline{Y}_y\,dx+a_{13}\int \overline{Z}_z\,d\alpha$$

$$v=(a_{12}\,\overline{X}_x+a_{22}\,\overline{Y}_y+a_{23}\,\overline{Z}_z)\,y$$

$$w=(a_{31}\,\overline{X}_x+a_{32}\,\overline{Y}_y+a_{33}\,\overline{Z}_z)\,z$$

Der Stab krümmt sich aus der zx und xy Ebene heraus, da in diesem Fall $\overline{X}_x$ $\overline{Y}_y$ $\overline{Z}_z$ Functionen von x allein sind. Da der Anfangspunkt des Coordinatensystems entlang der Linie der Stammmitte beliebig verschoben werden kann, so kann eine Linie gefunden werden, entlang der

$$\int \overline{X}_x dz=\int \overline{Y}_y dz=\int \overline{Z}_z dz=0$$

Ein solcher Stab krümmt sich nur in der xy Ebene.

Ist der Stab einer Spiegelplatte entnommen, so dass eine Linie gefunden werden kann, entlang der

$$\int \overline{X}_x dy = \int \overline{Y}_y dy = \int \overline{Z}_z dy = 0$$

ist, so krümmt sich der Stab gar nicht; er schwindet oder quillt in dieser Linie nur radial.

Wir fassen jetzt eine Hirnscheibe in's Auge. — Um eine solche zu untersuchen, ist es zweckmässig die Gleichung (4) in Cylindercoordinaten umzusetzen. Wir setzen zu dem Ende hypothetisch

$$R_r = c_{11}\frac{\partial \rho}{\partial r} + \frac{c_{12}}{r}\left(\rho + \frac{\partial \tau}{\partial \varphi}\right) + c_{13}\frac{\partial w}{\partial z}$$

$$\Phi_\varphi = c_{21}\frac{\partial \rho}{\partial r} + \frac{c_{22}}{r}\left(\rho + \frac{\partial \tau}{\partial \varphi}\right) + c_{23}\frac{\partial w}{\partial z}$$

$$Z_z = c_{31}\frac{\partial \rho}{\partial r} + \frac{c_{32}}{r}\left(\rho + \frac{\partial \tau}{\partial \varphi}\right) + c_{33}\frac{\partial w}{\partial z}$$

und untersuchen, wann die Druckcomponenten im System der Cylindercoordinaten in dieser Form dargestellt werden kann. Wir setzen

$$\alpha = \cos\varphi \qquad \beta = \sin\varphi$$

$$R_r = X_x\alpha^2 + Y_y\beta^2 + \alpha\beta X_y$$

$$\Phi_\varphi = X_x\beta^2 + Y\alpha^2 - \alpha\beta X_y$$

und führen die Ausdrücke in (2*a*) ein. Man had dann mit Rücksicht auf die Beziehung $\alpha^2 + \beta^2 = 1$

$$\alpha^2(c_{11}x_x + c_{12}y_y + c_{13}z_z) + \beta^2(c_{12}x_x + c_{11}y_y + c_{13}z_z)$$
$$+ \alpha\beta(c_{11} - c_{12})x_y = X_x\alpha^2 + Y_y\beta^2 + \alpha\beta X_y$$

$$\alpha^2(c_{21}x_x + c_{22}y_y + c_{23}z_z) + \beta^2(c_{21}y_y + c_{22}x_x + c_{23}z_z)$$
$$- \alpha\beta(c_{22} - c_{21})x_y = X_x\beta^2 + Y_y\alpha^2 - \alpha\beta X_y$$

$$x_x(\alpha^2 c_{31} + \beta^2 c_{32}) + y_y(\beta^2 c_{31} + \alpha^2 c_{32}) + \alpha\beta(c_{31} - c_{32})x_y$$
$$+ c_{33}z_z = Z_z = b_{31}x_x + b_{32}y_y + b_{33}z_z$$

Die beiden ersteren Gleichungen werden erfüllt durch

$$X_x = c_{11}x_x + c_{12}y_y + c_{13}z_z = c_{22}x_x + c_{21}y_y + c_{23}z_z$$

$$Y_y = c_{12}x_x + c_{11}y_y + c_{13}z_z = c_{21}x_x + c_{22}y_y + c_{23}z_z$$

$$X_y = (c_{11} - c_{12})x_y = (c_{22} - c_{21})x_y$$

was zur Folge hat

$$c_{11} = c_{22} \qquad c_{21} = c_{12} \qquad c_{13} = c_{23}$$

$$c_{11} - c_{12} = c_{22} - c_{21}$$

Wenn der Ausdruck $X_y = (c_{11} - c_{12})x_y$ mit $X_y = b_{12}x_y$ zusammenfallen, und $c_{11} = c_{22} = b_{11} = b_{22}$ sein soll, so muss

$$c_{12} = 2b_{12}$$

sein.
Die dritte Gleichung wird erfüllt, indem wir setzen

$$c_{31} = c_{32}$$

Man sieht somit, dass c mit den Coefficienten b identificirt und die Druckcomponenten im System der Cylindercoordinaten in der oben angegebenen Form dargestellt werden können, sobald wir annehmen, dass die Structur des Holzes um die Z-Axe symmetrisch sei. Wir wollen diese Annahme machen und setzen als Bedingungen des Gleichgewichtes

$$\overline{R}_r = b_{11}\frac{\partial \rho}{\partial r} + \frac{2b_{12}}{r}\left(\rho + \frac{\partial \tau}{\partial \varphi}\right) + b_{13}\frac{\partial w}{\partial z}$$

$$\overline{\Phi}_r = 2b_{21}\frac{\partial \rho}{\partial r} + \frac{b_{22}}{r}\left(\rho + \frac{\partial \tau}{\partial \varphi}\right) + b_{23}\frac{\partial w}{d z}$$

$$\overline{Z}_z = b_{31}\frac{\partial \rho}{\partial r} + \frac{b_{32}}{r}\left(\rho + \frac{\partial \tau}{\partial \varphi}\right) + b_{33}\frac{\partial w}{\partial z}$$

Man hat weiter

$$\frac{\partial \rho}{\partial r} = a_{11}\overline{R}_r + a_{12}\overline{\Phi}_\varphi + a_{23}\overline{Z}_z$$

$$\frac{1}{r}\left(\rho + \frac{\partial \tau}{\partial \varphi}\right) = a_{21}\overline{R}_r + a_{22}\overline{\Phi}_\varphi + a_{23}\overline{Z}_z$$

$$\frac{\partial w}{\partial z} = a_{31}\overline{R}_r + a_{32}\overline{\Phi}_\varphi + a_{33}\overline{Z}_z$$

wo

$$a_{11}=\frac{1}{\Delta}\begin{vmatrix} b_{22} & b_{32} \\ b_{23} & b_{33} \end{vmatrix} \qquad a_{12}=\frac{1}{\Delta}\begin{vmatrix} b_{23} & b_{33} \\ 2b_{21} & b_{31} \end{vmatrix} \qquad a_{13}=\frac{1}{\Delta}\begin{vmatrix} 2b_{21} & b_{31} \\ b_{23} & b_{33} \end{vmatrix}$$

$$a_{21}=\frac{1}{\Delta}\begin{vmatrix} b_{13} & b_{23} \\ 2b_{12} & b_{32} \end{vmatrix} \qquad a_{22}=\frac{1}{\Delta}\begin{vmatrix} b_{11} & b_{31} \\ b_{13} & b_{33} \end{vmatrix} \qquad a_{23}=\frac{1}{\Delta}\begin{vmatrix} 2b_{12} & b_{32} \\ b_{11} & b_{31} \end{vmatrix}$$

$$a_{31}=\frac{1}{\Delta}\begin{vmatrix} 2b_{12} & b_{22} \\ b_{13} & b_{23} \end{vmatrix} \qquad a_{32}=\frac{1}{\Delta}\begin{vmatrix} b_{13} & b_{23} \\ b_{11} & 2b_{21} \end{vmatrix} \qquad a_{33}=\frac{1}{\Delta}\begin{vmatrix} b_{11} & 2b_{21} \\ 2b_{12} & b_{22} \end{vmatrix}$$

und

$$\Delta=\begin{vmatrix} b_{11} & 2b_{12} & b_{13} \\ 2b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{vmatrix}$$

Auf ganz dieselbe Weise findet man weiter mit Rücksicht auf die Beziehungen $c_{11}-c_{12}=c_{22}-c_{21}=2b_{12}$ und $b_{13}=b_{23}$

$$\frac{\partial\tau}{\partial r}+\frac{1}{r}\frac{\partial\rho}{\partial\varphi}-\frac{\tau}{r}=\frac{1}{2b_{12}}R_{\varphi}$$

$$\frac{\partial\rho}{\partial z}+\frac{\partial w}{\partial r}=\frac{1}{b_{13}}Z_r \qquad \frac{\partial\tau}{\partial z}+\frac{\partial w}{r\partial\varphi}=\frac{1}{b_{23}}Z_r$$

Wir betrachten jetzt eine unendlich dünne Hirnscheibe, deren Dicke so klein sein mag, dass Z_z in Bezug auf z als constant angesehen werden kann. Wir haben dann für diesen Fall

$$\rho=a_{11}\int\overline{R}_r dr+a_{12}\int\overline{\Phi}_{\varphi}dr+a_{13}\int\overline{Z}_z dr$$

$$\tau=a_{12}r\int\overline{R}_r d\varphi+a_{22}r\int\overline{\Phi}_{\varphi}d\varphi+a_{23}r\int\overline{Z}_z d\varphi-\rho$$

$$w=(a_{31}\overline{R}_r+a_{32}\overline{\Phi}_{\varphi}+a_{33}\overline{Z}_z)z$$

wo z die Dicke der Scheibe bedeutet. Da wir uns die Function $\overline{R}_r$ als zunehmend mit wachsenden r denken müssen, so muss eine solche Scheibe, falls a_{31} nicht verschwindend klein

ist, die Form eines Kegels annehmen, wie man es in der That bei der dünnen Hirnscheibe einer im Splint stark schwindenden Holzart beobachtet.* Ist die Scheibendicke endlich, so dass $\overline{Z}_z$ mit z variirt, so kann eine Fläche gefunden werden, in Bezug auf welche

$$\int \overline{Z}_z dz = 0$$

ist. Wenn diese Fläche eine Ebene ist, so wirft sich die Scheibe gar nicht; die Hirnfläche der Scheibe krümmt sich um die Grösse

$$w = a_{31} \int_0^{z'} \overline{R}_r dz + a_{32} \int_0^{z'} \overline{\Phi}_\varphi dz + a_{33} \int_0^{z'} \overline{Z}_z dz$$

wo z' die eine Hirnfläche giebt.

Wir setzen zur Abkürzung

$$a_{11}\overline{R}_r + a_{12}\overline{\Phi}_\varphi + a_{13}\overline{Z}_z = \Psi_1$$

$$a_{21}\overline{R}_r + a_{22}\overline{\Phi}_\varphi + a_{23}\overline{Z}_z = \Psi_2$$

$$a_{31}\overline{R}_r + a_{32}\overline{\Phi}_\varphi + a_{33}\overline{Z}_z = \Psi_2$$

Ψ_1 ist die radiale Schwindungs-oder Quellungsgrösse, Ψ_2 die tangentiale, und Ψ_3 endlich die longitudinale. Es ist dann

$$\frac{\partial \rho}{\partial r} = \Psi_1 \qquad \frac{1}{r}\left(\rho + \frac{\partial \tau}{\partial \psi}\right) = \Psi_2$$

$$\frac{\partial w}{\partial z} = \Psi_3$$

Wenn wir die unendlich kleine Veränderung des Winkelelementes $d\varphi$ mit $d\psi$ bezeichnen und setzen,

$$(r+\rho)d\psi = d\tau$$

so erhält man

$$(\rho + r)\frac{d\psi}{d\varphi} = r\Psi_2 - \rho = r\Psi_2 - \int \Psi_1 dr$$

* Nördlinger: Die technischen Eigenschaften der Hölzer pag. 289.

oder

$$\Psi_2 = \frac{1}{r}\int \Psi_1 dr + \left(1 + \frac{\rho}{r}\right)\frac{d\psi}{d\varphi}$$

Da ψ die Veränderung der Winkels φ in Folge des Schwindens oder Quellens durchaus mit φ wachsen muss, and da ferner Ψ_2 Ψ_1 ρ ψ im Fall des Schwindens gleichzeilig ihr Vorzeichen ändern, so sieht man, dass so wohl beim Schwinden, als Quellen im Allgemeinen

$$\Psi_2 > \frac{1}{r}\int \Psi_1 dr$$

sein muss, d. h., *dass die tangentiale Schwindungs,- oder Quellungsgrösse im Allgemeinen grösser sein muss, als die radiale*, wenn wir, wie bei den Messungen der Schwindungs- oder Quellungsgrösse üblich, unter der radialen Schwindungs- oder Quellungsgrösse den Quotienten $\frac{\rho}{r}$ verstehen.

Haben wir ein Scheibendreieck vom Winkel φ, so haben wir für die Veränderung der Winkels φ

$$\psi(\varphi) - \psi(0) = \int_0^{\varphi} \frac{\Psi_2 d\varphi}{\left(1 + \frac{1}{r}\int \Psi_1 dr\right)} - \frac{1}{r}\int_0^{\varphi}\int_0^{r} \frac{\Psi_1 d\varphi dr}{\left(1 + \frac{1}{r}\int \Psi_1 dr\right)}$$

$$= \int_0^{\varphi} \frac{\left(\Psi_2 - \frac{1}{r}\int \Psi_1 dr\right)}{\left(1 + \frac{1}{r}\int \Psi_1 dr\right)} d\varphi$$

Wenn wir diese Gleichung auf eine Vollscheibe anwenden, so erhalten wir unter der Voraussetzung, dass $\frac{d\psi}{d\varphi}d\varphi$ nirgends endlich wird, d. h. die Vollscheibe nirgends radial aufreisst

$$\int_0^{2\pi} \frac{\left(\Psi_2 - \frac{1}{r}\int \Psi_1 dr\right)}{\left(1 + \frac{1}{r}\int \Psi_1 dr\right)} d\varphi = \psi(2\pi) - \psi(0) = 0$$

da die Bogenlänge eines mit dem Radius Eins beschriebenen Kreises auf keine Weise von dem Werth 2π abweichen kann. Diese Gleichung ist die Bedingung dafür, dass die Vollscheibe nirgends radial aufreisst, und setzt eine gewisse Vertheilung

der Druckcomponenten $\overline{R}_r$ etc. voraus. Wenn wir die Annahme machen, dass Ψ_2 und Ψ_1 so von φ abhängen, dass $\Psi_2 - \frac{1}{r}\int \Psi_1 dr$ das Vorzeichen nicht wechselt, während φ von 0 bis 2π zunimmt, dann erhalten wir

$$\Psi_2 = \frac{1}{r}\int \Psi_1 dr = \frac{\rho}{r} \qquad (5)$$

d. h., *wenn eine Vollscheibe schwinden oder quellen soll, ohne radial aufzureissen, so muss die tangentiale Schwindungs- oder Quellungsgrösse gleich sein der radialen.* Diese Bedingung lehrt uns kennen, wie die Druckcomponenten R_r etc. durch die Vollscheibe vertheilt sein müssen., damit diese nicht aufreisst. Es ist nämlich

$$a_{21} r \overline{R}_r + a_{22} r \overline{\Phi}_\varphi + a_{23} r \overline{Z}_z = a_{11}\int R_r dr + a_{12}\int \overline{\Phi}_\varphi dr + a_{13}\int \overline{Z}_z dr$$

was befriedigt wird durch

$$a_{21} r \overline{R}_r = a_{11}\int \overline{R}_r dr \qquad a_{22} r \overline{\Phi}_\varphi = a_{12}\int \overline{\Phi}_\varphi dr \qquad (5a)$$

$$a_{23} r \overline{Z}_z = a_{13}\int \overline{Z}_z dr$$

oder, indem wir diese Gleichungen nach r differentieren

$$r\frac{d\overline{R}_r}{dr} = R^2\left(\frac{a_{11}}{a_{21}} - 1\right) \qquad r\frac{d\overline{\Phi}_\varphi}{dr} = \overline{\Phi}_\varphi\left(\frac{a_{12}}{a_{22}} - 1\right)$$

$$r\frac{d\overline{Z}_z}{dr} = \overline{Z}\left(\frac{a_{13}}{a_{23}} - 1\right)$$

Man findet hieraus, indem

$$\frac{a_{11}}{a_2} - 1 = \varkappa_1 \qquad \frac{a_{12}}{a_{22}} - 1 = \varkappa_2 \qquad \frac{a_{13}}{a_{23}} - 1 = \varkappa_3$$

gesetzt werden

$$\overline{R}_r = C_1 r^{\varkappa_1} \qquad \overline{\Phi}_\varphi = C_2 r^{\varkappa_2} \qquad \overline{Z}_z = C_3 r^{\varkappa_3}$$

wo C willkürliche Constanten sind. Damit $\overline{R}_r$ $\overline{\Phi}_\varphi$ $\overline{Z}_z$ auch im Centrum der Scheibe nicht unendlich gross werden, ist es

nothwendig, dass $\varkappa_1\ \varkappa_2\ \varkappa_3$ positive Grössen sind, dass darum $\frac{a_{11}}{a_{12}}\ \frac{a_{12}}{a_{22}}\ \frac{a_{13}}{a_{23}}$ positive Grössen sind, welche grösser als Einheit sind. Nun sind

$$\frac{a_{11}}{a_{21}}=\frac{b_{22}b_{11}-b_{32}b_{23}}{b_{13}b_{32}-2b_{33}b_{12}}=\frac{9b^2_{12}-b_{32}b_{23}}{b_{13}b_{32}-2b_{33}b_{12}}$$

$$\frac{a_{12}}{a_{22}}=\frac{b_{23}b_{31}-2b_{33}b_{12}}{b_{11}b_{33}-b_{31}b_{13}}=\frac{b_{13}b_{31}-2b_{33}b_{12}}{3b_{12}b_{33}-b_{31}b_{31}}$$

$$\frac{a_{13}}{a_{23}}=\frac{2b_{21}b_{31}-b_{31}b_{23}}{2b_{12}b_{33}-b_{31}b_{23}}=\frac{2b_{12}b_{33}-b_{31}b_{23}}{2b_{12}b_{33}-b_{31}b_{23}}=1$$

Mithin

$$\varkappa_3=0$$

folglich

$$\overline{Z}_z=C_3.$$

Die longitudinale Druckkraft muss constant sein in Bezug auf r, wie es schon abgeleitet wurde. Führen wir weiter die Annahme ein, dass die elastischen Druckkräfte ein Potential haben, so ist

$$a_{13}=a_{31} \qquad a_{23}=a_{32}$$

Wir erhalten denn

$$\frac{a_{11}}{a_{21}}=\frac{9b^2_{12}-b^2_{13}}{b^2_{13}-2b_{33}b_{12}} \qquad \frac{a_{12}}{a_{22}}=\frac{b^2_{13}-2b_{33}b_{12}}{3b_{12}b_{33}-b^2_{13}}$$

Damit diese Grössen positiv werden, muss

$$b^2_{13}>2b_{33}b_{12}$$

$$b^2_{13}<3b_{33}b_{12}$$

d. h.

$$\frac{b^2_{13}}{b_{34}\,b_{12}}>2 \qquad \frac{b^2_{13}}{b_{33}\,b_{12}}<3$$

was keineswegs eine Unmöglichkeit darstellt. Die Constanten sollen ferner >1 sein; die Bedingungen dafür sind

$$9b^2_{12}+2b_{12}b_{33}-2b^2_{13}>0$$

$$2b^2_{13}-5b_{12}b_{33}>0$$

was auch keine Unmöglichkeit darstellt. Nimmt man an, dass $2b^2_{13}=5b_{12}b_{33}$ ist d. h. $\frac{a_{12}}{a_{.2}}=1$, so findet man

$$\frac{a_{11}}{a_{21}}-1=\frac{9b^2_{12}-\frac{6}{5}b^2_{13}}{b^2_{13}-2b_{33}b_{12}}=3\left(15\left(\frac{b_{12}}{b_{13}}\right)^2-2\right)$$

was bis zu
$$\frac{b_{12}}{b_{13}}=\sqrt{\frac{2}{15}}$$

positiv bleibt. Da indessen $\overline{\Psi}_\varphi$ eine Function von φ allein sein soll, so ist es nothwendig, dass damit die Gleichung (5*a*) besteht, $2b^2_{13}=5b_{12}b_{33}$ wird, wenn $\overline{\Psi}_\varphi$ nicht verschwindet. Wir sehen somit, dass wenn eine Vollscheibe nicht aufreissen soll, die Verhältnisse der elastischen Constanten zu einander zwischen gewissen Grenzwerthen liegen müssen, dass die radiale Druckkraft nach einem gewissen Gesetze durch die ganze Scheibe vertheilt sein muss. Wenn die Vollscheibe bei einer vollkommenen Kreisgestalt überall dieselbe Dicke hat, und das Verhalten des Holzes gegen Feuchtigkeit überall symmetrisch in Bezug auf das Herz ist, so verschwindet die tangentiale Druckkraft d. h. jede radiale Ebene erleidet dieselbe aber entgegengesetzte Druckkraft in tangentialer Richtung, dann kann die Scheibe ohne Riss bleiben, falls die Verhältnisse der elastischen Constanten einen gewissen Werth nicht übersteigen.

Es handelt sich überhaupt bei der Frage, ob eine Vollscheibe aufreisst oder nicht, darum, dass die tangentiale Druckcomponente $\overline{\Psi}_\varphi$ verschwindet. Nun kann $\overline{\Psi}_\varphi$ auch dadurch verschwinden oder wenigstens unendlich klein bleiben, dass Ψ radial sein Vorzeichen ändert, und zwar so, dass das Integral

$$\iint \Psi dr dz$$

verschwindet, oder verschwindend klein wird. Es ist dies der Fall, wenn die Vollscheibe z. B. eine starke weing dilatationsfähige Rinde besitzt und diese ungelähmt ist. Unter diesem Umstand kann auch R sein Vorzeichen ändern, und somit auch das Integral

$$\int\int R r d\varphi dz$$

Mithin kann $\overline{R}_r$ verschwinden, oder verschwindend klein werden, also dass die Bedingung

$$\Psi_2 = \frac{1}{r}\int \Psi_1 dr$$

erfüllt ist, was für Werthe die elastischen Constanten auch besitzen mögen. *Eine Vollscheibe mit starker ungelähmter Rinde reisst demnach nicht auf, und die radiale Schwindungs oder Quellungsgrösse muss dabei mit der tangentialen zusammenfallen;* eine Schlussfolgerung, welche der Versuch des Herrn Koide, wie ich glaube, vollständig bestätigt.

Wenn die Scheibendicke sehr gross wird, d. h. sich in einen Trumm verwandelt, so wird die Deformation eine andere. Dem Integral

$$\int_0^z \left[\int\int Z r d\varphi dr\right] dz$$

können wir in diesem Fall einen bedeutenden Werth beilegen, wenn z eine der Hirnebene bedeutet und dergleichen den beiden Integralen

$$\int\int R r d\psi dz, \qquad \int\int \Phi dr dz.$$

Werden $\overline{R}_r$ und $\overline{\Phi}_\varphi$ aber unendlich klein, etwa in Folge der Belassung der Rinde, und bleiben es in der ganzen Länge, so erleidet der Trumm keinen Riss, so lange $\overline{Z}_z$ einen mässigen Werth hat, dass Ψ_1 Ψ_2 Werthe erhalten, bei denen die Festigkeit des Holzes in der entsprechenden Richtung noch nicht beansprucht wird. In der Hirnfläche des Trumms wird $\overline{Z}_z$ gross und somit auch Ψ_1 und Ψ_2, wenn auch $\overline{R}_r$ und $\overline{\Phi}_\varphi$ nach wie vor unendlich klein sein würde. Die Festigkeit des Holzes in tangentialer und radialer Richtung wird hauptsächlich durch den longitudinalen Druck $\overline{Z}_z$ beansprucht. Wenn das Holz schwindet, so wirkt in der Hirnfläche der Druck $-\overline{Z}_z$, und wenn es einen Durchmesser giebt, in dem Ψ_2 Maximum ist, so muss der Trumm das Bestreben haben, in diesem Durchmesser aufzureissen, und in zwei Halbhölzer zu zerfallen.

Wenn das Holz in diesem Durchmesser aufgerissen ist, so gilt der Ausdruck (2c) für $\overline{\Psi}_\varphi$ nicht mehr, sondern (2b). Das Halbholz muss dann in dem Radius wo $\overline{\Phi}_\varphi = 0$ ist, wo also zwei gleiche entgegengesetzte tangentiale Druckkräfte wirken, aufzureissen und so in zwei Viertelhölzer zuzerfallen streben. Demnach muss ein schwindender Holztrumm das Bestreben haben, in vier Viertelhölzer zu zerfallen; eine Folgerung, welche die Wirklichkeit in der That bestätigt.

Wie man sieht, führt die Annahme, die wir über die Natur der Druckcomponenten $\overline{R}$. $\overline{\Psi}_\varphi$ $\overline{Z}_z$ gemacht haben, zu keinerlei Folgerung, die mit der Erfahrung im Widerspruch stünde. Indem ich mir vorbehalte, später nach näher auf diese Frage zurückzukommen, wollen wir uns hier nur mit der Annahme begnügen, dass die Druckkräfte $\overline{R}_r$ $\overline{\Psi}_\varphi$ $\overline{Z}_z$ in der angegebenen Form thatsächlich dargestellt werden können, dass die Functionen R Φ Z bekannt seien. Die Deformationen eines Holzkörpers von gegebener Gestalt lassen sich dann leicht finden, und somit die Gestalt desselben nach dem Schwinden oder Quellen. Es ist

$$\rho = \int \psi_1 dr \qquad \psi = \int \frac{\psi_2 d\varphi}{\left(1 + \frac{1}{r}\int \psi_1 dr\right)} - \frac{1}{r}\int \frac{\int \psi_1 dr \,.\, d\varphi}{\left(1 + \frac{1}{r}\int \psi_1 dr\right)}$$

$$w = \int \psi_3 dz$$

wo ψ_1 ψ_2 ψ_3 Functionen von r φ z sind, welche gegeben sind, wenn die ursprüngliche Gestalt des Holzstücks in Bezug auf die Stammmitte gegeben sind. Es sei diese $f(r\ \varphi\ z) = 0$
Es seien die Coordinaten eines Punktes nach dem Schwinden oder Quellen r' φ' z', so dass

$$r' = r + \rho \qquad \varphi' = \varphi + \psi \qquad z' = z + w.$$

Im Fall des Schwindens sind ρ ψ w selbstredend negativ zu nehmen. Denkt man sich diese Gleichungen nach r φ z auf gelöst, sodass r φ z als Functionen von r' φ' z' erscheinen. Wenn wir diese in die Gleichung $f(r\ \varphi\ z) = 0$ substituiren, erhalten wir eine Gleichung für die Gestalt, welche der Holzkörper nach dem Quellen oder Schwinden annimmt. Man kann

auch, wie folgt verfahren. Sind $r'\ \varphi'\ z'$ die Coordinaten eines Punktes nach dem Eintreten der Quellung, so kann man umgekehrt $r\ \varphi\ z$ als Coordinaten desselben Punktes nach dem Eintreten der Schwindung betrachten, da der Grünzustand des Holzes als Quellungszustand des geschwundenen Holzes angesehen werden kann. Ist daher die Gestalt eines Holzstücks durch $f(r'\ \varphi'\ z')=0$ bestimmt, so ist die Gestalt des Holzstücks nach dem Schwinden gegeben durch

$$f(r+\rho,\ \varphi+\psi,\ z+w)=0$$

Nun wollen wir eine Annahme machen, welche in der Natur nicht erfüllt ist, aber angenährt, wenn das Holzstück so dem Stamm entnommen ist, dass es entweder aus dem Splint oder Kern allein besteht. Wir nehmen nämlich an, dass $\psi_1\ \psi_2\ \psi_3$ Constanten seien, deren Werthe nur mit der Gestalt und der Feuchtigkeit des Holzstücks variiren. Unter dieser Annahme wird

$$\rho=\psi_1 r+\text{const.} \qquad \psi=\left(\frac{\psi_2-\psi_1}{1+\psi_1}\right)\varphi+\text{const.}$$

$$w=\psi_3 z+\text{const.}$$

Die willkürlichen Constanten bei ρ und w können $=0$ gesetzt werden, da ρ für $r=0$ verschwindet, und die Ebene $(r\ \varphi)$ so in dem Holzstück verschoben werden kann, dass w für $z=0$ verschwindet. Wir haben dann

$$r'=(1+\psi_1)r \qquad \varphi'=\left(\frac{1+\psi_2}{1+\psi_1}\right)\varphi+C$$

$$z'=(1+\psi_3)z$$

oder indem wir setzen

$$1+\psi_1=\mu \qquad \frac{1+\psi_2}{1+\psi_1}=\lambda \qquad 1+\psi_3=\varkappa$$

$$r'=\mu r \qquad \varphi'=\lambda\varphi+C \qquad z'=\varkappa z$$

Wir fassen jetzt den Fall in's Auge, wo eine Gerade auf einer Scheibe von constanter Dicke gezogen ist, und untersuchen die Gestalständerung dieser Gerade. Es sei hier bemerkt, dass wenn die Scheibe durch diese Gerade begrenzt ist, die Formel dieselbe bleibt, nur dass λ und μ einen anderen Werth erhalten.

Die Gleichung einer Gerade in Polarcoordinaten ist

$$\text{const} = \varepsilon = r \cos \varphi$$

Sie wird eine Curve nach dem Quellen, deren Gleichung

$$\varepsilon = \frac{r'}{\mu} \cos \frac{\varphi'}{\lambda}$$

Ist die Gerade im ursprünglichen Zustande des Holzes durch

$$\varepsilon = r' \cos \varphi'$$

bestimmt, so verwandelt sie sich nach dem Schwinden in eine Curve, deren Gleichung

$$\varepsilon = \mu r \cos \lambda \varphi.$$

Wie man sieht, lässt sich die Curve nach der Quellung aus der Curve nach der Schwindung ohne Weiteres finden, indem man für λ und μ ihre reciproken Werthe einsetzt. Es ist daher nicht nöthig, Formeln für Quellen besonders abzuleiten. Die Curve ist eine transcendente, wenn λ nicht eine ganze Zahl ist. Denkt man sich die Curve in rechtwinkeligen Coordinaten $x\ y$ dargestellt, und $x\ y$ als Functionen von φ, so ergiebt sich

$$\frac{dy}{dx} = \frac{\cos \lambda\varphi \cos \varphi + \lambda \sin \varphi \sin \lambda\varphi}{\lambda \sin \lambda\varphi \cos \varphi - \sin \varphi \cos \lambda\varphi}$$

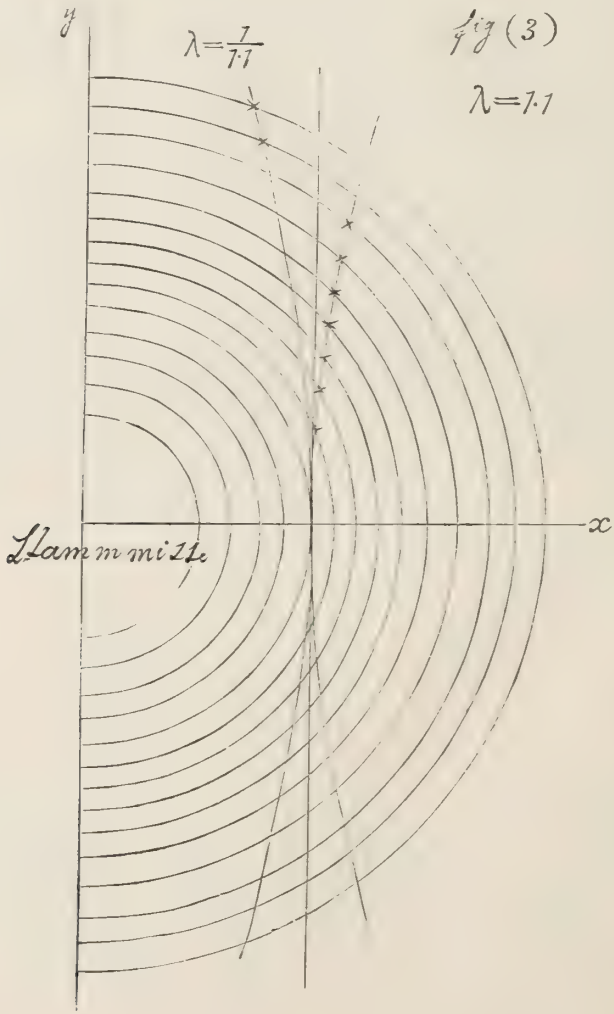
Hieraus findet man

$$\text{für } \varphi = 0 \qquad \frac{dy}{dx} = +\infty \qquad r = \frac{\varepsilon}{\mu}$$

$$\text{für } \varphi = \frac{\pi}{2\lambda} \qquad \frac{dy}{dx} = \operatorname{tg} \frac{\pi}{2\lambda} \qquad r = \infty$$

Die Curve schneidet die x-Achse in der Distanz $\frac{\varepsilon}{\mu}$ senkrecht, und hat zwei Asymptoten, deren Winkel mit der x-Achse $= \frac{\pi}{2\lambda}$ ist. Dieser Winkel ist kleiner als $\frac{\pi}{2}$, wenn $\lambda > 1$ ist. d. h. das Holz schwindet, und grösser als $\frac{\pi}{2}$, wenn das Holz quillt. Die Figur (3) stellt den ungefähren Verlauf der Curven

dar. In der That beobachtet man ähnlich verlaufende Curven, indem man auf einer Scheibe eine Gerade zieht und sie austrockenen oder quellen lässt. Die Tafeln X XI XII zeigen Scheiben von Quercus grandulifera. Die Curven waren Geraden, welche im frischen Zustande der Scheiben gezeichnet worden sind. In der Scheibe [Tafel XII] sind die Geraden, $A'B'$ und CB neben die Curven AB und BC' gezeichnet, um die Krümmung der letzteren zu verdeutlichen.



Ist die Scheibe geradlienig tangential abgeschnitten., wie die Figur (4) zeigt, so muss φ von dem Radius, der die Scheibe halbiert, und nicht verschoben wird d. h. von dem Radius AB aus gezählt werden. Mithin ist die Gleichung der Grenzegerade

$$\varepsilon = -r \cos \varphi$$

Nach dem Schwinden verwandelt sich diese Gerade in eine Curve, deren Gleichung

$$\varepsilon = -\mu r \cos (\lambda\varphi + C)$$

Die willkürliche Constante C ist so zu bestimmen, dass für $\varphi = \pi$ $\varepsilon = \mu r$ wird. d. h.

$$c = -\pi(\lambda - 1)$$

Mithin

$$\varepsilon = -\mu r \cos (\lambda(\varphi - \pi) + \pi)$$
$$= \mu r \cos [\lambda(\pi - \varphi)]$$

$\lambda(\pi - \varphi)$ muss dabei einen spitzen Winkel bedeuten, weil r positiv sein muss.
Es ist

$$\frac{dy}{dx} = \frac{-\lambda \sin \lambda(\pi - \varphi) \sin \varphi + \cos \lambda(\pi - \varphi) \cos \varphi}{-\lambda \sin \lambda(\pi - \varphi) \cos \varphi - \sin \varphi \cos \lambda(\pi - \varphi)}$$

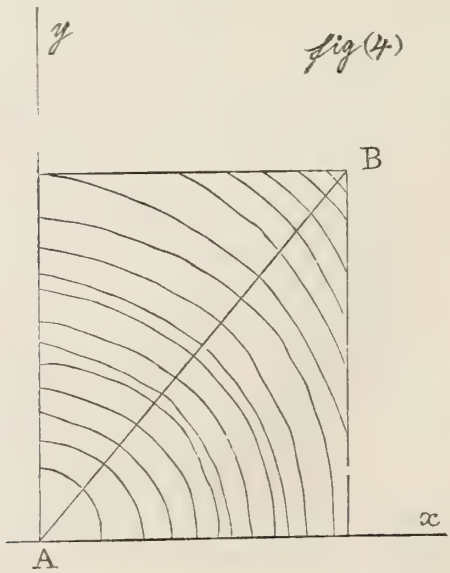
Dieses wird $-\infty$ für $\varphi = \pi$, und $= \operatorname{tag} \pi\left(\frac{2\lambda - 1}{2\lambda}\right)$ für $\lambda(\pi - \varphi) = \frac{\pi}{2}$ für welchen Werth $r = \infty$ ist. Die Curve schneidet die x-Achse senkrecht in der Distanz μr, und hat zwei Asymptoten, die den Winkel $\pi\left(\frac{2\lambda - 1}{2\lambda}\right)$ mit der positiven x-Achse schliessen. Der Winkel ist stumpf, wenn $\lambda > 1$ ist, d. h. wenn das Holz schwindet, und spitz, wenn $\lambda < 1$ d. h. wenn das Holz quillt. Der Zähler in dem Ausdruck für $\frac{dy}{dx}$ verschwindet nicht, weil $\lambda(\pi - \varphi)$ einen spitzen Winkel, und φ einen stumpfen bedeutet. Wegen dieses Umstandes könnte der Nenner verschwinden, so dass

$$-\lambda \operatorname{tag} \lambda(\pi - \varphi) = \operatorname{tag} \varphi$$

einen reellen Werth für φ geben würde. Allein, wie eine Curvenconstruction lehrt, wird diese Gleichung nur durch $\varphi=\pi$ befriedigt. Die in Rede stehende Curve krümmt sich darum concav- oder convex gegen die Stammmitte, je nachdem $\lambda > 1$ oder < 1 ist, d. h. je nachdem, das Holz schwindet, oder quillt. Die Figur 3 in der Tafel XIII stellt eine entrindete Scheibe des *Quercus grandulifera* dar, welche vor dem Schwinden geradelinig abgeschnitten worden ist. Die andere Hälfte der Scheibe zeigte anfangs eine concave Krümmung gegen die Stammmitte, sie ist jedoch beim weiteren Fortschreiten des Schwindens aufgerissen. Die Figur (2) zeigt eine Scheibe, aber mit der Rinde; aus dem Verlauf der Grenzecurve ist es ersichtlich, wie die Rinde das Schwinden besonderes des Splintes beeinflüsst.

Wir fassen jetzt eine viereckige Scheibe in's Auge, deren eine Ecke in der Stammmitte liegt, wie die Figur (4) zeigt. Die Kanten der Scheibe sollen senkrecht auf einander stehen, und durch die Geraden

$$r_1=\frac{\varepsilon_1}{\cos\varphi} \qquad r_2=\frac{\varepsilon_2}{\sin\varphi}$$



gebildet sein. Nach dem Schwinden oder Quellen werden diese Geraden

$$r_1 = \frac{\mu\varepsilon_1}{\cos(\lambda\varphi + \alpha)} \qquad r_2 = \frac{\mu\varepsilon_2}{\sin(\lambda\varphi + \beta)} \tag{6}$$

wo α β zwei willkürliche Constanten sind. Es soll bei $\varphi = \text{arct.}\,\frac{\varepsilon_2}{\varepsilon_1} = \gamma$ $r_1 = r_2$ sein. Diese Bedingung giebt

$$\frac{\varepsilon_2}{\varepsilon_1} = \frac{\sin(\lambda\gamma + \beta)}{\cos(\lambda\gamma + \alpha)} = \text{tag}\,\gamma.$$

Indem wir $\alpha = \beta$ setzen, ergiebt sich hieraus

$$\alpha = (1 - \lambda)\gamma$$

Die Kanten $\varphi = 0$ und $\varphi = \frac{\pi}{2}$ verdrehen sich um die Stammmitte A, indem sie sich in der Länge verändern. Die Bedingung dafür ist

$$r_1 = \mu\varepsilon_1 \qquad r_2 = \mu\varepsilon_2$$

d. h.

$$\lambda\varphi_0 + \alpha = 0 \qquad \lambda\varphi_0' + \alpha = \frac{\pi}{2}$$

wo φ_0 φ_0' die Winkel der Kanten bezeichnen, welche sie mit der x-Achse schliessen. Man hat

$$\varphi_0 = -\frac{\alpha}{\lambda} = \left(\frac{\lambda - 1}{\lambda}\right)\gamma \qquad \varphi_0' = \frac{\pi}{2\lambda} - \frac{\alpha}{\lambda} = \frac{\pi}{2\lambda} + \left(\frac{\lambda - 1}{\lambda}\right)\gamma$$

Die Verdrehung der Kante $\varphi = 0$ ist sonach

$$0 - \varphi_0 = -\left(\frac{\lambda - 1}{\lambda}\right)\gamma$$

Diejenige der Kante $\varphi = \frac{\pi}{2}$

$$\frac{\pi}{2} - \varphi_0' = \left(\frac{\lambda - 1}{\lambda}\right)\left(\frac{\pi}{2} - \gamma\right)$$

Die Differenz

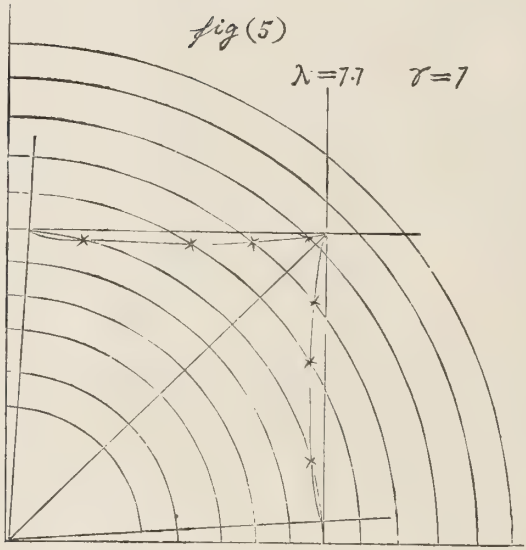
$$\frac{\pi}{2} - \left(\frac{\lambda - 1}{\lambda}\right)\gamma - \left(\frac{\lambda - 1}{\lambda}\right)\left(\frac{\pi}{2} - \gamma\right) = \frac{\pi}{2\lambda}$$

giebt den Winkel, welchen die beiden Kanten nach dem Schwinden oder Quellen mit einander schliessen. Die Diagonale A B verdreht sich aber nicht; denn es ist

$$\frac{\varepsilon_1}{\cos(\lambda\varphi_1+(1-\lambda)\gamma)}=\frac{\varepsilon_2}{\sin(\lambda\varphi_1+(1-\lambda)\gamma)}$$

Mithin $$\lambda\varphi_1+(1-\lambda)\gamma=\operatorname{arct}\frac{\varepsilon_2}{\varepsilon_1}=\gamma$$

d. h. $$\varphi_1=\gamma.$$



Die Figur (5) stellt die Deformation der rechteckigen Scheibe im Fall $\lambda > 1$ dar und fig (1) in der Tafel XIII zwei Scheiben des *Quercus granduliferа*. Wie man sieht, ist die wirkliche Deformation einer rechteckigen Scheibe ähnlich derjeingen, welche durch die Formeln (6) dargestellt ist. Wenn die Kanten $\varphi=0$ und $\varphi=\frac{\pi}{2}$ in Wirklichkeit sich etwas krümmen, so rührt dieses selbstredend von der Verschiedenheit der tangentialen Schwindungsgrösse im Splint und Kern her.

Wir betrachten eine Kreisfigur, welche entweder auf einer Scheibe gezeichnet, oder aus der Scheibe ausgearbeitet ist. Die Gleichung des Kreises im Grünzustande sei,

$$r^2-2rc\cos\varphi+c^2=R^2$$

wo c die Distanz des Kreismittelpunktes von der Stammmitte bedeutet. Nach dem Schwinden oder Quellen verwandelt sich dieser Kreis in eine Curve, deren Gleichung

$$\mu^2 r^2 - 2\mu r c \cos \lambda\varphi + c^2 = R^2$$

ist, oder indem wir setzen $\frac{R}{c} = \gamma$

$$r = \frac{c}{\mu}(\cos \lambda\varphi \pm \sqrt{\gamma^2 - \sin^2\lambda\varphi})$$

Es ist keine algebraische Curve mehr, wenn λ nicht eine ganze Zahl ist. Wenn $\gamma < 1$ ist, d. h. umfasst der ursprüngliche Kreis nicht die Stammmitte, so ist die Curve eine geschlossene, und eine nicht geschlossene, wenn der Kreis die Stammmitte umfasst. Wir setzen zur Abkürzung

$$\cos \lambda\varphi = \alpha \qquad \sin \lambda\varphi = \beta$$

Es ist

$$\frac{dy}{dx} = \frac{\sqrt{\gamma^2 - \beta^2} \mp \lambda\beta \operatorname{tag} \varphi}{\mp\lambda\beta - \operatorname{tag} \varphi\sqrt{\gamma^2 - \beta^2}}$$

Ist $\gamma < 1$, so kann β nicht den Werth γ übersteigen. Die Curve besteht dann aus zwei Zweigen. Der eine ist dargestellt durch

$$r = \frac{c}{\mu}(\cos \lambda\varphi + \sqrt{\gamma^2 - \sin^2\lambda\varphi})$$

und der andere

$$r = \frac{c}{\mu}(\cos \lambda\varphi - \sqrt{\gamma^2 - \sin^2\lambda\varphi})$$

Beide Zweige gehen selbstredend continuirlich in einander über bei dem Winkel

$$\varphi = \frac{1}{\lambda} \arcsin \gamma.$$

Nimmt man das obere Vorzeichen, so ist

$$\frac{dy}{dx} = \frac{\sqrt{\gamma^2 - \beta^2} - \lambda\beta \operatorname{tag} \varphi}{-\lambda\beta - \operatorname{tag} \varphi\sqrt{\gamma^2 - \beta^2}}$$

für $\varphi=0$, wird dieses $=-\infty$; die Curve schneidet die x-Achse senkrecht in der Distanz $\frac{c}{\mu}(1+\gamma)=\frac{1}{\mu}(R+c)$. Die Tangente an der Curve macht mit der x-Achse einen stumpfen Winkel so lange, bis

$$\sqrt{\gamma^2-\beta^2}=\lambda\beta \operatorname{tag} \varphi$$

wird d. h.

$$\gamma^2=\sin^2\lambda\varphi(1+\lambda^2 \operatorname{tag}^2\varphi)$$

Nimmt man das untere Vorzeichen, so kommt

$$\frac{dy}{dx}=\frac{\sqrt{\gamma^2-\beta}+\lambda\beta \operatorname{tag} \varphi}{\lambda\beta-\operatorname{tag} \varphi\sqrt{\gamma^2-\beta^2}}$$

Für $\varphi=0$, wird dieses $=+\infty$; die Curve schneidet die x-Achse senkrecht in der Distanz $\frac{c}{\mu}(1-\gamma)=\frac{1}{\mu}(c-R)$. Die Tangente macht einen spitzen Winkel mit der x-Achse., bis $\beta=\gamma$ d. h. $\varphi=\operatorname{arc} \sin \gamma$ wird.

Bezeichnet man den Krümmungshalbmesser der Curve mit ρ, so erhält man

$$\rho=\frac{c}{\mu}\left[\frac{(\alpha\pm\sqrt{\gamma^2-\beta^2})^2\left(1+\frac{\lambda^2\beta^2}{\gamma^2-\beta^2}\right)^{\frac{3}{2}}}{(\alpha\pm\sqrt{\gamma^2-\beta^2})\left(1+\frac{2\lambda^2\beta^2}{\gamma^2-\beta^2}\right)+\lambda^2\left(\alpha\pm\frac{\alpha^2\beta^2}{\sqrt{(\gamma^2-\beta^2)^3}}\pm\frac{(\alpha^2-\beta^2)}{\sqrt{(\gamma^2-\beta^2)}}\right)}\right]$$

Wenn wir die Krümmungshalbmesser in den Punkten

$$\varphi=0 \qquad r=\frac{1}{\mu}(R+c) \qquad \text{und} \qquad \varphi=0 \qquad r=\frac{1}{\mu}(c-R)$$

mit ρ' ρ'' bezeichnen, so hat man

$$\rho'=\frac{c}{\mu}\frac{(1+\gamma)^2}{(1+\gamma)+\lambda^2\left(1+\frac{1}{\gamma}\right)}=\frac{c}{\mu}\frac{(1+\gamma)}{\left(1+\frac{\lambda^2}{\gamma}\right)}$$

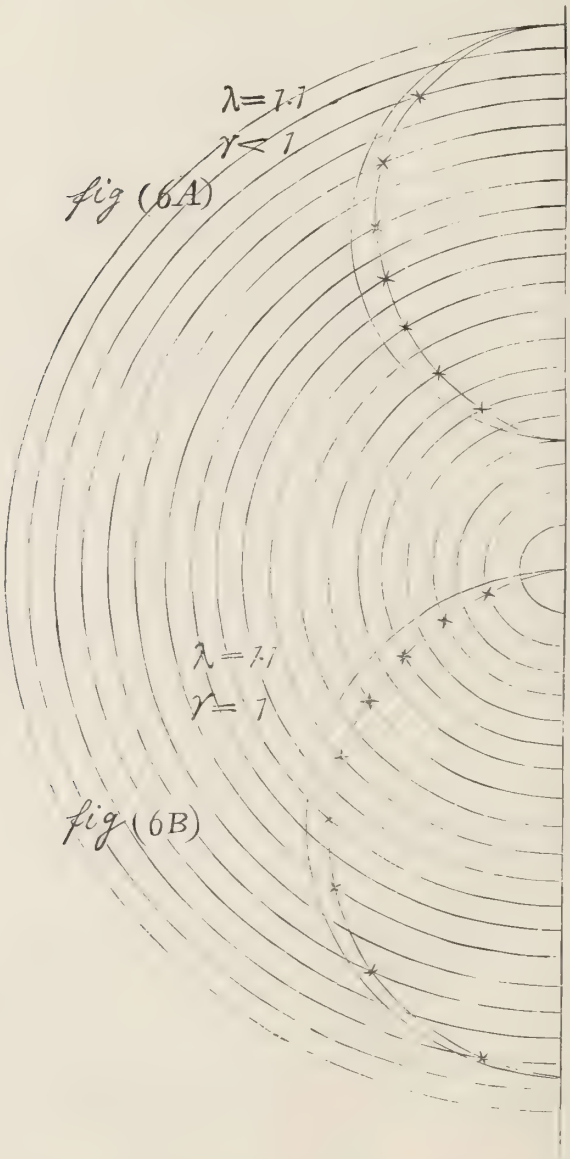
$$\rho''=\frac{c}{\mu}\frac{(1-\gamma)^2}{(1-\gamma)+\lambda^2\left(1-\frac{1}{\gamma}\right)}=\frac{c}{\mu}\frac{(1-\gamma)}{\left(1-\frac{\lambda^2}{\gamma}\right)}=-\frac{c}{\mu}\frac{(1-\gamma)}{\left(\frac{\lambda^2}{\gamma}-1\right)}$$

Indem wir mit ρ'' seinen absoluten Werth bezeichnen, folgt,

$$\frac{1}{\rho''}-\frac{1}{\rho'}=\frac{2(\lambda^2-1)}{(1-\gamma^2)}\cdot\frac{\mu}{c}$$

Die rechter Hand stehende Grösse ist positiv, wenn $\lambda > 1$ is und negativ, wenn $\lambda < 1$ ist. Wenn also das Holz schwindet, so ist $\rho' > \rho''$. Wenn hingegen das Holz quillt, so ist $\rho' < \rho'$ Die in Rede stehende Curve hat eine ovale Gestalt, deren spitzere Stelle gegen die Stammmitte oder von Stammmitte ab gerichtet ist, je nachdem das Holz schwindet oder quillt, wie die Figur (*6A*) zeigt. Die Verwandlung eines Kreises in eine solche ovale Figur beobochtet man in der That, wie die Scheiben von *Quercus grandulifera* (Tafeln VIII IX X XII) es zeigen. Die Curven kehren ihre spitzere Stelle gegen das Herz, wenn das Holz schwindet und umgekehrt, gegen den Splint, wenn es quillt. Die innere Curve in den Tafeln (X XII) ist ein Kreis, der nach vollendetem Schwinden mit dem Radius in tangentialer Richtung gezeichnet worden ist. Viel deutlicher spitzt sich die ovale Curve nach der Stammmitte zu, wenn man eine kreisformige Scheibe ausarbeitet, und sie schwinden lässt. Nördlinger* hat auch an Brettsteinen oder Cylinder von Hirnholz, die aus einem frischgefällten Stamm geschnitten ist, eine solche Zuspitzung der ovalen Umfangscurven nach der Kernseite zu beobachtet. Er meinte, dass die Markstrahlen sich kaum an dieser Erscheinung betheiligt sein dürften, und überzeugte sich auch davon, dass der Unterschied zwischen jüngerem und älterem Holz zur Erklärung nicht zu dienen vermag. An den Cylindern aus Splint von *Quercus rubra* bewies er, dass man sich, um eine nothdürftige Erklärung zu gewinnen, auch nicht an die Jahresringe halten könne. Ein Cylinder aus dem genannten Holz mit beinah parallelen nicht concentrischen Jahresringen zeigte eine starke Zuspitzung auf der Kernseite, ein Cylinder mit entschieden einspringenden Jahresringen, eine zwar schwächere aber deutliche Zuspitzung nach der Stammmitte zu. Indessen; diese Erscheinung stellt sich heraus als eine nothwendige Folge auch unserer sonst wenig wahrscheinlichen Annahme, dass die radiale und tangentiale Schwindungsgrösse constant seien. Wenn man sich demnach mit Annährung

* Nördlinger: Die technischen Eigenschaften der Hölzer, pag. 283.



begnügt, so ist die Thatsache zur Erklärung dieser Erscheinung ausreichend, dass die Bogenlänge der von der Stammmitte aus gezogenen Kreise in einem ausserhalb der Stammmitte gezogenen Kreis verschieden gross ist.

Umfasst der Kreis die Stammmitte, d. h. $\gamma > 1$, so kann φ von 0 bis 2π variiren. Man hat als Gleichung der Curve

$$r = \frac{c}{\mu}(\cos \lambda\varphi + \sqrt{\gamma^2 - \sin^2\lambda\varphi})$$

und

$$\frac{dy}{dx} = \frac{\sqrt{\gamma^2 - \beta^2} - \lambda\beta \operatorname{tag} \varphi}{-\lambda\beta - \operatorname{tag} \varphi \sqrt{\gamma^2 - \beta^2}}$$

wo wieder $\sin \lambda\varphi = \beta$ gesetzt ist. Es ist wieder

$$\text{für } \varphi = 0 \qquad \frac{dy}{dx} = -\infty$$

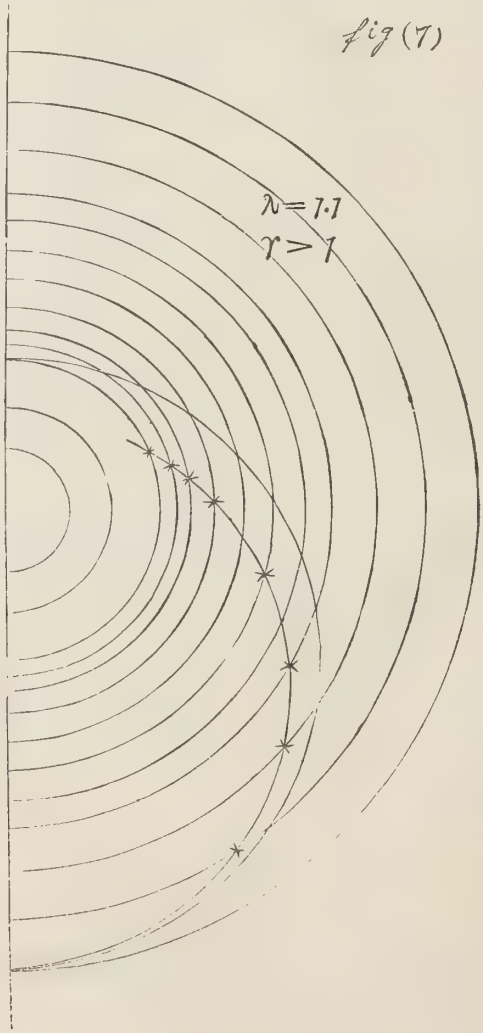
die Curve schneidet die x-Achse senkrecht in der Distanz $r = \frac{c}{\mu}(1+\gamma) = \frac{1}{\mu}(c+R)$. Für $\varphi = \frac{\pi}{\lambda}$ wird $\frac{dy}{dx} = -\cot\frac{\pi}{\lambda}$ d. h. die Curventangente steht senkrecht auf dem Radius vector $r = \frac{c}{\mu}(\gamma - 1)$ $= \frac{1}{\mu}(R - c)$. Es ist dies der Radius, in dem die Scheibe aufreissen müsste, bei dem Werth, den λ hat, wenn das Holz schwindet, denn der Radius r wird in dem weiteren Verlauf der Curve von $\frac{\pi}{\lambda}$ bis π kleiner als $\frac{1}{\mu}(c+R)$ und $\frac{dy}{dx}$ negativ, und die Curve müsste für $\varphi = \pi$ eine Spitze haben. Es ist hier von keinem Nutzen, den ferneren Verlauf der Curve zu betrachten; es sei nur bemerkt, dass sie, wenn λ einen einfachen Bruch bedeutet, nach vielem Umlauf zu demselben Radius vector zurückkehrt. Wenn das Holz quillt, und λ ein echter Bruch ist, so ist $\frac{\pi}{\lambda} > \pi$. Handelt es sich um eine Vollscheibe, so kann φ nicht den Werth π übersteigen. Demnach ist der Radius vector, der dem Radius vector $\frac{c}{\mu}(R+c)$ diametrial entgegengesetzt ist

$$= \frac{c}{\mu}(\cos \lambda\pi + \sqrt{\gamma^2 - \sin^2\lambda\pi})$$

was kleiner ist, als $\frac{1}{\mu}(R-c)$ und die Curve schneidet die x-Achse unter dem Winkel, dessen Tangente

$$= \frac{\sqrt{\gamma^2 - \sin^2 \lambda\pi}}{-\lambda \sin \lambda\pi}$$

ist. Der Winkel ist ein stumpfer; die Curve muss hier eine Spitze bilden. Die Figur (7) stellt den Verlauf der Curve dar für den Fall, dass das Holz schwindet. Die äussere Curve ist dabei der ursprüngliche Kreis. Es war nicht möglich gewesen, diese Curve mit der Wirklichkeit zu vergleichen. In den Scheiben, welche nicht aufgerissen sind, weicht die Curve nicht sonderlich von einem Kreis.



Wir fassen schliesslich den Fall in's Auge, wo der Kreis durch die Stammmitte geschlagen ist, d. h. den Fall $\gamma = 1$. In diesem Fall wird die Curvengleichung

$$r = \frac{2c}{\mu} \cos(\lambda \varphi)$$

Es ist eine Art von Lemniscate oder Cardioide, je nachdem $\lambda > 1$ oder < 1 ist. Sie spitzt sich in dem Punkt $r = 0$. Denn; es ist

$$\frac{dy}{dx} = \frac{\cos \lambda\varphi - \lambda \sin \lambda\varphi \,.\, \operatorname{tag} \varphi}{-\lambda \sin \lambda\varphi - \operatorname{tag}\varphi \,.\, \cos \lambda\varphi}$$

für $\varphi = 0$ wird dieses $= -\infty$. Die Curve schneidet wieder senkrecht die x-Achse in der Distanz $r = \frac{2c}{\mu}$. Es wird für $\varphi = \frac{\pi}{\lambda}$

$$\frac{dy}{dx} = \operatorname{tag} \frac{\pi}{2\lambda}$$

Die Curve durchsetzt die Stammmitte unter dem Winkel $\frac{\pi}{2\lambda}$, und bildet so eine Spitze. Ist $\lambda < 1$, so ist $\frac{\pi}{2\lambda}$ stumpf. Die Curve greift über die y-Achse hinaus unter dem spitzen Winkel $\operatorname{arct}\left(\lambda \operatorname{tag} \frac{\lambda\pi}{2}\right)$, und wendet sich nach der Stammmitte zu.

Die Figur (6 *B*) stellt den Verlauf der Curve im Fall des Schwindens dar. Die Tafeln (VIII X) zeigen dieselbe auf geschwundenen Scheiben von *Quercus granduliferа*; die Risschen durch das Herz machte den Verlauf der Curve dort undeutlich. Jedoch sieht man an einem Curvenzweig, der von Riss frei ist, nicht undeutlich, dass die Curve dort eine Spitze bildet. Die Tafel (XIV) stellt eine gequellte Halbscheibe von derselben Holzart dar. Die Curve ($\beta\beta$) war ursprünglich ein durch die Stammmitte geschlagener Kreis. Man sieht doch deutlich eine cardioidenartige Einbiegung der Curve in dem Herz. Dieselbe Tafel zeigt auch im lufttrockenen Zustande der Scheibe gezeichneten Kreise (α) und (ε) so wie eine Gerade

(AB), während die Gerade $(A'cB')$ vor dem Schwinden gezeichnet wurde, und sich bei vollzogenem Schwinden convex gegen das Herz gekrümmt hat. Die Kreise sind Ovale geworden, die sich deutlich im Splinte spitzen, und die Geraden Curven, welche sich concav gegen das Herz krümmen.

Betrachten wollen wir noch eine Kreisfigur auf einem longitudinal geschnittenen Brett. Es sei in dem Grünzustand der Kreis

$$x^2 + z^2 = R^2$$

die Stammmitte als Mittelpunkt gezogen oder herausgeschnitten. Da in Folge der Gleichung,

$$r' = \sqrt{x'^2 + y'^2} = \mu\sqrt{x^2 + y^2}$$

$$x' = \mu x \qquad y' = \mu y$$

sein müssen, so verwandelt sich der Kreis nach dem Schwinden oder Quellen in eine Curve, deren Gleichung

$$\mu^2 x^2 + \varkappa^2 z^2 = R^2$$

ist. Es ist eine Ellipse, mit den beiden Halbmessern $\frac{R}{\mu}$ $\frac{R}{\varkappa}$; sie ist in der z-Achse abgeplattet, wenn $\mu > 1$ $\varkappa < \mu$ ist, d. h. wenn das Holz schwindet. Die photographierten Tafeln (VI) (VII) stellen zwei Bretter von *Quercus grandulifera* dar. (VI) ist aus Spiegel hergestellt, und (VII) aus Sehne. Die innere Curve ist ein Kreis, der mit dem kleinsten radialen Halbmesser nach vollendetem Schwinden gezogen worden ist.

Wenn gleich die Annahme, auf der die Ableitung solcher Curven beruht, jeder Thatsächlichkeit entbehrt,- wenn gleich ferner die Methode, Schwinden und Quellen messend zu verfolgen, in Bezug auf die Schärfe Vieles zu wünschen übrig lässt, wollen wir näher prüfen, wie weit die Ähnlichkeit der Curven mit den thatsächlich beobachteten geht. Zu dem Ende habe ich die Curvencoordinaten sowohl in den mit einem Sägeschnitte bis

zum Herz versehenen Hirnscheiben (Tafeln VIII IX X XI) als in den Brettern (Tafeln VI VII) möglichst scharf gemessen, wobei φ mittelst einer bekannten Formel aus den bestimmten Längen der Dreieckseiten berechnet wurde, indem die Curven in gleiche Theile getheilt, jeder Theilungspunct mit der Stammmitte geradlinig verbunden, und die Distanz des Theiluugspunktes von einer radial gezogenen Grundlinie bestimmt wurde. Vom Gebrauch kleiner Metallstiftchen nahm ich Abstand, da es sich als sehr schwierig erwies, beim Einschlagen derselben gerade den Curvenpunkt zu treffen. Die Curven sind zuvor möglichst fein mittelst des Bleistiftes gezeichnet und nach den Messungen nachgetuscht, behufs sie zu photographieren. Der Nonius an dem gebrachten Maassstab gestattet nur Ablesung bis auf 0.1^{mm}; bei der Sorgfalt, die angewandt worden ist, bin ich indessen überzeugt, dass ich schwerlich Fehler begangen haben möchte, welche 0.1^{mm} übersteigen.

Kreis auf einer Spiegelplatte (9) Tafel (VI).

z' urspr.	z geschw	x' urspr.	x geschw	$\frac{z'-z}{z'}$	$\frac{x'-x}{x'}$	$\frac{x'-x}{1}$	z berechnet	Differ	x berechnet	Differ.	z' berechnet	Differ.
—	—	8cm	7,85cm	—	1,88%	3%	—	—	7,82	−0,03	—	—
3,96cm	3,92c	7	6,88	1,010%	1,71	2	3,93	+0,01	6,84	−0,04	3,93	−0,03
5,36	5,34	6	5,90	0,373	1,67	1	5,33	−0,01	5,86	−0,04	5,33	−0,03
6,32	6,31	5	4,91	0,158	1,80	3	6,27	−0,04	4,89	−0,02	6,28	−0,04
7,01	7,00	4	3,94	0,143	1,50	2	6,96	−0,04	3,91	−0,03	6,82	−0,19
7,48	7,06	3	2,96	0,267	1,33	1	7,42	−0,04	2,93	−0,03	7,45	−0,03
7,83	7,78	2	1,97	0,638	1,50	1	7,77	−0,01	1,96	−0,01	7,77	−0,05
8,00	7,97	1	0,98	0,375	2,00	2	7,94	−0,03	0,98	0	7,99	+0,01
8,05	8,00	0	0	0,621			7,99	−0,01	—	—	8,05	0
8,00	7,95	1	0,95	0,621	5,00	5	7,94	−0,01	0,98	+0,03	7,99	+0,01
7,80	7,76	2	1,91	0,513	4,50	4	7,77	+0,01	1,96	+0,05	7,77	−0,03
7,46	7,43	3	2,90	0,400	3,33	1	7,42	−0,01	2,93	+0,03	7,45	−0,01
7,00	6,92	4	3,88	1,143	3,00	2	6,96	+0,04	3,91	+0,03	6,82	−0,18
6,28	6,23	5	4,90	0,796	2,00	2	6,27	+0,04	4,89	−0,01	6,28	0
5,37	5,26	6	5,88	2,048	2,00	2	5,33	+0,07	5,86	−0,02	5,33	−0,04
3,96	3,84	7	6,85	3,030	2,14	3	3,93	+0,09	6,84	−0,01	3,93	−0,03
		8	7,83		2.13	3			7,82	−0,01		
			Mittel	0,754	2,335	2,290						

Kreis auf einer Sehnenplatte (7) Tafel (VII).

z' urspr.	z geschw	x' urspr.	x geschw	$\frac{z'-z}{z'}$	$\frac{x'-x}{x'}$	$\frac{x'-x}{1}$	z berechnet	Differ.	x berechnet	Differ.	z' berechnet	Differ.
—	—	8 cm	7,73 cm	—	3,37 %	5 %	—	—	7,71	−0,02		
3,78 cm	3,77 cm	7	6,78	0,265 %	3,14	4	3,76	−0,01	6,75	−0,03	3,87	+0,09
5,33	5,25	6	5,82	1,509	3,00	0	5,30	+0,05	5,78	−0,05	5,29	−0,04
6,25	6,23	5	4,82	0,320	3,60	3	6,22	−0,01	4,82	0	6,25	0
6,95	6,93	4	3,85	0,288	3,75	5	6,91	−0,02	3,86	+0,01	6,93	−0,02
7,46	7,42	3	2,90	0,536	3,33	6	7,42	0	2,83	−0,07	7,42	−0,04
7,76	7,74	2	1,96	0,258	2,00	3	7,72	−0,02	1,93	−0,03	7,75	−0,01
7,93	7,92	1	0,99	0,126	1,00	1	7,89	−0,03	0,96	−0,03	7,94	+0,01
8,00	8,00	0	—	0	—	—	7,96	−0,04	—	—	8,00	0
7,93	7,92	1	0,98	0,126	2,00	2	7,89	−0,03	0,96	−0,02	7,94	+0,01
7,78	7,76	2	1,90	0,257	5,00	8	7,74	−0,02	1,93	+0,03	7,75	−0,03
7,46	7,41	3	2,84	0,670	5,33	6	7,42	+0,01	2,83	−0,01	7,42	−0,04
6,98	6,92	4	3,82	0,860	4,25	2	6,94	+0,02	3,86	+0,04	6,93	−0,05
6,30	6,26	5	4,80	0,635	4,00	2	6,27	+0,01	4,82	+0,02	6,25	−0,05
5,40	5,31	6	5,75	1,667	4,17	5	5,37	+0,06	5,78	+0,03	5,29	−0,11
4,00	3,95	7	6,73	1,250	3,86	2	3,98	+0,03	6,75	+0,02	3,87	−0,13
		8	7,70		4,25	3			7,71	+0,01		
			Mittel	0,548	3,745							

Man sieht hier deutlich, dass die Schwindungsgrössen $\frac{z-z'}{z}$ und $\frac{x-x'}{x}$ mit zunehmendem x wächst, dass es eigentlich von einer Constanz nicht gut die Rede sein kann. Die Platten schwanden dabei in einer Hälfte longitudinal mehr, als die andere Hälfte, besonders die Spiegelplatte. Nimmt man für ψ_3 und ψ_1 das arithmetische Mittel der Quotienten $\frac{z'-z'}{z}$ und $\frac{x'-x'}{x}$, und berechnet z und x aus der Relation,

$$z' = (1 + \psi_3) z \qquad x' = (1 + \psi_1) x$$

so erhält man Werthe, welche höchstens um Bruchtheil von 1^{mm} von den beobachteten Werthen abweichen und die Abweichung zeigen wieder deutlich, dass die Platten radial und longitudinal in den beiden Hälften ungleich geschwunden sind und auch ungleich im Splint und Kern. Wenn wir die bestimmten Werthe von x in die Gleichung

$$z = \sqrt{\left(\frac{R}{1+\psi_3}\right)^2 - \left(\frac{1+\psi_1}{1+\psi_3}\right)^2 x^2}$$

einführen., und z berechnen, so ergeben sich grössere Abweichungen. Die Ursache ist aber, dass die beobachteten Coordinaten keineswegs der Gleichung für den Kreis genügen, dass der gezogene Kreis während der Zubereitung der Platten sich merklich deformirt hat, wie es die Zahlen unter der Rubrik (z' berechnet) darthun.

Gerade auf einer Hirnscheibe (3) Tafel (X).

r' urspr.	r geschw.	φ' urspr.	φ geschw.	$\frac{r'-r}{r'}$	$\frac{\varphi'-\varphi}{\varphi'}$	r berech.	Differ.	r' berech.	Differ.
9,12 cm	8,78 cm	63°,2639	62°,5111	4,69 %	1,19 %	8,73	−0,05	8,96	−0,06
8,23	7,97	60,0690	59,0749	3,16	1,66	7,87	−0,10		
7,37	7,17	56,0024	55,4111	2,71	1,06	7,04	−0,07	7,39	+0,02
6,56	6,37	51,1333	50,0056	2,90	2,21	6,26	−0,11	6,42	−0,06
5,77	5,61	44,7861	43,3639	2,77	3,18	5,53	−0,08	5,68	−0,09
5,10	4,97	36,6639	35,0694	2,55	4,51	4,90	−0,07	5,03	−0,07
4,58	4,44	26,3944	24,9222	3,06	5,58	4,38	−0,06	4,50	−0,08
4,21	4,05	13,9611	13,3528	3,80	4,36	4,05	0	4,16	−0,05
4,03	3,96	——	——	1,74	——	3,93	−0,03	4,03	0
4,14	4,09	13,9611	13,6805	1,21	6,31	4,05	−0,04	4,16	+0,02
4,48	4,39	26,3944	14,6833	2,01	6,48	4,38	−0,01	4,50	+0,02
4,94	4,86	36,6639	35,0694	1,62	4,35	4,90	+0,04	5,03	+0,09
5,58	5,45	44,7861	43,6667	2,33	2,50	5,53	+0,08	5,68	+0,10
6,36	6,26	51,1333	49,8150	1,57	2,58	6,26	0	6,42	+0,06
7,10	6,88	56,0024	54,5889	3,10	2,58	7,04	+0,16	7,39	+0,29
			Mittel	2,615	3,468				

Gerade auf einer Hirnscheibe (4) Tafel (XI).

r' urspr.	r geschw.	φ' urspr.	φ geschw.	$\frac{r'-r}{r'}$	$\frac{\varphi'-\varphi}{\varphi'}$	r berech.	Differ.	r' berech.	Differ.
7,32 cm	7,07 cm	55°,315	54°,100	3,415 %	2,197 %	7,29	+0,22	7,42	+0,10
6,53	6,27	50,384	48,901	3,951	2,943	6,51	+0,24	6,62	+0,09
5,80	5,59	44,155	42,633	3,621	3,447	5,79	+0,24	5,88	+0,08
5,16	4,93	36,303	34,584	4,457	4,740	5,15	+0,22	5,24	+0,08
4,65	4,34	26,456	24,684	6,682	6,725	4,65	+0,31	4,71	+0,06
4,32	4,15	14,611	13,208	3,935	13,368	4,29	+0,14	4,36	+0,04
4,22	4,09	——	——	3,081	——	4,15	+0,06	4,22	0
4,34	4,23	12,040	13,739	2,535	−14,941	4,24	+0,01	4,32	−0,02
4,69	4,55	23,750	24,222	2,985	−1,987	4,53	−0,02	4,61	−0,08
5,20	5,06	34,497	34,300	2,692	0,571	5,04	−0,02	5,12	−0,08
5,86	5,69	42,744	42,364	2,901	0,889	5,65	−0,04	5,75	−0,11
6,61	6,45	49,333	48,361	2,421	1,970	6,36	−0,09	6,47	−0,14
7,43	7,25	54,425	54,292	2,422	0,331	7,13	−0,02	7,25	−0,18
			Mittel	3,469	1,687				

Bei den Geraden auf einer Hirnscheibe ist es bemerkenswerth, dass die tangentiale Schwindungsgrösse mit dem wachsendem Abstand von der Stammmitte abnimmt. Bei der Scheibe (3) wurd r aus Gleichung

$$r = \frac{4.03}{(1.0262) \cos (1.0347\, \varphi)}$$

berechnet. Die Abweichung der so berechneten Werthe von den Beobachteten ist derart vertheilt, dass man sie nicht allein dem verschiedenen Schwinden des Splintes und Kerns zuschreiben kann. Die Gerade schien sich ein wenig verdreht zu haben, ehe die Messung der Coordinaten begann, wie die Zahlen unter (r' berechnet) es darthun. Bei der Scheibe (3) theilt die Gerade, welche senkrecht auf die Gerade gefällt ist, dieselbe in ungleiche Hälfte; die Folge davon ist, dass die radiale Schwindungsgrösse auf der kürzeren Hälfte der Gerade kleiner ist, als auf der längeren Hälfte. Auf der Scheibe (4) war die Gerade ursprünglich so gezeichnet, dass eine von der Stammmitte auf sie senkrecht gefällte Gerade sie in annährend gleiche Hälfte theilte. Der ziemlich starke Riss hat aber die Schwindungsgrösse so einseitig verschoben, dass die mittlere tangentiale Schwindungsgrösse geringer ausfiel, als die radiale, welche einen Werth hat, den die tangentiale hätte sonst haben müssen. Auch diese Gerade hat sich ziemlich stark verdreht.

Kreis auf einer Hirnscheibe (2) Tafel (VIII).

r' urspr.	r geschw.	φ' urspr.	φ geschw.	$\frac{r'-r}{r}$	$\frac{\varphi'-\varphi}{\varphi'}$	r berechnet	Differ.	φ berechnet	Differ.	r' berechnet	Differ.
cm	cm			%	%						
8,00	7,82	0°	0°,	2,250	——	7,85	+0,03	0	——	8,00	0
7,95	7,71	7,5	8,0667	3,019	−7,560	7,78	+0,07	7,093	−0,974	7,93	−0,02
7,72	7,50	15	14,8000	2,850	8,000	7,58	+0,08	14,185	−0,615	7,73	+0,01
7,38	7,14	22,5	17,4333	3,252	22,520	7,25	+0,09	21,325	+3,892	7,39	+0,01
6,93	6,71	30	29,2333	3,175	2,557	6,80	+0,09	28,369	−0,864	6,93	0
6,36	6,15	37,5	36,1000	3,302	3.733	6,23	+0,08	35,461	−0,639	6,35	−0,01
5,66	5.48	45	43,3333	3,180	3,704	5,56	+0,08	42,553	−0,780	5,67	+0,01
4,86	4,73	52,5	50,1000	2,675	4,571	4,78	+0,05	49,645	−0,355	4,87	+0,04
3,97	3,92	60	58,0667	1,259	3,222	3,93	+0,01	56,607	−1,460	4,01	−0,01
3,07	3,06	67,5	64,6000	0,325	4,296	3,00	−0,06	63,829	−0,770	3,06	−0,03
2,05	2,06	75	72,9667	−0,488	2,711	2,04	−0,02	70,922	−2,045	2,08	
2,05	2,06	75	67,9333	−0,488	9,423	2,04	−0,02	70,922	+2,639		
3,07	3,04	67,5	62,3000	1,000	7,704	3,00	−0,04	63,829	+1,529		
3,97	3,96	60	55,6333	0,252	7,278	3,93	−0,02	56,607	+0.974		
4,86	4,80	52,5	48,2667	1,235	8,063	4,78	−0,02	49,645	+1,178		
5,66	5,54	45	41,9333	2,120	6,816	5,56	+0,02	42,553	+0,620		
6,36	6,20	37,5	34,8000	2,516	7,200	6,23	+0,03	35,461	+0,661		
6,93	6,73	30	28,0333	2,886	6,532	6,80	+0,03	28,369	+0,336		
7.38	7,21	22,5	21,2000	2,304	5,778	7,25	+0,04	21,325	+0,125		
7,72	7,56	15	14,0667	2,073	6,211	7,58	+0,02	14,185	+0,118		
7,95	7,77	7,5	7,3333	2,264	2,227	7,78	+0,01	7,093	−0,240		
			Mittel	1,950	5.749						

Durch diesen Kreis geschah ein Riss im Herz. In Folge davon wurde $\frac{r'-r'}{r'}$ in dem Herz negativ und $\frac{\varphi'-\varphi}{\varphi'}$ im äussersten Splint. Wenn gleich die Zunahme des $\frac{r'-r}{r'}$ gegen Splint zu constatiren ist, so ist die Vertheilung des $\frac{\varphi'-\varphi}{\varphi}$ auf der einen Hälfte regellos, in der es einmal negativ wird, und auf der anderen Hälfte nimmt es deutlich vom Kern aus gegen Splint ab. Wenn wir das arithmetische Mittel der Quotienten $\frac{r'-r}{r'}$ und $\frac{\varphi'-\varphi}{\varphi}$ nehmen und setzen

$$\varphi'_1 = 0.0195 \qquad \varphi'_2 = 0.0575$$

so findet man aus der Gleichung

$$r = \frac{2 \times 4}{(1.0195)} \cdot \cos\,(1.0575\,\varphi)$$

die Zahlen unter der Rubrik (r berechnet). Die Differenzen von den beobachteten Werthen sind zwar ziemlich erheblich sie aber bleiben unter 1^{mm}, und ihre Vertheilung der Grösse und dem Vorzeichen nach ist derart, dass man sie der verschiedenheit des Schwindens allein zuschreiben könnte, da der Kreis sich während der Zubereitung der Scheibe sich nur wenig deformirt hat, wie die aus der Kreisgleichung

$$r' = (2 \times 4.) \cos \varphi'$$

berechneten Werthe von r' darthun.

Kreis auf einer Hirnscheibe (1) Tafel (IX).

r' urspr.	r geschw	φ' urspr.	φ geschw.	$\frac{r'-r}{r'}$	$\frac{\varphi'-\varphi}{\varphi'}$	r berechn.	Differ.	φ berechnet	Differ.	r' berechn.	Differ.
8,50cm	8,25cm	0°	0°	2,941%	——	8,24	−0,01	——	——	8,50	0
8,37	8,11	7°,0178	6°,7278	3,104	4.132%	8,11	0	6,633	−0,095	8,41	+0,04
8,00	7,79	13,9008	12,9078	2,625	7,435	7.75	−0,04	13,139	+0,231	8,03	+0,03
7,50	7,24	20,1975	18,9689	3,464	6,085	7,27	+0,03	19,090	+0,121	7,48	−0,02
6,73	6,50	25,9494	24,4411	3,418	4,962	6,52	+0,02	24,526	−0.085	6,72	−0,01
5,82	5,62	30,3939	28,2754	3,437	6,972	5,64	+0,02	29,396	+1,121	5,85	+0,03
4,79	4,68	32,7584	30,7761	2,296	6,151	4,64	−0,04	30,962	−0,186	4,89	+0,10
3,80	3,65	30,3825	28,1878	3.975	7,225	3,68	+0,03	29.386	+1,198	3,67	+0,13
2,90	2,80	20,6486	17,3650	3,793	15,904	2,81	+0,01	19,517	+2,152	2.89	−0,01
2,52	2,45	——	——	2,778	——	2,44	−0,01	——	——	2,52	0
2.90	2.80	20,6486	20 0033	3 448	0,989	2.81	+0,01	19,517	−0,486		
3.80	3,65	30,3825	28.8261	3,947	5,121	3,68	+0,03	29.386	+0,560		
4.79	4 65	32,7584	30,9566	2,923	5,501	4,64	−0,01	30,962	+0,006		
5.82	5,68	30,3939	28,7366	2,406	5,452	5 64	−0,04	29,396	+0,559		
6,73	6,55	25.9494	24.4766	2,675	5,677	6,52	- 0,03	24.526	+0.050		
7,50	7,23	20,1975	19.1877	3,600	5,006	7,27	+0,04	19,090	−0,097		
8,00	7,72	13,9008	13,5876	3,500	2,259	7.75	+0,03	13,139	−0,448		
8,37	8,08	7 0178	6,9195	3.465	1,397	8,11	+0,03	6,633	−0,287		
			Mittel	3,211	5.809						

Bei dieser Hirnscheibe ist $\frac{r'-r}{r'}$ fast constant, während $\frac{\varphi'-\varphi}{\varphi'}$ deutlich vom Kern aus gegen den Splint abnimmt. Wenn wir das arithmetische Mittel dieser Quotienten nehmen und setzen

$$\psi_1 = 0.03211$$
$$\psi_2 = 0.05809$$

so erhalten wir als Curvengleichung

$$r = 5.3386\left(\cos\lambda\varphi \pm \sqrt{0.29433 - \sin^2(\lambda\varphi)}\right)$$
$$\lambda = 1.05809$$

da die Distanz des Mittlepunktes des ursprünglichen Kreises von der Stammmitte $c = 5.51^{cm}$, und der Halbmesser des Kreises $= 2.99^{cm}$ war, so dass

$$\left(\frac{R}{c}\right)^2 = \left(\frac{2,99}{5,51}\right)^2 = 0.29433$$

$$\frac{c}{1+\varphi_1} = \frac{5,51}{1,0321} = 5,3386$$

ist. Die unter der Rubrik (r berechnet) stehenden Zahlen sind aus der Relation

$$r = \frac{r'}{1.0321}$$

berechnet. Die Übereinstimmung zwischen den beobachteten und berechneten Werthen ist zeimlich befriedigend, wenn auch eine Tendenz der Abweichungen gegen den Splint zu wachsen fühlbar ist. Der Kreis schien sich indessen bei der Grenze zwischen Splint und Kern. d. h. zwischen den radialen Abständen 3.80^{cm} und 5.82^{cm} etwas deformirt zu haben, wie die aus der Kreisgleichung

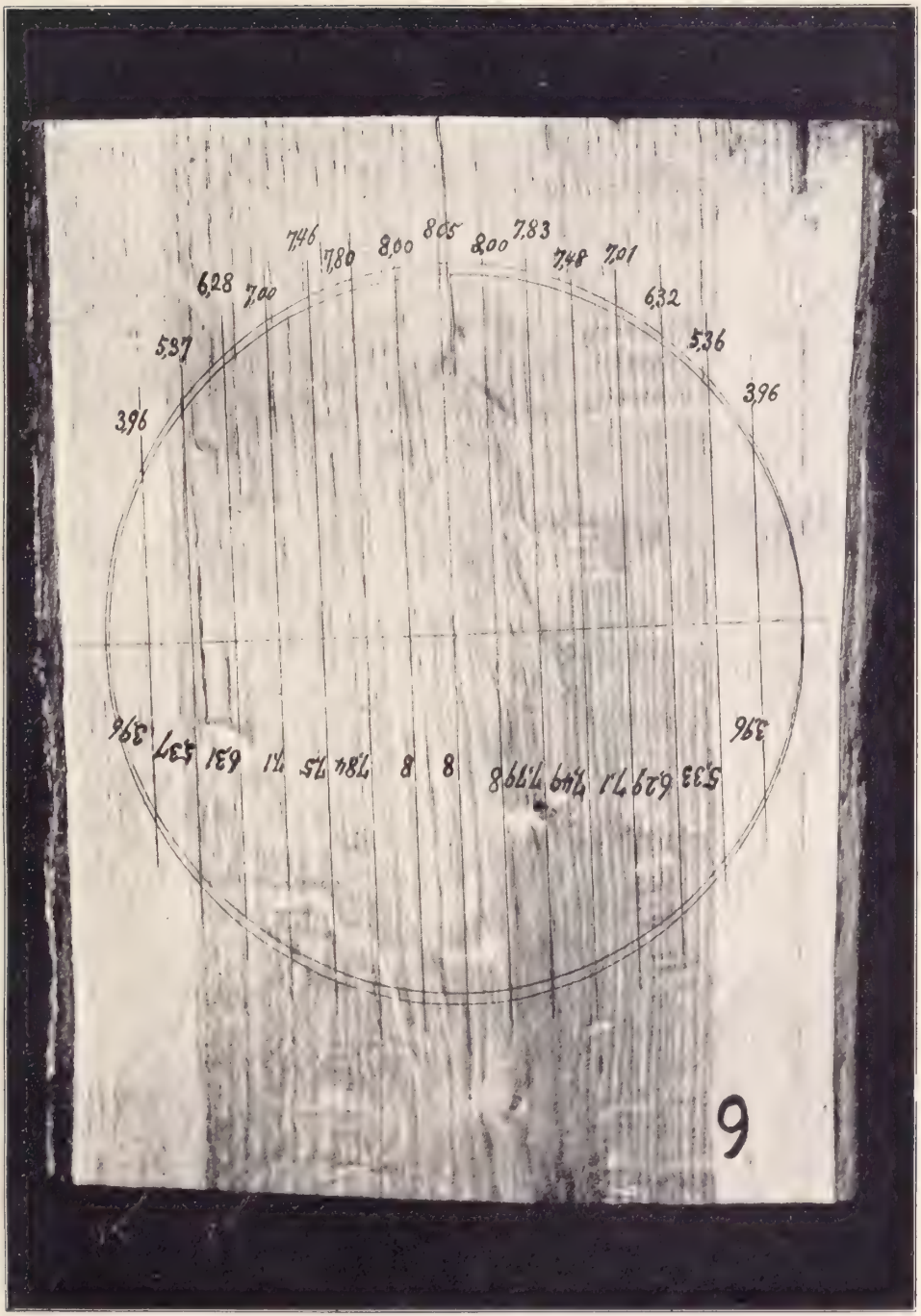
$$r' = 5.51\left(\cos\varphi' \pm \sqrt{0.29433 - \sin^2\varphi'}\right)$$

berechneten Zahlen es darthun.

Das Resultat unserer Untersuchung ist, wie zu erwarten, ein negatives. So lange der Unterschied der Schwindungsgrössen zwischen dem Splint und Kern nicht ausser Acht gelassen wird, sind die Curven, in die eine Gerade oder ein Kreis nach dem vollendeten Schwinden sich verwandelt, auf keine Weise zum Zusammenfallen mit denen zu bringen, welche wir abgeleitet haben, unter der Annahme, dass die Schwindungsgrössen überall constant seien. Indessen sind die Abweichungen nicht all zu erheblich, und indem wir von dem Unterschied der Schwindungsgrösse im Splint und Kern absehen, können wir immerhin

eine ungefähre Vorstellung gewinnen von der Gestalt eines geschwundenen oder gequellten Holzstücks, dessen Gestalt vor dem Schwinden,- (auch wohl vor dem Quellen), dessen mittlere Schwindungs- (respectiv Quellungs) grösse gegeben ist.

Ich bemerke noch, dass man auch leicht die Gestalt eines Holzstücks von gegebener Gestalt nach dem Schwinden oder Quellen auf dem Wege der Construction finden kenn, wenn die Schwindungs- oder Quellungsgrössen als constant angesehen werden. Man zeichnet die Hirnfläche des Holzstücks, von der Stammmitte aus ein System Strahlen, und dazu ein System concentrischer Kreise. Wenn man die Strahlen, so weit sie in der Hirnfläche des Holzstücks liegen, im Verhältniss $1 : 1+\psi_1$ verkürzt, oder verlängert, wenn man ferner die Bogenstrecken der concentrischen Kreise in der Hirnfläche ebenfalls im Verhältniss $1 : 1+\psi_2$ verkürzt oder verlängert, so erhält man die Punkte der Contouren der Hirnfläche nach dem Schwinden oder Quellen. Die Curven in den Figuren (3) (5) (6) (7) sind auf diese Weise gezeichnet worden.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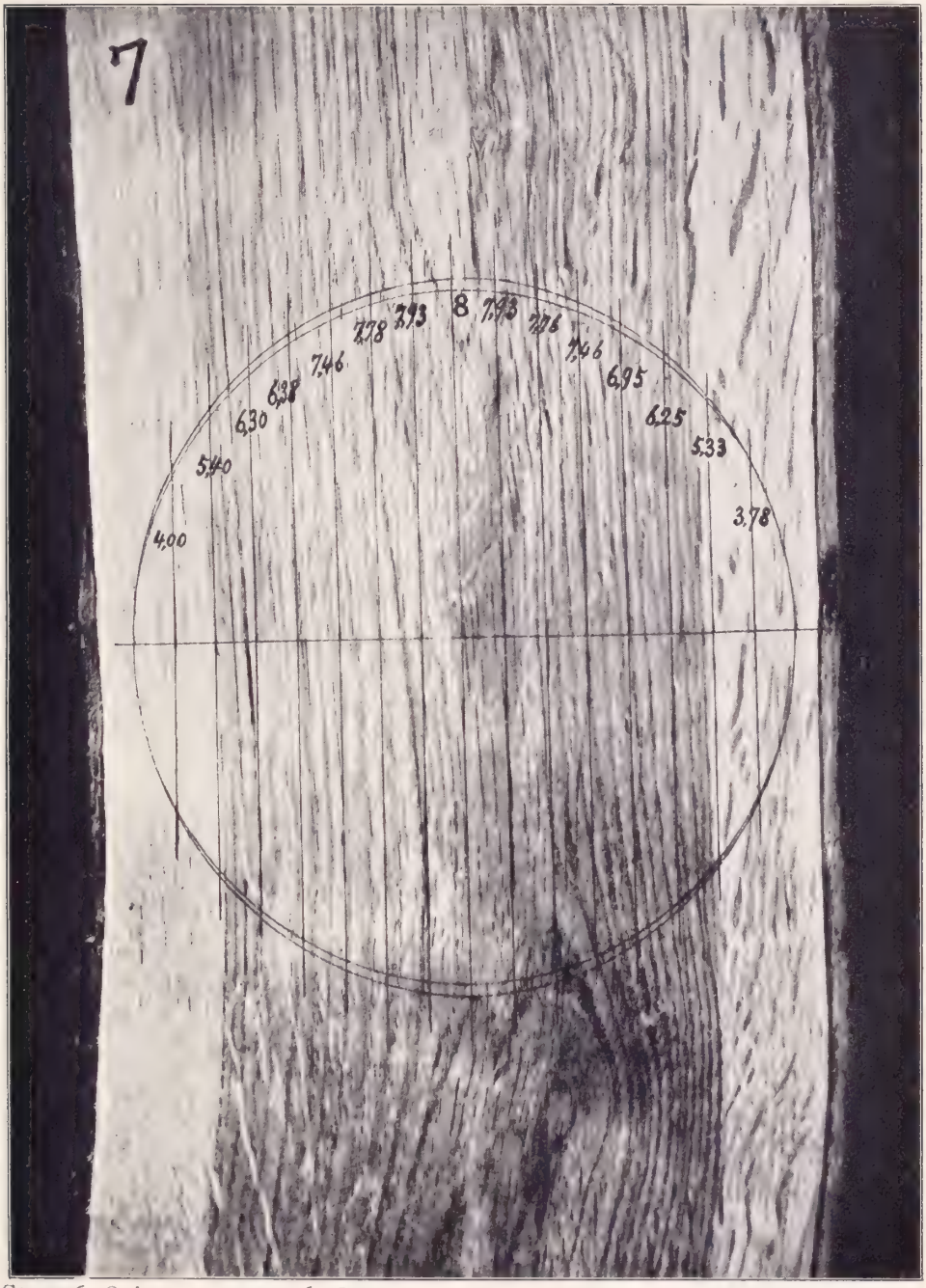

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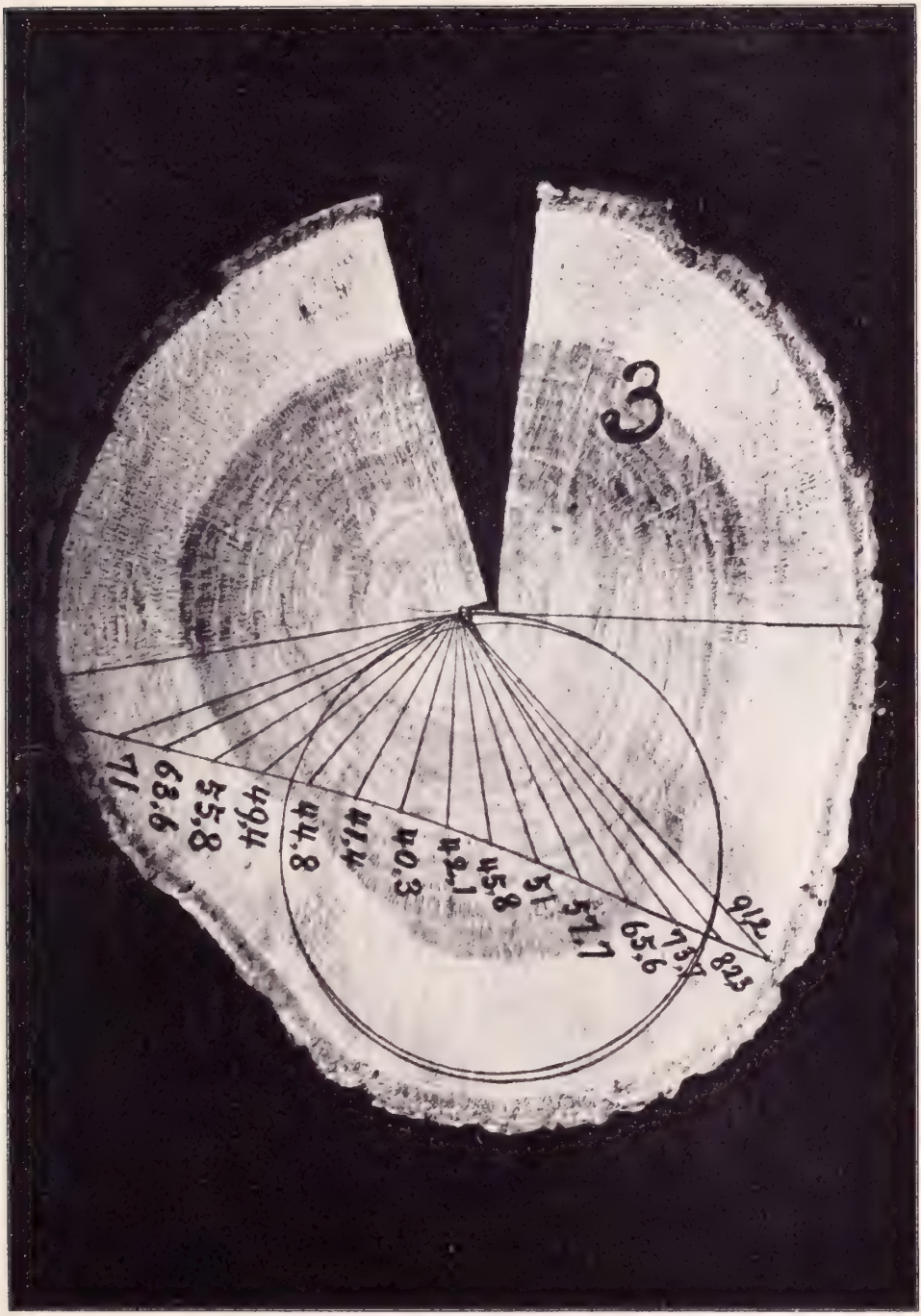
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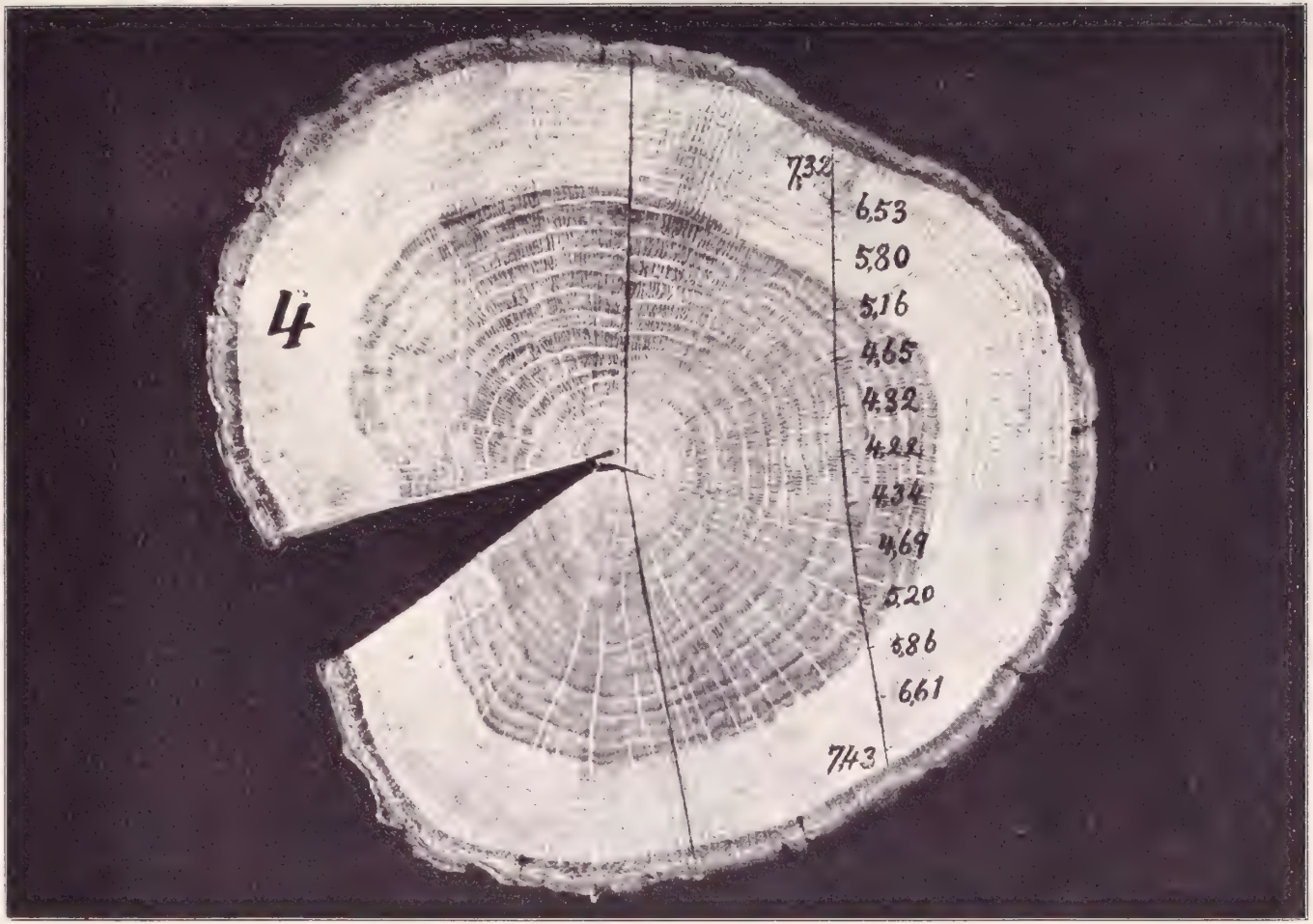
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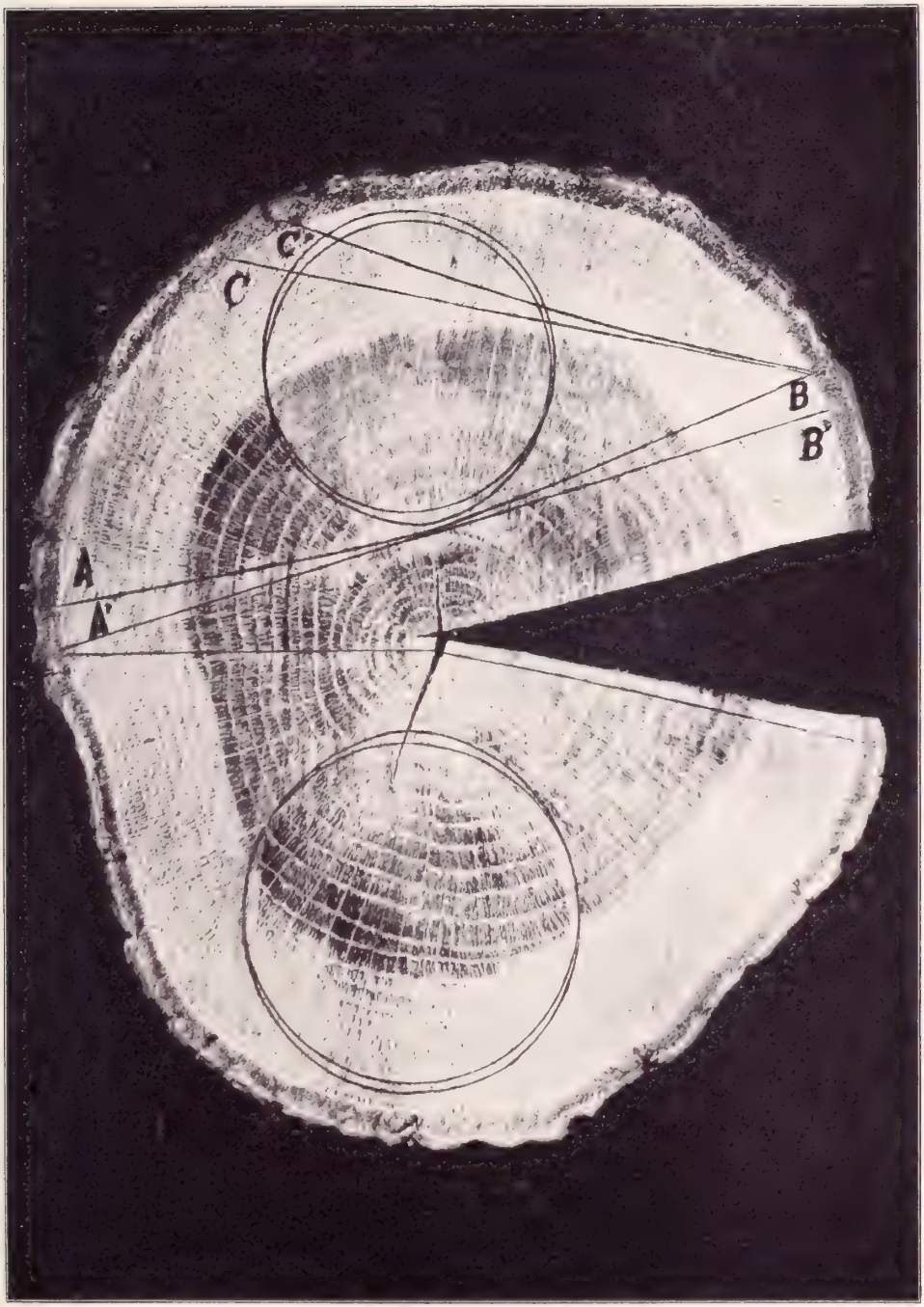
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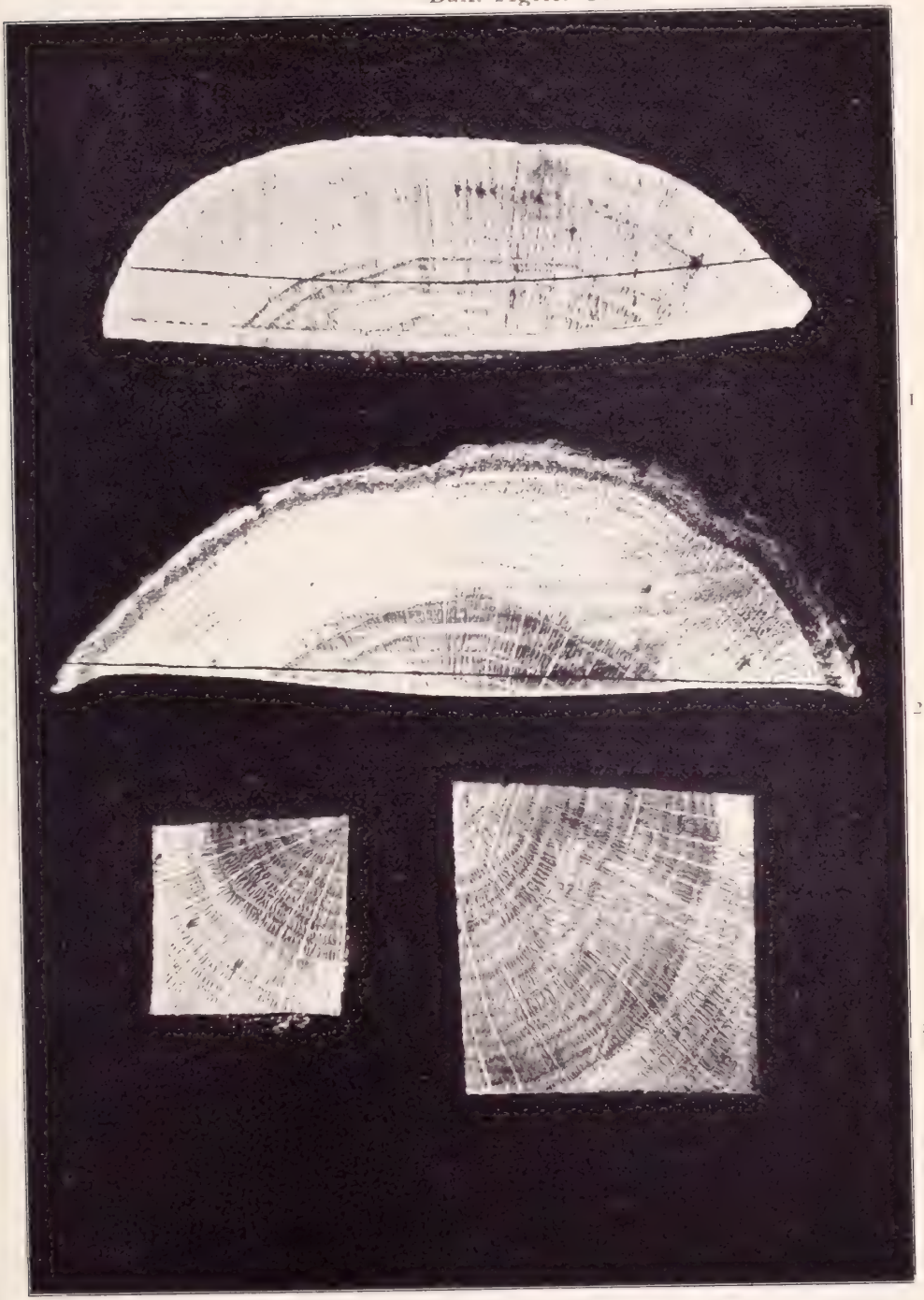

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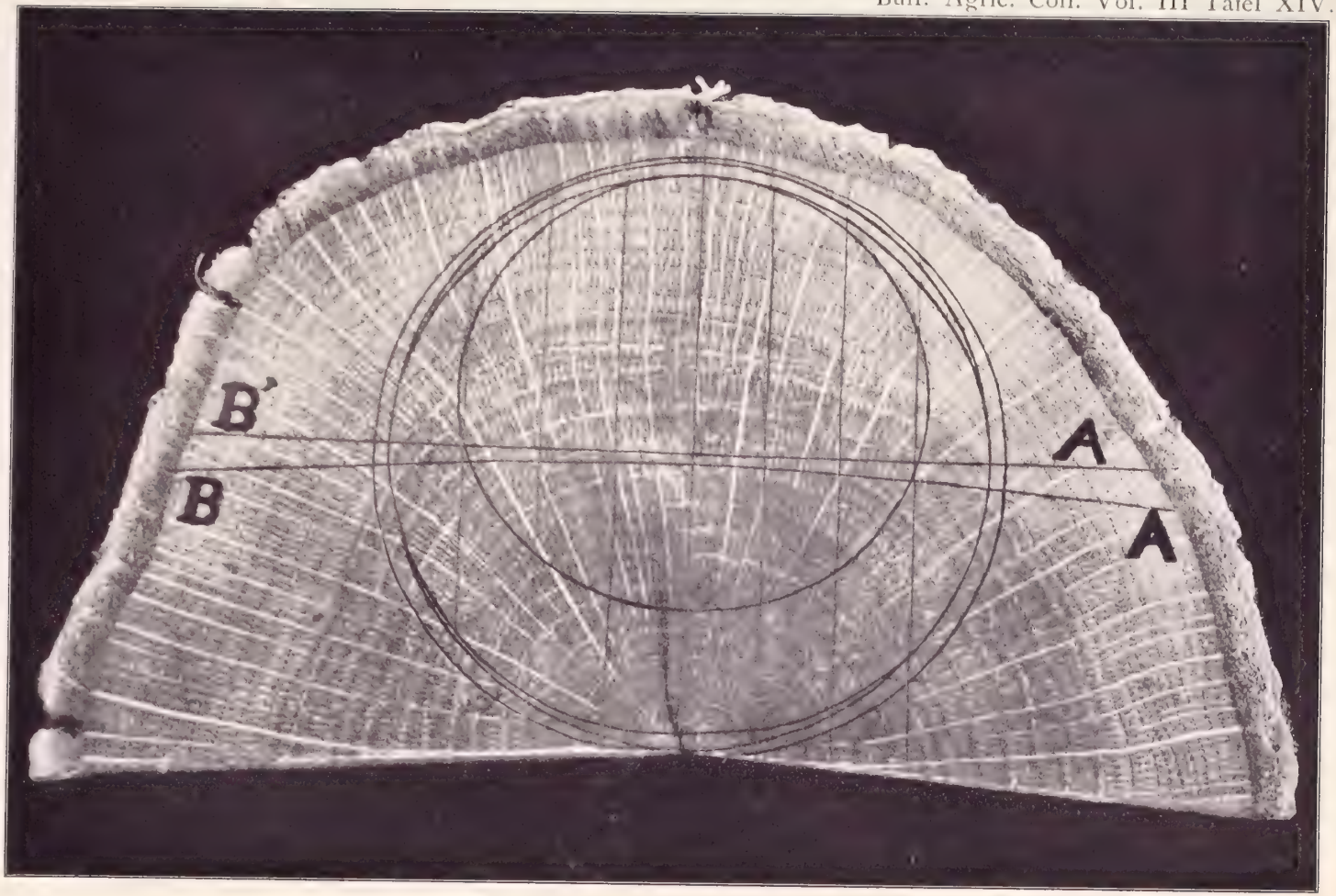
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Manuring Experiments with Paddy Rice.

(*Fourth, Fifth and Sixth Years*: 1892—1894.)

BY

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These experiments have been in progress since 1889 and 1890[1] and were carried on for the purpose of getting some information on the following points:

1) The exhaustion of soil nutriments by the successive cultivation of rice, and the quantity of the fertilizer required for the soil to recuperate, as judged by the quantities of nutriments contained in the crop.

2) The after effect of unrecovered phosphoric acid applied as sodium phosphate.

3) The after effect of various phosphatic manures.

The method of experiments was exactly the same as in the preceding years. After cutting the rice, the plots which were surrounded by deep wooden frames, were left untouched till the spring of the next year. In the beginning of June, these plots were irrigated and carefully stirred until the soil was converted into a fine uniform mud. In the mean time, the young rice plants raised carefully in a seed bed were transplanted after manuring the plots. Each plot received 16 bundles each of 12 healthy plants. Irrigation was at once commenced, the water being supplied from wooden tanks with a capacity of about 70 litres each placed on the northern side of the

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1) These experiments were originally commenced in 1889 by Hofrath, Prof. Dr. O, Kellner, formerly Professor of Agricultural Chemistry in the Imperial University, under whose direction they were carried on till 1892, when he returned to Germany to succeed the late Prof. Dr. G. Kühn at Möckern experimental station. The results obtained up to that date have been already published by him in Die landwirthschaftliche Versuchs Stationen Vol. 39, (1891). p. 361, and Vol. 40, (1892) p. 295, as well as in this Bulletin, Vol. I. No. 8, No. 10, and No. 11.

2) Bulletin Vol. I. No. 10, College of Agriculture, Imperial University.

plots and kept constantly filled with water. Toward the end of September, the irrigation was stopped as is usually done by farmers, and the water was afterwards given only for two days at the time of flowering. The variety of rice chosen for these experiments was "Satsuma," since its vegetation period is of medium length. In 1892 the weather was fairly good, but in 1893 it was very unfavourable, while in 1894 it was exceedingly favourable.

I. SERIES.

Exhaustion of Soil Nutriments by the Successive Cultivation of Rice and the Quantity of the Fertilizer required for the Soil to recuperate, as judged by the Quantities of Nutriments contained in the Crop.

As already stated, these experiments were carried on in order to ascertain the quantity of each of the three essential nutriments which the soil may yield to the rice in the plots not supplied with the respective nutriments but manured with the other essential nutriments, and to determine the nutriment required by the soil, as inferred from the quantities of nutriments contained in the crop. The plots used in these experiments were those that had served the same purpose in the preceding years. The quantities of nutriments supplied to the plots were the same every year, and were as follows (per tan=0,0992 hectare):

1) 3 plots were left unmanured.

2) 3 plots did not receive any phosphatic manure, but were supplied with 10 kilogrms. of nitrogen and 10 kilogrms. of potash.

3) 3 plots did not receive any nitrogenous manure, but were supplied with 10 kilogrms. of phosphoric acid and 10 kilogrms. of potash.

4) 3 plots did not receive any potassic manure, but were supplied with 10 kilogrms. of phosphoric acid, and 10 kilogrms. of nitrogen.

5) 3 plots received a complete manure containing 10 kilogrms. of nitrogen, 10 kilogrms. of phosphoric acid, and 10 kilogrms. of potash.

In these experiments, nitrogen was supplied in the form of ammonium sulphate, phosphoric acid in that of double superphosphate and potash in that of carbonate.

The development of the plants was essentially the same in the three years during which the experiments were carried on. The plants growing in the plots supplied with a complete manure showed the best development, next to these came the plants without potash, which were much inferior as compared with the former, the difference becoming more and more noticeable as the year advanced, evidently owing to the gradual exhaustion of the stock of potash in the soil. Then followed, both in point of vigour and height, the plants without nitrogen, which turned pale in an early stage of vegetation and ripened earlier than those grown in the other plots; and last of all came the plants without phosphoric acid and those without any manure, which showed a most meager development and ripened a little later than the others. The average yield of grain and straw was as follows:

	Straw. Grms.	Full grain. Grms.	Empty grain. Grms.	Whole crop. Grms.
1892; Variety Satsuma.				
Unmanured	210	151	3	364
Without phosphoric acid	264	168	3	435
,, nitrogen	382	375	5	762
,, potash	526	427	10	963
Complete manure	573	532	12	1117
1893; Variety Satsuma.				
Unmanured	108	61	1	170
Without phosphoric acid	161	95	2	258
,, nitrogen	361	330	5	696
,, potash	501	432	5	938
Complete manure	574	486	10	1070
1894; Variety Satsuma.				
Unmanured	315	296	8	619
Without phosphoric acid	362	329	16	707
,, nitrogen	449	382	9	840
,, potash	587	521	17	1125
Complete manure	633	554	16	1203

In their main features, the results of each experimental year agree not only with each other but also with those obtained in the three preceding years, which may be quoted here for the sake of comparison.

	Straw. Grms.	Full grain. Grms.	Empty grain. Grms.	Whole crop. Grms.
1889 ; Variety Satsuma.				
Unmanured	197	106	6	310
Without phosphoric acid	193	90	6	289
,, nitrogen	459	367	15	841
,, potash	714	564	24	1302
Complete manure	832	575	31	1438
1890 ; Variety Shiratama.				
Unmanured	325	277	2	604
Without phosphoric acid	358	261	3	621
,, nitrogen	536	413	3	952
,, potash	770	583	8	1361
Complete manure	975	638	8	1621
1891 ; Variety Koniwa.				
Unmanured	290	213	3	506
Without phosphoric acid	371	271	5	647
,, nitrogen	476	341	5	822
,, potash	730	415	11	1056
Complete manure	780	576	9	1365

Thus we see, that of the three important ingredients of plant food, phosphoric acid is present in our soil in the minimum, and that a partial manuring with nitrogen and potash does not bring about any considerable augmentation of yield over the plots not supplied with any fertilizing substance. The stock of nitrogen in the soil is not so poor as that of phosphoric acid but it is far from being sufficient to meet the requirement for maximum yield. The supply of soil potash, too, is not sufficient for maximum production, but of the three essential nutriments, it is the most abundant.

As to the yields of similarly treated plots, some differences are found in such of the six experimental years, especially with regard to the unmanured plots and those not supplied with phosphoric acid; the produce of 1890 and 1894 being much greater than that of the other years. This difference, though principally due to the condition of weather which was exceedingly favourable to the growth of the plants in these two years, may also have been due to the different varieties of the rice used as well as to different degree of development of the young plants in the seed bed at the time of transplantation. In the young plants used for transplantation there were contained for each plot the following quantities of nutriments.

	Dry matter. Grms.	Nitrogen. Grms.	Phosphoric acid. Grms.	Potash. Grms.
1889	20.55	0.366	0.087	0.192
1890	62.66	1.774	0.334	0.653
1891	19.00	0.364	0.073	0.245
1892	17.47	0.309	0.097	0.151
1893	12.61	0.359	0.061	0.146
1894	15.53	0.222	0.077	0.175

The exceedingly large amount of the nutriments in the plants of 1890 also secured a better development, especially on the plots not supplied with these nutriments.

We have now to consider the degree of exhaustion of soil nutriments caused by the continual cultivation of rice. First concerning the consumption of nitrogen we have obtained the following results:

	Experimental year.	Nitrogen in the dry matter of the whole crop.		Nitrogen in the manure. Grms.	Nitrogen extracted from the soil, resp. soil and manure. Grms.
		%.	Grms		
Unmanured	1889	1.435	3.84	0	3.47
,,	1890	1.078	5.66	0	3.89
,,	1891	1 130	5.01	0	4.65
,,	1892	1.182	3.67	0	3.66
,,	1893	1.450	2.09	0	1.72
,,	1894	0.989	6.06	0	5.84
Without nitrogen	1889	1.054	7.54	0	7.17
,, ,,	1890	0.937	7.43	0	5.66
,, ,,	1891	0.893	6.39	0	6.03
,, ,,	1892	0 786	5.09	0	4.78
,, ,,	1893	0.888	5.32	0	4.96
,, ,,	1894	0.852	6.27	0	6.05
Complete manure	1889	1.096	13.37	9.18	13.00
,, ,,	1890	0.943	12.46	9.18	10.69
,, ,,	1891	1.002	11.93	9.18	11.57
,, ,,	1892	1.026	9.69	8.33	9.39
,, ,,	1893	1.049	9.63	8.33	9.37
,, ,,	1894	0.962	10 10	8.33	9.88

In considering these results, it must be noticed that our soil is very rich in nitrogen, this forming as much as 0.49 % of the dry matter. The high percentage of this nutriment in the plants grown on the unmanured plots clearly proves that the stock of nitrogen in the soil could not to be reduced to the minimum by the successive cultivation of rice during the six years, and that the deficiency of the other nutriments does not cause a greater consumption of it. The percentage of nitrogen in the plants grown on the plots supplied with much phosphoric acid and potash but not with nitrogen was the lowest, since the stock of this nutriment, though pretty large, was not sufficient to secure maximum production of organic

matter. According to the researches previously made by us, rice plants consume 62 % of nitrogen from ammonium sulphate; hence its supply from the natural sources (soil atmosphere and the water of irrigation) would, on the same assumption, be represented by the following figures:

	per plot.	per tan.
in 1889	11.56 grms.	13.9 kilogrms.
,, 1890	9.13 ,,	11.0 ,,
,, 1891	9.72 ,,	11.7 ,,
,, 1892	7.71 ,,	9.3 ,,
,, 1893	8.00 ,,	9.6 ,,
,, 1894	9.76 ,,	11.7 ,,

Thus the annual supply of nitrogen from the natural sources was nearly constant and amounted on the average of the last five years to 10.6 kilograms of ammoniacal nitrogen per tan, and would suffice in round number for the production of 420 kilograms of unhulled grains.[1]

Of the nitrogen applied as ammonium sulphate to the plots with complete manure the following proportions were absorbed by the plants (in grms. per plot).

	1887	1890	1891	1892	1893	1894
In the whole crop	13.37	12.46	11.93	9.69	9.63	10.10
In the crop grown without nitrogen	7.57	7.43	6.39	5.09	5.32	6.27
Taken up from the manure.	5.83	5.03	5.54	4.60	4.31	3.83
Applied in the manure	9.18	9.18	8.33	8.33	8.33	8.33
Absorbed percentage of the nitrogen applied	63.0	54.8	66.5	55.2	51.7	46.0

Thus on the average of the six years' experiments performed on the same plots, we find the assimilation factor for ammoniacal nitrogen to be 56.2.

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(1) For the production of 100 kilogrms. of unhulled grain a supply of 2.53 kilogrms. of ammoniacal nitrogen is required, assuming that the soil is completely free from nitrogen.

Secondly, as to the consumption of phosphoric acid by rice, our researches have given the following results:

	Experimental year.	Phosphoric acid in the dry matter of the whole crop.		Phosphoric acid in the manure.	Phosphoric acid extracted from the soil resp. from soil and manure.
		%.	Grms.	Grms.	Grms.
Unmanured	1889	0.240	0.64	0	0.55
,,	1890	0.165	0.86	0	0.53
,,	1891	0.180	0.80	0	0.73
,,	1892	0.242	0 75	0	0.65
,,	1893	0 159	0.23	0	0 17
,,	1894	0.205	1.10	0	1.02
Without phos. acid	1889	0.232	0.61	0	0.52
,, ,,	1890	0.165	0 88	0	0.55
,, ,,	1891	0.171	0 96	0	0.89
,, ,,	1892	0.211	0.78	0	0.68
,, ,,	1893	0.179	0.39	0	0.33
,, ,,	1894	0.201	1.25	0	1.17
Complete manure	1889	0.320	4.12	18.36	4.03
,, ,,	1890	0.206	2.73	18.36	2.40
,, ,,	1891	0.220	2.62	8 33	2.55
,, ,,	1892	0.256	2.42	8.33	2.32
,, ,,	1893	0.262	2.40	8.33	2 34
,, ,,	1894	0.275	2.88	8.33	2.80

The proportions of the phosphoric acid taken up by the plants from the soil of the unmanured plot and the plot without phosphoric acid did not decrease, but increased with the lapse of years. This shows that the rate of the conversion of the difficultly soluble phosphoric constituents of the soil into an assimilable form also increases. As stated in a former number of this bulletin[1] this is

(1) This Bulletin Vol. I. No. 11.

principally due to the repeated mechanical treatment to which the soil was subjected for many years before the experiments were commenced, and to the indirect action of the ammonium sulphate and potassium carbonate, which were liberally supplied to the plots without phosphoric acid. According to our previous researches, rice plants consume 24 % of phosphoric acid from superphosphate; hence its supply from the natural sources during the six experimental years would, on the same assumption, be represented by the following figures:

	per plot.	per tan.
in 1889	2.17 grms.	2.60 kilogrms.
,, 1890	2.29 ,,	2.75 ,,
,, 1891	3.71 ,,	4.45 ,,
,, 1892	2.83 ,,	3.40 ,,
,, 1893	1.38 ,,	1.66 ,,
,, 1894	4.87 ,,	5.84 ,,

Thus the annual supply of phosphoric acid from the natural sources amounted on the average of six years to 3.45 kilogrms. per tan of phosphoric acid equivalent to that of superphosphate. This quantity is sufficient for the production of 2.50 kilogrms. of unhulled grain.[1]

(1) For the production of 100 kilogrms. of unhulled grain a supply of 1 42 kilogrms. superphosphate-phosphoric acid is necessary.

Lastly, as to the consumption of potash by rice, we have obtained the following results :

	Experimental year.	Potash in the dry matter of the whole crop.		Potash in the manure.	Potash extracted from the soil, resp. soil and manure.
		%.	Grms.	Grms.	Grms.
Unmanured	1889	0.705	1.89	0	1.70
,,	1390	0.886	4.65	0	4.00
,,	1891	0.595	2.64	0	2.39
,,	1892	0.481	1.50	0	1.35
,,	1893	0.510	0.76	0	0.61
,,	1864	0.620	3.37	0	3.19
Without potash	1889	0.429	4.78	0	4.59
,, ,,	1890	0 386	4.32	0	3.67
,, ,,	1891	0.341	3.14	0	2.89
,, ,,	1892	0.388	3.16	0	3 01
,, ,,	1893	0.315	2.55	0	2.40
,, ,,	1894	0.392	3.82	0	3.65
Complete manure	1889	0.710	9.25	9.18	9.06
,, ,,	1890	0.770	10.17	9.18	9.52
,, ,,	1891	0.660	7.85	8.33	7.60
,, ,,	1892	0.533	5.57	8.33	5.44
,, ,,	1893	0,639	5.79	8.33	5.64
,, ,,	1894	0.638	6.69	8.33	6.51

Thus we see that the crop grown with complete manure is the richest in potash and that the crop grown without any manure comes next, while the crop supplied with much nitrogen and phosphoric acid, but not with potash, is the poorest in the latter. This proves that the stock of this nutriment in the soil is pretty large and can not be reduced by six successive years of cultivation to the minimum, but that at the same time it is not sufficient to secure maximum production. According to the researches formerly made

by us, rice plants can assimilate 50 % of potash from its soluble salt; hence the supply from the natural sources would be equal to the following quantities of potash having the same manurial value as that of the soluble salt.

	per frame.	per tan.
in 1889	9.18 grms.	1.10 kilogrms.
,, 1890	7.34 ,,	8.8 ,,
,, 1891	5.78 ,,	6.9 ,,
,, 1892	6.02 ,,	7.2 ,,
,, 1893	4.80 ,,	5.8 ,,
,, 1894	7.30 ,,	8.8 ,,

Thus the annual supply of assimilable potash amounted on the average of the results of the last five years' experiments, to 7.5 kilogrms. per tan. This quantity is sufficient for the production of 5.70 kilogrms. of unhulled grain.[1]

By the method explained above we can easily calculate, as O. Kellner[2] has proposed, the figures which give reliable informations on the requirement of fertilizer by the soil. Thus according to the experiments hitherto made we have found that for the production of 100 kilogrms. of unhulled rice grain, 2.53 kilogrms. of nitrogen in the form of ammonium salt, 1.42 kilogrms. of phosphoric acid as superphosphate and 1.31 kilogrms. of potash as a salt are required. Now we found that after six experimental years there were still present in the soil 1.17 kilogrms. of nitrogen, 5.84 kilogrms. of phosphoric acid and 8.8 kilogrms. of potash. Hence for the production of 500 kilogrms. of unhulled grain there must be supplied the following quantities of the nutriments:

	Nitrogen.	Phosphoric acid.	Potash.
The quantities of the nutriments necessary for the production of 500 kilogrms. of unhulled grain	12.7 kilogrs.	7.1 kilogrs.	6.6 kilogrs.
The quantities of the nutriments present in the soil	11.7	5.8	8.8
The minimum quantities of the nutriments to be applied as manure	1.0	1.3	—

(1) For the production of 100 kilogrms. of unhulled grain a supply of 1.31 kilogrms. of the assimilable potash is necessary. In this calculation, the results of the experiments of the first year have been omitted, since in that year there was a liberal supply of soil potash, in consequence of which rice plants might have consumed this nutriment over and above what was absolutely necessary for the production of organic matter.

(2) Die landwirthschaftliche Versuchsstationen 1892, p. 302.

Thus if we supply to the soil 1.0 kilogrms. of nitrogen as ammonium salt and 1.3 kilogrms. of phosphoric acid as superphosphate we can get 500 kilogrms. of unhulled rice grain without any waste of the nutriments. This method of calculation may of course be applied to any kind of crops.

II. SERIES.

After Effect of unrecovered Phosphoric Acid as Sodium Phosphate.

(*Fourth and Fifth Years.*)

These experiments was performed on those plots to which phosphoric acid was applied in 1889[1] in various proportions as sodium phosphate, besides much nitrogen as ammonium sulphate and much potash as carbonate. On these plots rice was cultivated in the following years with the supply of nitrogen and potash in the form of the same salts as before in the proportion of 10 kilogrms. of each nutriment per tan. The quantities of phosphoric acid applied in 1889 and those left unabsorbed as well as the phosphoric in the fourth year (1892) will be seen from the following table, in which, however, for the sake of comparison, the yields obtained from the plot without phosphoric acid and with a complete manure are also recorded :

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(1) This Bulletin, Vol. I, No. 10.

Phosphoric acid applied per frame in 1889. Grms.	Phosphoric acid not recovered.			Yield per frame in 1892.			
	in 1889. Grms.	in 1890. Grms.	in 1891. Grms.	Straw. Grms.	Full grain. Grms.	Empty grain. Grms.	Whole crop. Grms.
0	—	—	—	264	168	3	435
4.59	3.65	3.65	3.53	279	165	3	447
9.18	6.99	6.99	6.59	266	160	3	429
13.77	10.86	10.38	9 73	263	181	2	446
18.36	14.81	13 92	13.08	293	209	3	505
22.54	19.32	18 09	16.95	300	229	3	532
27.54	23 29	21.73	20.66	355	270	3	628
Complete manure				573	532	12	1117

We see from the above table that the three smallest quantities of phosphoric acid applied in 1889 had no effect upon the crop of 1892, whilst the residues from the larger doses produced some increase in the crop. The yield of grain by the plot supplied with the largest quantity of phosphoric acid was 60 % higher than that produced without application of phosphoric acid, but it was only half as much as that obtained with a complete manure containing 8.33 grms. of phosphoric acid as double superphosphate. Similar results were obtained by the determination of the phosphoric acid taken up by the plants from the residues in the soil, as is shown in the following table:

Phosphoric acid grms. per frame.	1	2	3	4	5	6	Freshly manured.
In the whole crop of 1892.	0.65	0.68	0.77	0 83	1.02	1.15	2.62
In the crop of 1892 produced without phosphoric acid.	0.78	0.78	0.78	0.78	0 78	0.78	0.78
Consumed from the residual phosphoric acid. ..	—	—	—	0.05	0.24	0 37	1.84
Residual phosphoric acid in 1892.	3.53	6.56	9 73	13.08	16.95	20.66	— — —
Amount consumed, in per cent of this residue.	—	—	—	0.38	1.42	1.79	———

Thus the residues left from the smaller doses of phosphoric acid were no longer available, while the residues from the larger doses were assimilated by the plants to a certain extent. But the freshly applied phosphoric acid was far more accessible to the plants than the residues left in the soil. In order to show how much phosphoric acid was assimilated from the sodium phosphate originally applied, the following table has been prepared :

	1	2	3	4	5	6
Phosphoric acid applied per frame in 1889. Grms.	4.58	9.18	13.77	18 36	22 95	27.54
Percentage consumption of the phosphoric acid originally applied in 1889	20.5	22.8	21.1	19.4	15.9	15.4
„ 1890	–	-	3.5	4.5	5.4	5.7
„ 1891	2.6	4.7	4.7	4.6	5.0	3.9
„ 1892	- -		—	0 3	1 0	1.3
In the four years	23.1	27.5	29.3	28.8	27.3	26.3

To study still further the after-action of sodium phosphate in the fifth year after its application, we cultivated rice again on the same plots in 1893, manuring them only with nitrogen and potash in the form of the same salts and in the same proportions as in the preceding year. The following table shows the quantities of phosphoric acid originally applied and those left unrecovered, as well as the produce in the fifth season:

Phosphoric acid applied per frame in 1889. Grms.	Phosphoric acid not recovered.				Yield per frame in 1893.			
	in 1889 Grms.	in 1890 Grms.	in 1891 Grms.	in 1892. Grms.	Straw. Grms.	Full grain. Grms.	Empty grain. Grms.	Whole crop. Grms.
0.	—	—	—	—	161	95	2	258
4.59	3.65	3.65	3.53	3.53	119	71	1	191
9.18	6.99	6.99	6.59	6.59	149	98	3	250
13 77	10.86	10.38	9.73	6.73	144	89	2	233
18.36	14 81	13.92	13.08	13.03	209	147	3	359
22.95	19.32	18.09	16.95	16.73	198	155	3	356
27.54	23 29	21.73	20.66	20.29	178	132	3	313
Complete manure.					574	486	10	1069

Thus the residues of the phosphoric acid applied in 1889 in the three largest doses had still some effect upon the crop. In the following table are shown the proportions of phosphoric acid assimilated by the plants from the residues in the soil.

	1	2	3	4	5	6
Phosphoric acid applied per frame in 1889. Grms.	4 59	9.18	13.77	18.36	22.95	27.54
Percentage consumption of the phosphoric acid originally applied in 1889.	20.5	22.8	21.1	19 4	15.9	15.4
1890.	—	—	3.5	4.5	5.4	5.7
,, 1891.....	2.6	4.7	4 6	5.0	5.0	3.9
,, 1892....	—	—	—	0.3	1.0	1.3
,, 1893.....	—	–	—	0.8	0.7	0.4
In the five years.....	23.1	27.5	29.3	29.6	28.0	26.7

The results of these experiments bring into relief the fact that easily soluble phosphatic manures show their chief action soon after application, but that they have but a subordinate effect in subsequent seasons. These results also prove the fact that the excess of

the phosphoric acid left in the soil is pretty rapidly converted into the forms which are but difficultly assimilable by plants. It is consequently advisable to apply phosphoric acid, at least in the case of soluble phosphatic manures to each crop according to its want. The same fact has also been noticed by Maercker [1] with different kinds of soils. The conversion of easily soluble phosphates into the forms not easily assimilable by plants is much favoured by the presence of hydrated sesquioxides of iron and aluminium, which are present in extremely large quantities in our soils. In other kinds of soils the conversion will not be so rapid as in the soil under experiment.

III. SERIES.

After Effect of various Phosphatic Manures.

(*Third, Fourth and Fifth Years.*)

These experiments were commenced in 1890 and were continued until last year for determining the after effect of various phosphatic manures. They were made with 57 plots with 9 different kinds of manures, so that 6 plots were used for each manure, 3 with a small dose and 3 with a large dose, the latter being just double of the former, while the remaining 3 plots were left without any phosphatic manure. After harvesting the crop these plots were always left untouched until the May of the next year, when their soil was well mixed with water. In the middle of June they were supplied with 10 kilogrms. of nitrogen as ammonium sulphate and 10 kilogrms. of potash as carbonate. The average yield of the third experimental year (1892) is shown in the following table:

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[1] Landwirthschafliche Jahrbücher. Bd. XXII. (1893). Ergänzungsband II. p. 37.

Phosphoric acid applied per frame in 1890.	Unrecovered phosphoric acid.		Kinds of phosphatic manures.	Yield per frame 1892.			
	in 1890.	in 1891.		Straw.	Full grain.	Empty grain.	Whole crop.
Grms.	Grms.	Grms.		Grms.	Grms.	Grms.	Grms.
0	0	0	No phosphatic manure..	164	76	2	242
3.89	2.95	2.792	Double superphosphate.	144	70	2	216
7.78	6.40	5.844	,, ,,	193	108	2	303
4.59	3.44	3.099	Precipitated phosphate.	194	104	2	300
9.18	7.53	6.884	,, ,,	201	111	2	314
6.97	6.39	5.939	Peruvian guano	179	97	3	279
13.94	13.07	12.135	,, ,,	247	145	3	395
6.885	5.94	5.486	Thomas phosphate.....	209	113	3	324
13.77	12.35	11.360	,, ,,	281	171	3	455
6.885	5.91	5.518	Steamed bone dust	183	95	2	280
13.77	11.66	10.744	,, ,, ,,	254	165	3	422
6.885	5.88	5.466	Crude bone dust	171	90	2	263
13.77	11.65	10.750	,, ,, ,,	197	113	3	313
6.885	6.43	6.232	Bone ash.....	190	102	3	295
13.77	12.75	12.393	,, ,,	180	102	2	384
6.885	6.77	6.615	Phosphorite	189	98	2	289
13.77	13.69	13.318	,,	219	120	2	341

In 1893 the experiments were repeated on the some plots just in the same manner as in the preceding year. The average yield per frame was as follews :

Phosphoric acid per frame.		Kinds of phosphatic manures.	Yield per frame 1893.			
Applied in 1890. Grms.	Unrecovered in 1892. Grms.		Straw. Grms.	Full grain. Grms.	Empty grain. Grms.	Whole crop. Grms.
0	0	No phosphatic manure	131	71	2	204
3.89	2.792	Double superphosphate	156	92	2	250
7.78	5.721	,, ,,	155	93	3	251
4.59	2.982	Precipitated phosphate.....	145	92	2	239
9.18	6.699	,, ,,	147	97	2	246
6.97	5.835	Peruvian guano.....	147	89	2	238
13.94	11.875	,, ,,	181	122	3	306
6.885	5.316	Thomas phosphate.....	169	112	2	283
13.77	10.929	,, ,,	190	141	3	334
6.885	5.405	Steamed bone dust	156	97	2	255
13.77	10.348	,, ,, ,,	184	126	4	314
6.885	5.406	Crude bone dust	197	104	2	303
13.77	10.473	,, ,. ,,	184	126	3	313
6.885	6.107	Bone ash..... .	130	76	2	208
13.77	12.262	,, ,,	155	96	2	253
6.884	6.571	Phosphorite	151	91	2	244
13.77	13.571	,,	157	92	3	252

In 1894 the same experiments were repeated. The average yield was as follows :

Phosphoric acid per frame.		Kinds of phosphatic manures.	Yield per frame 1894			
Applied in 1890. Grms.	Unrecovered in 1893. Grms.		Straw. Grms.	Full grain. Grms.	Empty grain. Grms.	Whole crop. Grms.
0	0	No phosphatic manure	269	177	5	451
3.89	2.624	Double superphosphate.....	246	170	6	422
7.78	5.438	,, ,,	248	163	3	414
4.59	2.898	Precipitated phosphate	217	136	5	358
9.18	6.418	,, ,,	245	173	5	428
6.97	5.744	Peruvian guano	283	211	9	503
13.94	11.643	,, ,,	299	218	9	526
6.885	5.142	Thomas phosphate.....	276	196	6	478
13.77	10.686	,, ,,	291	212	6	509
6.885	5.289	Steamed bone dust.....	234	167	6	407
13.77	10.059	,, ,, ,,	277	219	6	502
6.885	5.279	Crude bone dust.....	219	143	4	466
13.77	10.245	,, ,, ,,	280	200	7	487
6.885	6.103	Bone ash	219	140	4	363
13.77	12.158	,, ,,	266	189	6	461
6.885	6.490	Phosphorite	275	202	9	466
13.77	13.043	,,	275	209	5	489

Now in order to see clearly the after effect of these phosphatic manures we have calculated the extra-yield caused by the residual phosphoric acid in the last three experimental years :

Phosphoric acid applied per frame in 1890. Grms.	Kinds of phosphatic manure.	Increase per frame.					Increase caused.				
		in 1892 Grms.	in 1893 Grms.	in 1894 Grms.	in 1891 Grms.	in 1890 Grms.	by 100 grms. of unrecovered phosphoric acid in 1892 Grms.	in 1893 Grms.	in 1894 Grms.	in 1891 Grms.	by 100 grms. of original phosphoric acid in the first season (1890). Grms.
3.89	Double superphosphate	—	21	—	34	243	—	752	—	1153	6247
7.78	,, ,,	32	22	—	97	352	561	384	—	1516	4524
4.59	Precipitated phosphate..	28	21	—	49	307	913	704	—	1424	6688
6.18	.. ..	35	26	—	144	416	507	388	—	1912	4532
6.97	Peruvian guano	21	18	34	122	146	354	308	592	1908	2295
13.94	.. ..	69	51	41	186	195	564	429	352	1428	1363
6.885	Thomas phosphate.....	37	41	19	133	213	671	771	370	2240	3093
13.77	,, ,,	95	70	35	204	322	845	642	328	1652	2339
6.885	Steamed bone dust	19	26	—	142	229	348	481	-	2393	3326
13.77	,, ,, ,,	89	55	41	243	381	831	532	410	2084	2768
6.885	Crude bone dust	14	33	—	101	259	260	610	—	1717	3762
13.77	,, ,, ,,	37	55	23	180	454	344	526	225	1545	3296
6.885	Bone ash	26	5	—	34	125	413	82	—	529	1816
13.77	,, ,,	26	25	12	76	259	218	204	99	595	1874
6.885	Phosphorite	22	20	25	40	56	328	304	385	561	313
13.77	..	44	21	32	136	50	327	155	245	826	363

We see from the above table that the after effect of various phosphatic manures, though perceptible in the fourth or even in the fifth season after their application, are not so great as one might anticipate. Already in the second season their action was considerably diminished, with the only exception of the peruvian guano which increased the crops by nearly the same proportion. Double superphosphate and precipitated phosphate showed a very insignificant after-effect, and in the fifth season, not the least action was to be observed. Steamed and crude bone dusts showed a more long continued action than the two kinds of manure just mentioned, but in small doses they were also no longer effective in the fifth year.

Peruvian guano and Thomas phosphate showed their effect longest, the effect being still visible in the fifth season after application. Bone ash and phosphorite had rather a small after-effect, although the richness of our soil in acid humus must favour the decomposition of insoluble calcic phosphate.

Now for the purpose of getting an information as to the relative efficacy of the various phosphatic manures we have calculated from the above table the following figures, taking into account only the extra-yields of grain caused by the smaller doses of phosphoric acid:

Kind of phosphatic manure.	Increase of full grain caused by 100 grms. of phosphoric acid applied in 1890.					Relative increase, [illegible] superphosphate = 100				
	in the 1st season. Grms.	in the 1st & 2nd seasons. Grms.	in the 1st, 2nd & 3rd seasons. Grms.	in the 1st, 2nd, 3rd & 4th seasons. Grms.	in the 1st, 2nd, 3rd, 4th & 5th seasons. Grms.	in the 1st season. Grms.	in the 1st & 2nd seasons. Grms.	in the 1st, 2nd & 3rd seasons. Grms.	in the 1st, 2nd, 3rd & 4th seasons. Grms.	in the 1st, 2nd, 3rd, 4th & 5th seasons. Grms.
Double superphosphate.....	6247	7121	7121	7661	7661	100.	100.	100.	100.	100.
Precipitated phosphate	6688	7756	8366	8824	8824	107.1	108.9	117.4	116.5	116.5
Peruvian guano..	2095	3845	4146	4405	4892	33.5	54.0	58.2	57.5	63.9
Thomas phosphate.....	3093	5025	5563	6158	6434	49.5	70.6	78.1	80.4	84.0
Steamed bone dust	2326	5388	5664	6004	6004	53.5	75.7	79.5	78.3	78.3
Crude bone dust	3762	5229	5432	5911	5911	60.2	73.4	76.4	77.2	77.2
Bone ash.....	1816	2309	2687	2760	2760	29.1	32.4	37.7	36.0	36.0
Phosphorite	813	1394	1714	2004	2367	13.0	19.4	24.1	26.2	30.9

Before entering into a discussion of these results we shall consider the proportion of phosphoric acid absorbed by the plants from the residual phosphates. Chemical analysis of the crop of 1892 gave the following results:

Phosphoric acid applied in 1890. Grms.	Phosphoric acid absorbed in the 1st season %	Phosphoric acid left in the soil 1890. Grms.	Phosphoric acid absorbed in the 2nd season %	Phosphoric acid left in the soil 1891 Grms.	Kind of phosphatic manures.	Phos. acid absorbed from the residue. Grms.	Phos. acid absorbed from the residue. %	Phosphoric acid absorbed from the original manure. in the 3rd season. %	Phosphoric acid absorbed from the original manure. in the 1st, 2nd & 3rd seasons. %	Phosphoric acid absorbed from the original manure. Average. %
3.89	24.1	2.95	4.1	2.792	Double superphos.	—	—	—	28.2	27.3
7.78	17.7	6.40	7.1	5,844	,, ,,	0.123	2.1	1.6	26.4	
4.59	25.1	3.44	7.4	3.009	Precipit. phos.	0.117	3.8	2.5	35.0	31.0
9.18	18.0	7.53	7.0	6.884	,, ,,	0.185	2.7	2.0	27.0	
6.97	8.3	6.39	6.5	5.939	Peruvian guano	0.104	1.7	1.5	16.3	15.6
13.94	6.3	13.07	6.7	12.135	,, ,,	0.260	2.1	1.9	14.9	
6.885	13.7	5.94	6.6	5.486	Thomas phosphate	0.171	3.2	2.5	22.8	21.7
13.77	10.3	12.35	7.2	11.360	,, ,,	0.431	3.8	3.1	20.6	
6.885	14.2	5.91	5.7	5.518	Steamed bone dust	0.113	2.0	1.6	21.5	23.2
13.77	15.3	11.66	6.6	10.744	,, ,, ,,	0.396	3.7	2.9	24.8	
6.885	14.6	5.88	6.0	5.466	Crude bone dust	0.060	1.1	0.9	21.5	22.3
13.77	15.4	11.65	6.5	10.750	,, ,, ,,	0.277	2.6	2.0	23.9	
6.885	6.6	6.43	2.9	6.232	Bone ash	0.125	2.0	1.8	11.3	11.1
13.77	7.4	12.75	2.6	12.393	,, ,,	0.131	1.1	0.9	10.9	
6.885	1.7	6.77	2.2	6.615	Phosphorite	0.044	0.7	0.6	4.5	4.5
13.77	0.6	13.69	2.7	13.318	,,	0.166	1.3	1.2	4.5	

Chemical analysis of the crops of 1893 was also made and the results shown in the following table :

Phosphoric acid applied in 1890 Grms.	Phosphoric acid absorbed in the 1st, 2nd & 3rd seasons. %	Phosphoric acid left in the soil 1892 Grms.	Kind of phosphatic manure.	Phosphoric acid absorbed from the residue. Grms.	Phosphoric acid absorbed from the residue. %	Phosphoric acid absorbed from the original manure in the 4th season. %	Phosphoric acid absorbed from the original manure in the 1st, 2nd, 3rd & 4th seasons. %	Phosphoric acid absorbed from the original manure Average. %
3.89	28.2	2.792	Double superphosphate.	0.1680	6.0	4.3	32.5	30.8
7.78	26.4	5.721	,, ,,	0.2827	4.0	3.6	30.0	
4.59	35.0	2.982	Precipitated phosphate.	0.0844	2.8	1.8	36.8	33.5
9.18	27.0	6.699	,, ,,	0.2808	4.2	3.1	30.1	
6.97	16.3	5.835	Peruvian guano.....	0.0908	1.6	1.3	17.9	17.3
13.94	14.9	11.875	,, ,,	0.2315	2.0	1.7	16.6	
6.885	22.8	5.316	Thomas phosphate	0.1740	3.3	2.5	25.3	23.8
13.77	20.6	10.929	,, ,,	0.2430	2.2	1.8	22.2	
6.885	21.5	5.405	Steamed bone dust	0.1164	2.2	1.7	23.2	25.1
13.77	24.8	10.348	,, ,, ,,	0.2891	2.8	2.1	26.9	
6.885	21.5	5.406	Crude bone dust	0.1274	2.4	1.9	23.4	24.4
13.77	23.9	10.473	,, ,, ,,	0.2283	2.2	1.7	25.6	
6.885	11.3	6.107	Bone ash	0.0044	0.1	0.1	11.4	11.6
13.77	10.9	12.262	,, ,,	0.1036	0.8	0.8	11.7	
6.885	4.5	6.571	Phosphorite	0.0812	1.2	1.2	5.7	5.5
13.77	4.5	13.152	,,	0.1094	0.8	0.8	5.3	

Similarly the analysis of the crop of 1894 gave the following results :

Phosphoric acid applied in 1890 Grms.	Phosphoric acid absorbed in the 1st, 2nd, 3rd & 4th seasons. %	Phosphoric acid left in the soil 1893 Grms.	Kind of phosphatic manure.	Phosphoric acid absorbed from the residue. Grms.	Phosphoric acid absorbed from the residue. %	Phosphoric acid absorbed from the original manure in the 5th season. %	Phosphoric acid absorbed from the original manure in the 1st, 2nd, 3rd, 4th, & 5th seasons. %	Phosphoric acid absorbed from the original manure Average. %
3.89	32.5	2.624	Double superphosphate.	—	—	—	32.5	31.3
7.78	30.0	5.438	,, ,,	—	—	—	30.0	
4.59	36.8	3.898	Precipitated phosphate..	—	—	—	36.8	33.5
9.18	30.1	6.418	,, ,,	—	—	—	30.1	
6.97	17.9	5.744	Peruvian guano	0.050	0.9	0.7	18.6	17.9
13.94	16.6	11.643	,, ,,	0.073	0.6	0.5	17.1	
6.885	25.3	5.142	Thomas phosphate.....	0.027	0.5	0.4	25.7	24.2
13.77	22.2	10.686	,, ,,	0.055	0.5	0.4	22.6	
6.885	23.2	5.289	Steamed bone dust	—	—	—	23.2	25.3
13.77	26.9	10.059	,, ,, ,,	0.071	0.7	0.5	27.4	
6.885	23.4	5.279	Crude bone dust	—	—	—	23.4	24.7
13.77	25.6	10.245	,, ,, ,,	0.035	0.3	0.3	25.9	
6.885	11.4	6.103	Bone ash	—	—	—	11.4	11.6
13.77	11.7	12.158	,, ,,	0.010	0.1	0.1	11.8	
6.885	5.7	6.490	Phosphorite	0.035	0.5	0.5	6.2	5.9
13.77	5.3	13.043	,,	0.038	0.3	0.3	5.6	

In harmony with the action of the various phosphatic manures in increasing the yield of grain we find from the above tables that the proportions of the phosphoric acid assimilated from the residues are much smaller than those absorbed from the freshly applied phosphates and that a large fraction of assimilable phosphoric acid of the manures was converted in the course of time into difficultly assimilable forms and was simply left unrecovered in the soil. This fact is, as already stated, of great practical importance and warrants the application of easily soluble phosphatic manures for each crop, as we do wish rapidly acting nitrogenous manures.

Now assuming the assimilability of the phosphoric acid of double superphosphate to be 100, and calculating, on this basis, the relative assimilability of the other forms of phosphoric acid we obtain the following figures; and we add, for the sake of comparison the relative increase of grains previously mentioned.

Kind of phosphatic manure.	Relative assimilability					Relative increase of grains				
	in the 1st season.	in the 1st and 2nd seasons.	in the 1st, 2nd, and 3rd seasons.	in the 1st, 2nd, 3rd, & 4th seasons.	in the 1st, 2nd, 3rd, 4th & 5th seasons.	in the 1st season.	in the 1st and 2nd seasons.	in the 1st, 2nd and 3rd seasons.	in the 1st, 2nd, 3rd and 4th seasons.	in the 1st, 2nd, 3rd, 4th & 5th seasons.
Double superphosphate	100	100	100	100	100	100	100	100	100	100
Precipitated phosphate	104.0	115.2	124.2	113.2	113.2	107.1	108.9	117.4	11.65	116.5
Crude bone dust	60.4	73.0	76.2	72.0	72.0	60.2	73.4	76.4	77.2	77.2
Steamed bone dust	58.6	70.6	76.2	71.4	71.4	53.5	75.7	79.5	78.3	78.3
Thomas phosphate	56.9	72.0	80.8	77.8	79.1	49.5	70.6	78.1	80.4	84.0
Peruvian guano	45.3	50.2	57.7	55.1	57.2	33.5	54.0	58.2	57.5	63.9
Bone ash	27.4	33.7	40.0	35.1	35.1	29.1	32.4	37.7	36.0	36.0
Phosphorite	7.1	13.6	16.2	17.5	19.1	13.0	19.4	24.1	26.2	30.9

The figures for the relative assimilability of the various forms of phosphoric acid agree very well with those for the relative increase of grain. The average of these two series of figures may be taken as basis for the calculation of the quantities of various phosphatic manures to be applied for rice under conditions similar to those that obtained in our experiments in regard to soil and climate.

	Relative manurial value				
	in the 1st season.	in the 1st and 2nd seasons.	in the 1st, 2nd and 3rd seasons.	in the 1st, 2nd, 3rd and 4th seasons.	in the 1st, 2nd, 3rd, 4th and 5th seasons.
Double superphosphate	100	100	100	100	100
Precipitated phosphate	106	112	121	115	115
Thomas phosphate	53	71	79	79	82
Crude bone dust	60	73	76	75	75
Steamed bone dust	56	73	78	75	75
Peruvian guano	39	52	58	56	61
Bone ash	28	33	39	36	36
Phosphorite	10	17	20	22	22

From these figures and the explanations given in the preceding pages the results of the five years' experiments on various phosphatic manures with paddy rice may be summarized as follows.

(1.) Of the various phosphatic manures in our experiments, precipitated calcic phosphate, which in our case consisted chiefly of dicalcic phosphate mixed with some tricalcic phosphate was the most effective. Its action was most efficient in the first year of its application, while in subsequent years the effect was considerably diminished and in the fifth year not the least action was to be seen. The superiority of this manure over superphosphate, though not great, was distinctly seen. This fact has been frequently observed by several investigators and may be due in our case to the extreme richness of the soil in hydrated sesquioxides of iron and aluminium, by which the easily soluble monocalcic phosphate of the superphosphate is more readily converted into the basic compounds which are difficultly assimilable than the dicalcic phosphate contained in precipitated calcium phosphate. Considering that precipitated phosphate can be obtained cheaper per unit of phosphoric acid than superphosphate, the conclusion is unavoidable, that the former is a more economical source of phosphoric acid for paddy rice than the latter.

(2.) Very similar though somewhat inferior to precipitated phosphate was superphosphate, whose action though great in the beginning did not continue long and was wholly inefficient in the fifth year after its application. The great solubility of the phosphoric

acid contained in this manure warrants its application for soils with a medium absorptive power, since in soils with a low absorptive power too great distribution is effected while in those with a high absorptive power, a rapid conversion into basic compounds takes place, neither of which is favourable to the absorption of phosphoric acid by plants.

(3.) The two kinds of bone manure, steamed bone dust and crude bone dust, were also very effective. Of these steamed bone dust proved to be somewhat less effective than crude bone dust in the first year, probably owing to the loss of some of its gelatinoid substance; but in subsequent years the former acted a little better, so that the two became axactly same in effect. These manures acted somewhat rapidly and showed excellent results for surpassing those observed by European investigators. The same results were observed still more distinctly in our experiments on the upland soil.[1] This proves that in countries with warm climate and copious rain as in this country bone measures may be used in a crude state with advantage.

(4.) Thomas phosphate was found to have a long continued action, its effect being still observable in the fifth year after its application. This manure was a little inferior to bone manures in the first year, but in subsequent years it acted better so that when the after effect is taken into account, its effect is a little greater than that of bone manures.

(5.) Peruvian guano, bone ash and phosphorite were also found to have a long continued action, but it was very slow, in spite of the richness of our paddy soil in acid humus which favours the decomposition of insoluble calcic phosphate.

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(1) This Bullettin Vol. I. No. 12.

YIELD OF THE SINGLE PLOTS.

No. of plot.		Straw. Grms.	Full grain. Grms.	Empty grain. Grms.
	I. SERIES.			
	Unmanured, partial and complete manure.			
	1892			
8	Unmanured	190	136.5	2.5
32	.. ..	229	183.5	3.0
61	.. .	211	132.0	2.0
11	Without phosphoric acid	235	156.5	3.4
35	.. .. ..	210	121.5	2.7
64	.. .. ..	348	227.0	3.0
9	Without nitrogen	330	333.5	4.5
33	.. ..	376	381.5	4.5
62	.. ..	440	400.0	5.0
10	Without potash	603	486	3.9
34	.. ..	470	339	11.0
63	.. ..	506	398	9.0
12	Complete manure	530	532.5	11.0
36	,, ..	581	520.5	9.0
56	.. ..	609	544.0	14.5
	1893			
8	Unmanured	91	38.0	1.9
32	.. ..	92	51.0	1.0
61	.. ..	140	92.5	1.5
11	Without phosphoric acid	168	10.60	1.5
35	,, ,, ,,	122	04.0	2.0
64	.. . ..	192	114.5	1.5

No. of plot.		Straw. Grms.	Full grain. Grms.	Empty grain. Grms.
9	Without nitrogen	346	311.0	4.0
33	,, ,,	326	310.0	5.0
62	,, ,,	411	369.0	4.5
10	Without potash	574	470.5	6.5
34	,, ,,	387	344.5	6.2
63	,, ,,	543	481.5	10.0
12	Complete manure	613	481.5	10.0
36	,, ,,	448	385.0	6.0
56	,, ,,	662	590.0	6.5
	1894			
8	Unmanured	324	302.0	8.0
32	,, ,,	313	296.0	5.0
61	,, ,,	309	291.0	12.0
11	Without phosphoric acid	384	360.0	15.0
35	,, ,, ,,	414	384.0	22.0
64	,, ,, ,,	287	242.0	10.0
9	Without nitrogen	411	327.0	11.0
34	,, ,,	437	363.0	10.0
63	,, ,,	499	455.0	7.0
10	Without potash	650	570.0	10.0
34	,, ,,	507	447.0	27.0
63	,, ,,	605	547.0	14.0
12	Complete manure	680	575.0	15.0
36	,, ,,	611	514.0	14.0
56	,, ,,	607	572.0	18.0

No. of plot.		Straw. Grms.	Full grain. Grms.	Empty grain. Grms.
	II. SERIES.			
	Unrecovered phosphoric acid applied in 1889 as sodium phosphate.			
	1892			
27	3.53 grms. unrecovered P_2O_5	306	148.5	2.8
37	,, ,, ,, ,,	356	184.0	2.1
42	,, ,, ,, ,,	274	161.5	2.7
28	6.59 grms. unrecovered P_2O_5	224	143.0	2.1
38	,, ,, ,, ,,	234	132.0	2.8
43	,, ,, ,, ,,	340	205.0	3.9
29	9.73 grms. unrecovered P_2O_5	239	160.0	2.2
39	,, ,, ,, ,,	257	175.0	3.1
44	,, ,, ,, ,,	293	208.0	3.6
30	13.03 grms. unrecovered P_2O_5	258	285.0	2.9
40	,, ,, ,, ,,	281	189.0	3.2
45	,, ,, ,, ,,	250	153.0	2.6
17	16.95 grms. unrecovered P_2O_5	299	205.0	3.3
24	,, ,, ,, ,,	300	252.0	4.0
31	20.66 grms. unrecovered P_2O_5	279	292.0	3.4
41	,, ,, ,, ,,	320	233.0	2.8
46	,, ,, ,, ,,	365	286.0	3.8
	1893			
27	3.53 grms. unrecovered P_2O_5	119	65.0	1.0
37	,, ,, ,, ,,	117	74.0	1.0
42	,, ,, ,, ,,	121	78.5	1.0
28	6.59 grms. unrecovered P_2O_5	150	102.0	2.5
38	,, ,, ,, ,,	184	125.0	2.0
43	,, ,, ,, ,,	114	66.0	3.0

No. of plot.		Straw. Grms.	Full grain. Grms.	Empty grain. Grms.
29	9.73 grms. unrecovered P_2O_5	126	80.0	1.5
39	,, ,, ,, ,,	166	99.0	1.5
44	,, ,, ,, ,,	141	83.0	2.0
30	13.03 grms. unrecovered P_2O_5	134	90.0	2.0
40	,, ,, ,, ,,	208	138.0	3.5
45	,, ,, ,, ,,	285	212.0	3.5
7	16.73 grms. unrecovered P_2O_5	196	160.0	3.0
24	,, ,, ,, ,,	200	150.0	3.0
31	20.29 grms. unrecovered P_2O_5	150	125.0	2.0
41	,, ,, ,, ,,	172	128.5	2.5
46	,, ,, ,, ,,	212	143.0	4.0
	III. SERIES,			
	Unrecovered phosphoric acid from various phosphates.			
	1892			
1	No P_2O_5	159	66.0	1.6
39	,, ,,	168	86.0	1.5
4	Double superphosphate, single dose.....	133	53.0	1.8
23	,, ,, ,, ,,	133	67.0	1.4
42	,, ,, ,, ,,	167	88.5	1.9
5	,, ,, double dose.	222	134.0	2.1
24	,, ,, ,, ,,	150	82.0	1.7
43	,, ,, ,, ,,	206	107.5	1.8
6	Precipitated phosphate, single dose	226	12.50	2.4
25	,, ,, ,, ,,	166	84.5	1.6
44	,, ,, ,, ,,	194	103.0	2.0
7	,, ,, double dose	216	122.0	2.3
26	,, ,, ,, ,,	195	117.0	2.1

No. of plot.		Straw. Grms.	Full grain. Grms.	Empty grain. Grms.
45	Precipitated phosphate, double dose	192	93.0	2.5
82	Peruvian guano, single dose	157	88.5	2.5
27	,, ,, ,, ,,	159	82.5	2.0
49	,, ,, ,, ,,	221	120.0	3.5
92	,, ,, double dose	240	131.0	2.9
28	,, ,, ,, ,,	212	116.0	2.8
47	,, ,, ,, ,,	288	186.0	4.0
10	Thomas phosphate, single dose	205	102.5	2.4
29	,, ,, ,, ,,	119	113.0	2.6
48	,, ,, ,, ,,	223	123.0	3.0
11	,, ,, double dose	235	139.0	2.4
30	,, ,, ,, ,,	307	203.0	3.0
49	,, ,, ,, ,,	300	171.0	3.4
12	Steamed bone dust, single dose	168	90.5	2.2
31	,, ,, ,, ,, ,,	205	113.0	2.3
50	,, ,, ,, ,, ,,	176	82.0	1.7
13	,, ,, ,, double dose	264	173.0	3.5
32	,, ,, ,, ,, ,,	252	164.0	3.5
51	,, ,, ,, ,, ,,	245	159.0	3.4
14	Crude bone dust, single dose	170	88.5	2.3
33	,, ,, ,, ,, ,,	170	102.0	1.9
52	,, ,, ,, ,, ,,	173	80.0	1.8
15	,, ,, ,, double dose	192	107.0	1.6
34	,, ,, ,, ,, ,,	193	113.0	2.3
53	,, ,, ,, ,, ,,	206	119.0	3.7
16	Bone ash, single dose	119	47.5	1.6
35	,, ,, ,, ,,	158	69.5	1.8
54	,, ,, ,, ,,	294	188.0	4.3
17	,, ,, double dose	158	72.0	1.8

No. of plot.		Straw. Grms.	Full grain. Grms.	Empty grain. Grms.
36	Bone ash, double dose	156	87.0	1.9
55	,, ,, ,, ,,	226	147.0	3.0
18	Phosphorite, single dose	179	81.0	2.1
37	,, ,, ,,	172	87.0	2.5
56	,, ,, ,,	216	125.0	2.4
19	,, double dose	239	136.0	2.4
57	,, ,, ,,	203	103.5	2.3
	1893			
1	No. P_2O_5	119	65.0	1.0
20	,, ,,	(95)	(44.5)	(2.0)
39	,, ,,	142	76.0	2.0
23	Double superph., single dose	155	89.5	2.0
42	,, ,, ,, ,,	157	95.0	2.0
5	,, ,, double dose	137	87.0	1.5
24	,, ,, ,, ,,	119	57.7	1.5
43	,, ,, ,, ,,	209	134.0	4.5
6	Precipitated phosphate, single dose	121	64.0	2.0
25	,, ,, ,, ,,	136	87.5	2.7
44	,, ,, ,, ,,	178	123.5	2.5
7	,, ,, double dose	124	74.5	1.5
26	,, ,, ,, ,,	127	75.0	2.5
45	,, ,, ,, ,,	189	141.0	2.0
8	Peruvian guano, single dose	98	49.0	1.5
27	,, ,, ,, ,,	139	75.2	3.0
46	,, ,, ,, ,,	204	143.0	2.5
9	,, ,, double dose	164	103.5	1.7
28	,, ,, ,, ,,	200	141.0	3.5
47	,, ,, ,, ,,	178	122.0	2.5
10	Thomas phosphate, single dose	161	113.0	2.0

No. of plot.		Straw. Grms.	Full grain. Grms.	Empty grain. Grms.
29	Thomas phosphate, single dose	185	121.5	2.0
48	,, ,, ,, ,,	160	102.5	2.5
11	,, ,, double dose	203	144.5	2.0
30	,, ,, ,, ,,	207	177.0	3.0
49	,, ,, ,, ,,	166	101,0	3.0
12	Steamed bone dust, single dose	158	102 5	2.5
31	,, ,, ,, ,, ,,	164	105.0	2.0
50	,, ,, ,, ,, ,,	145	84 0	2.0
13	,, ,, ,, double dose	171	114.0	2.0
32	,, ,, ,, ,, ,,	226	170.0	6.7
51	,, ,, ,, ,, ,,	155	95.0	3.0
14	Crude bone dust, single dose	120	68.5	1.5
33	,, ,, ,, ,, ,,	181	123.0	3.0
52	,, ,, ,, ,, ,,	192	121.5	2.0
15	,, ,, ,, double dose	157	102.0	2.0
34	,, ,, ,, ,, ,,	227	160.5	2.5
53	,, ,, ,, ,, ,,	169	117.5	3.0
16	Bone ash, single dose	92	48.0	2.0
35	,, ,, ,, ,,	178	106.3	2.0
54	,, ,, ,, ,,	119	74.0	1.5
17	,, ,, double dose	137	77.0	2.0
36	,, ,, ,, ,,	171	110.2	2.0
55	,, ,, ,, ,,	156	101.0	2.5
18	Phosphorite, single dose	151	91.0	2.0
37	,, ,, ,,	175	105.2	3.0
56	,, ,, ,,	126	75.5	2.0
19	,, double dose	124	69.0	2.0
38	,, ,, ,,	209	132.5	3.5
57	,, ,, ,,	139	76.5	3.0

No. of plot.		Straw. Grms.	Full grain. Grms.	Empty grain. Grms.
	1894			
1	No. P_2O_5	321	204.5	5.0
20	,, ,,	253	162.0	6.0
39	,, ,,	233	166.0	4.0
4	Double superph., single dose	339	254.0	9.0
23	,, ,, ,, ,,	198	120.0	6.0
42	,, ,, ,, ,,	201	136.0	4.0
5	,, ,, double dose	338	233.0	4.0
24	,, ,, ,, ,,	212	130.0	3.5
43	,, ,, ,, ,,	195	125.0	3.5
6	Precipitated phosphate, single dose	260	173.5	6.0
25	,, ,, ,, ,,	219	131.5	3.5
44	,, ,, ,, ,,	172	102.5	4.5
7	,, ,, double dose	252	179.5	4.0
26	,, ,, ,, ,,	222	140.0	7.5
45	,, ,, ,, ,,	261	199.0	4.0
8	Peruvian guano, single dose	268	203.5	5.5
27	,, ,, ,, ,,	260	181.0	1.0
46	,, ,, ,, ,,	320	249.0	1.3
9	,, ,, double dose	318	249.0	8.5
28	,, ,, ,, ,,	260	168.0	12.5
47	,, ,, ,, ,,	313	237.0	6.5
10	Thomas phosphate, single dose	208	134.0	4.0
29	,, ,, ,, ,,	249	173.5	7.5
48	,, ,, ,, ,,	370	279.5	6.0
11	,, ,, double dose	314	222.0	8.0
30	,, ,, ,, ,,	262	208.0	3.0
49	,, ,, ,, ,,	296	207.0	6.5
12	Steamed bone dust, single dose	277	201.0	6.0

No. of plot.		Straw. Grms.	Full grain. Grms.	Empty grain. Grms.
31	Steamed bone dust, single dose	214	155.5	3.0
50	,, ,, ,, ,, ,,	210	145.5	9.0
13	,, ,, ,, double dose	251	188.5	4.5
32	,, ,, ,, ,, ,,	269	209.0	6.5
51	,, ,, ,, ,, ,,	310	258.0	6.0
14	Crude bone dust, single dose	235	152.0	8.0
52	,, ,, ,, ,, ,,	259	183.0	3.0
15	,, ,, ,, double dose	262	198.5	4.5
34	,, ,, ,, ,, ,,	250	177.5	4.5
53	,, ,, ,, ,, ,,	329	225.0	11.0
16	Bone ash, single dose	195	123.5	5.0
35	,, ,, ,, ,,	226	146.0	2.5
54	,, ,, ,, ,,	230	150.0	4.0
17	,, ,, double dose	269	199.5	5.0
36	,, ,, ,, ,,	243	166.0	3.5
55	,, ,, ,, ,,	286	203.0	8.0
18	Phosphorite, single dose	243	158.0	4.5
37	,, ,, ,,	271	205.0	5.0
56	,, ,, ,,	312	243.0	17.0
19	,, double dose	245	165.0	3.5
38	,, ,, ,,	253	210.5	4.3
57	,, ,, ,,	327	250.5	7.0

On the Consumption of Water in Rice Fields.

BY

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With plate XV.

It is well known that rice requires more water for cultivation than other cereals, but there is as yet no quantitative study on the subject. I therefore undertook to measure during the main vegetative period of rice (June 18—October 20) last year at intervals of 2 or 3 days, the quantity of water evaporated from the leaves and stems of the rice plants in the field of the College of Agriculture. The apparatus I used for this purpose is roughly shown in figure I, Plate XV, in which (W) is the outer wall of a room, and (A), a part of the apparatus, is placed outside the house in the open air, while (B) is placed in the room. (A) is a cylindrical zinc pot having the diameter of 25 cm, in which one batch of rice is planted. The height of the pot-stand can be regulated by means of three screws. (B) is a very long (1.5 m) cylindrical zinc bottle in which a certain quantity of water is always kept and carrying a graduated gauge (a) by means of which the height of the water can be easily measured. This bottle is thus simply a modification of a Mariotte's bottle. If we place the lower end of the tube (b) on the same level as the surface of the water in pot (A), the water of the pot will remain at a constant level. As the water evaporates from the pot, an equal quantity passes into it from bottle (B) through the tube (c); so that we can measure the water evaporated from the pot by reading off its diminution in (B). But as the quantity of water evaporated from the pot is not altogether equal to that of transpiration from the plant, we must deduct from the measurement thus made the quantity of water, evaporated from around the stems of the plants. This is done approximately by measuring the area of the water surface in the pot at intervals of 2 or 3 days and calculating the corresponding evaporation of water by means of a common evaporimeter placed by the

side of the pot. (C) is an accumulator of the water that has overflown from (A) after rain, wind, and diminution of atmospheric pressure. The quantity of water collected in (C) is not to be neglected, as it sometimes amounts to a factor of some importance. If we deduct the quantity of rain taken from the ombrometer, from the quantity of water collected in (C), the difference is exactly the quantity of overflow due to wind or diminution of atmospheric pressure. This quantity is also to be deducted from the measurement as made by reading off the gauge. Then the remainder is the actual amount of transpiration from the rice planted in the pot.

In the course of the experiment made last year I became aware of three points in which the apparatus could be improved, excluding at the same time all sources of error and increasing its usefulness for practical purposes. The following changes were therefore made in the apparatus this year :—

(1.) The side mouth (d) of the pot (A) was arranged, as shown in Figure II, (e), so that the water level could be easily regulated by means of a screw (f). By this new arrangement, the inconvenience arising from overflow was obviated, and the 3 screws for the pot-stand could be dispensed with.

(2.) A drain tube (g) was fitted to the pot (A), by means of which about 250 c. cm. of water, the quantity to be deducted from the measurement as made by reading off the gauge, is drawn out from the pot every day. This arrangement was made because in ordinary rice fields there is a loss of about an equal quantity of water by transmission through the soil, and this transmission seems to me to favour the growth of the crop by avoiding the bad effect of stagnation.

(3.) Several batches of rice were planted in the pot, so as to secure as nearly as possible the conditions that obtain in the field.

This arose from the consideration that in general the evaporation from an isolated plant as (A) in Figure III is always larger than that of a plant surrounded by other plants as (B), since in (A) there are 4 open sides (α, β, γ, δ) besides the upper surface (a), whereas in (B) all the 4 sides are mostly covered in by the surrounding plants. Hence we can not obtain the transpiration-water for 9 plants, such as are shown in (B) by simply multiplying the quantity of transpiration from one isolated plant by the number of plants in the batch. It has long been a mystery to scientists that the quantity of evaporation from a certain area of a cultivated field during the period of vegetation always exceeds very much the quantity of rain that falls down

on the same area; but this apparent mystery must be due, as Dr. W. Detmer says,[1] to the error above pointed out of calculating the quantity of evaporation from the results of experiments made in small plots with isolated plants, by simple multiplication. If we equalize as much as possible the conditions of the plants used for experiment and those of the plants in ordinary fields, the quantity of evaporation from the plants used for experiment will perhaps decrease, and the result of multiplication of this quantity by the number of plants contained in a certain area in the field will not show such a great discrepancy with the quantity of rain that falls on the same area. This remark I owe to Prof. Dr. D. Kitao, my teacher.

The rice experimented on last year was Shiratama, a sort of var. Japonica, the seed of which I selected by a salt solution having the specific gravity of 1.12. The selected seeds were steeped in water on the 25th of April, and were sown on the 5th of May. I planted 15 seedlings in one batch in a pot on the 18th of June. As already stated no water was drained in this experiment through the soil in the pot. The plants grew, however, apparently in a normal condition, sending out 19 shoots between the 1st and the 9th of September, and ripening on the 20th of October. The quantity of water evaporated from the plants and from the ordinary water surface during the experiment was as follows:—

Date. (noon—noon)	Weather.	Evaporation of water from	
		ordinary water surface. (m.m)	one batch (=15 plants) of rice. (litre)
18. June—20. June.	Clear.	12.4	0.054
20. ,, —22. ,,	Cloudy and a little rain.	3.8	0.021
22. ,, —24. ,,	Clear.	8.6	0.057
24. ,, —26. ,,	Clear except one single shower.	10.8	0.046
26. ,, —28. ,,	Clear.	11.2	0.034
28. ,, —30. ,,	,,	10.7	0.088
30. ,, — 2. July.	,,	12.2	0.040
2. July — 4. ,,	,,	12.6	0.170

(1) Die Naturwissenschaftlichen Grundlagen der allgemeinen Bodenkunde, P. 245.

Date. (noon—noon)	Weather.	Evaporation of water from ordinary water surface. (m.m).	Evaporation of water from one batch (= 15 plants) of rice. (litre)
4. July — 6. July.	Cloudy and a little rain.	7.2	0.167
6. ,, — 8. ,,	Clear and cloudy.	7.7	0.306
8. ,, —10. ,,	Clear.	10.1	0.299
10. ,, —12. ,,	,,	14.3	0.380
12. ,, —14. ,,	,,	14.6	0.638
14. ,, —16. ,,	,,	14.2	0.620
16. ,, —18. ,,	Cloudy and a little rain.	12.3	0.752
18. ,, —20. ,,	,, ,, ,, ,, ,,	9.1	0.451
20. ,, —23. ,,	Clear except a little rain.	15.5	0.769
23. ,, —25. ,,	Clear.	12.2	0.710
25. ,, —27. ,,	Clear except a little rain.	9.5	0.829
27. ,, —29. ,,	Clear.	12.4	0.818
29. ,, —31. ,,	Cloudy and a little rain.	10.0	0.628
31. ,, — 2. August.	Clear.	10.4	0.715
2. August.— 4. ,,	Cloudy and rainy.	6.6	1.087
4. ,, — 6. ,,	Clear.	13.5	0.402
6. ,, — 8. ,,	,,	14.8	1.211
8. ,, —10. ,,	,,	14.3	1.336
10. ,, —13. ,,	,,	20.2	2.048
13. ,, —15. ,,	Cloudy and rainy.	12.3	0.679
15. ,, —17. ,,	,, ,, ,,	6.1	0.406
17. ,, — 19. ,,	Cloudy and stormy.	13.2	0.555
19. ,, — 21. ,,	Cloudy and rainy.	4.3	0.969
21. ,, — 23. ,,	Cloudy and a little rain.	8.3	1.087
23. ,, — 25. ,,	Fine.	11.4	1.374
25. ,, —27. ,,	Cloudy and a little rain.	6.1	0.941
27. ,, —29. ,,	Cloudy and rainy.	4.2	0.745
29. ,, —31. ,,	Clear except a little rain.	8.3	1.169

Date. (noon—noon)	Weather.	Evaporation of water from ordinary water surface. (m. m.)	Evaporation of water from one batch (=15 plants) of rice. (litre)
31. Aug. — 2. Sept.	Clear except one single shower.	8.2	0.770
2. Sept. — 4. ,,	Clear, strong wind and a little rain.	12.4	1.059
4. ,, — 6. Sept.	Clear.	11.2	1.120
6. ,, — 8. ,,	,,	11.7	1.395
,, —10. ,,	Clear, often a little rain.	11.6	1.066
10. ,, —12. ,,	,, ,, ,, ,, ,,	12.5	0.754
12. ,, —14. ,,	Fine.	11.8	0.853
14. ,, —16. ,,	Cloudy.	6.6	0.972
16. ,, —18. ,,	Cloudy and rainy.	4.4	0.880
18. ,, —20. ,,	Cloudy and a little rain.	5.0	0.576
20. ,, —22. ,,	Cloudy and rainy.	1.2	0.434
22. ,, —25. ,,	,, ,, ,,	3.6	0.548
25. ,, —27. ,,	,, ,, ,,	1.5	0.490
27. ,, —29. ,,	Cloudy.	5.1	0.698
29. ,, — 2. October.	Rainy.	4.4	0.893
2. Oct. — 4. ,,	Cloudy and rainy.	2.9	0.590
4. ,, — 7. ,,	Rainy and fine.	5.8	0.518
7. ,, — 9. ,,	Clear.	6.0	0.511
9. ,, —11. ,,	,,	5.3	0.494
11. ,, —13. ,,	Cloudy and a little rain.	2.7	0.110
13. ,, —16. ,,	Cloudy and rainy.	3.1	0.143
16. ,, —18. ,,	,, ,, ,,	3.8	0.121
18. ,, —20. ,,	Cloudy and a little rain.	7.4	0.081
Sum (124 days).....		533.6	37.677

As 135,000. batches of rice are commonly planted on 1 ha in Japan, and as each batch covers, during its main vegetation period, the space of about 16 sq. cm. on an average, we see from the above table that in 1 ha of rice field daily about 41 cb. m. of water eva-

porates from the plant itself, and 42 cb. m. from the surface of the water in which the rice is cultivated.

To obtain the actual quantity of water necessary for rice-culture, we must, however, take the filtration water into consideration. It is said that 50 cb. m. of water per day, is commonly lost per ha in this way, so that we have, by adding 50,

$$41+42+50=133. \text{ cb. m. per day, per ha.}$$

$$\text{or } 1.539 \text{ litre per ha, per second.}$$

But as a matter of fact all this quantity of water is not needed for irrigation, because there is a supply of rain, which according to the observations of the Central Signal Office in Tokyo, amounts on the average of 18 years, to 0.582 litre per ha, per second during the main vegetation period of rice. Deducting this quantity from the above figure we have as remainder the necessary quantity for irrigation :

$$1.539-0.582=0.957 \text{ litre per ha, per second.}$$

I have studied the subject also practically in connection with irrigation water in Iwashiro district which I have personally inspected. There the water is supplied from Lake Inawashiro through a large canal which divides itself into 8 during its course. The quantity of water that passes through each of these branches and the area of the rice fields irrigated by it is shown in the following table :

Branch of Canal.	Area of irrigated field. ha.	Water passing through per second, in litres.
1st Branch.	713.658	704.536
2nd ,,	992.927	932.688
3rd ,,	341.712	276.601
4th ,,	251.141	293.077
5th ,,	1579.701	1884.364
6th ,,	133.492	99.165
7th ,,	170.208	181.581
8th ,,	252.855	366.002
Sum.	4435 689	4738.014

From these figures we see that the quantity of water required for rice culture is :

max.	min.	average.	
1.447	0.743	1.068	litre per ha, per second.

Hence I conclude that the consumption of water in rice fields is smaller here in Japan than in Italy, where, according to Cav. Patriarca,[1] the following quantities are required for irrigation :

On very heavy soil	2.081 litre per ha, per second
On heavy soil	2.398 ,, ,, ,, ,, ,,
On mean soil	3.486 ,, ,, ,, ,, ,,
On light soil	4.773 ,, ,, ,, ,, ,,
mean	2.637 litre per ha, per second.

This difference in the two countries is mostly due to the difference of climate, especially of moisture in the air. I can not say at present that the transpiration from rice plants is much affected by climate, but the evaporation from the water surface must vary, of course, with the hygroscopic conditions of air. In Japan the air in summer is very richly loaded with the moisture (76—94 % on an average during summer) carried hither by the S. and S.W. monsoon from the Pacific Ocean. In Italy the case is quite different. There prevails in summer a S. wind, which is naturally very dry, coming as it does from the hot continent of Africa over the Mediterranean Sea. Moreover, the wet wind coming from the north is entirely intercepted by the Alps, and the moisture is mostly condensed, leaving only a moderate quantity to pass over the peninsula during summer (dampness being 52—69 %).

The moist condition of the air in Japan leads me to believe that this country is favorable to the cultivation of the plant, because the vapor in the atmosphere not only diminishes the loss of the water of irrigation, and gives us a natural advantage but also gives off its heat of condensation to the soil at night and thus protects the plant from the injurious effect of nocturnal cooling. The temperature is, however, (relatively) lower in Japan than in Italy, being influenced by that of the neighboring Asiatic continent. Why the rice, despite of this, can be cultivated so far north as 43°, where the mean temperature in summer is only 18.5° C, is explained by three reasons, viz :—

(1) Severe cooling at night is avoided by the heat of condensation of atmospheric vapor.

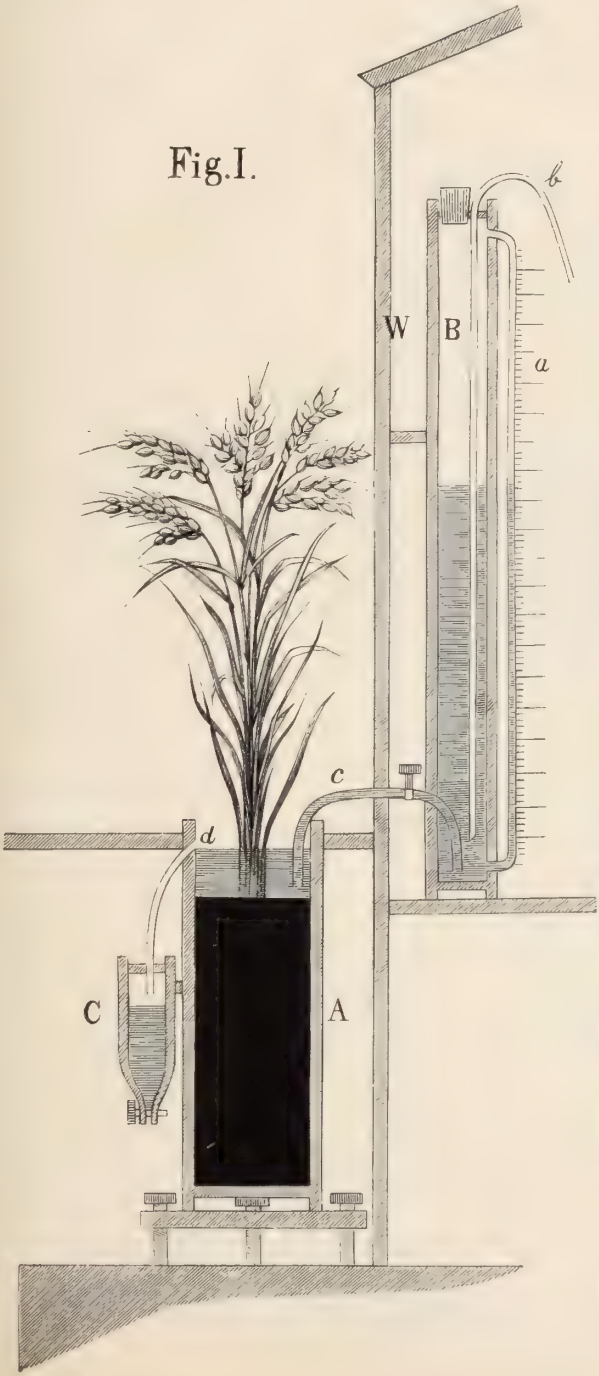
(1) Vergl. Markus, d. landw. Meliorationswesen 1881. S. 59

(2) The constant gain of heat by condensation on the part of the soil.

(3) The comparatively small loss of heat from evaporation due to the wet condition of the air.

It is for these reasons that such a tropical plant as rice has a relatively wide distribution in Japan, and forms the staple product of the country.

Fig. I.



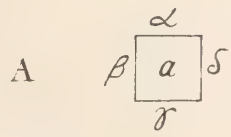


Fig. III.

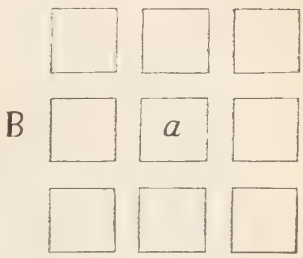
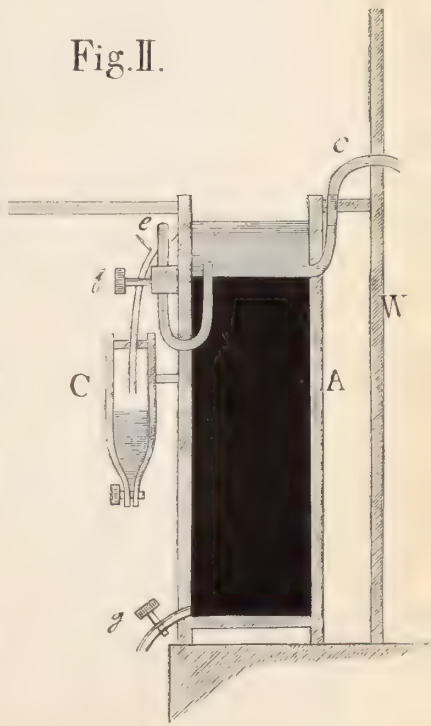


Fig. II.



On the Number of Rice Shoots.

BY

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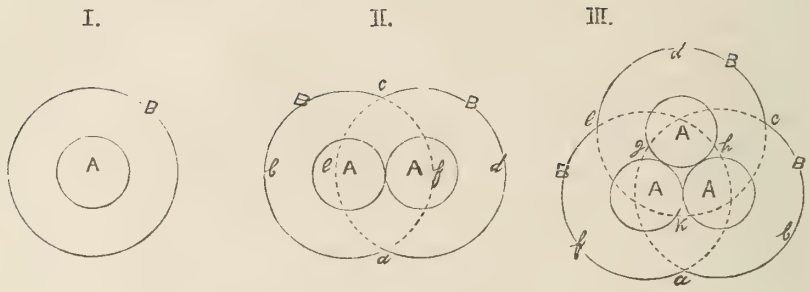
The number of shoots that spring from a single rice seedling varies greatly according to varieties :— thus with Shinriki 10—25 are the commonest numbers, while with Shiratama they are only 5—12. The number also depends to a great extent, on climate, soil, manure, the temperature of the water with which the fields are irrigated, the mode of cultivation, etc. The number of the seedlings planted together in a batch has also, without doubt, an important effect upon the number of shoots produced by each. For example the experiments made with "Shiratama" by the Tōkyō Agricultural Station gave on the average of 12 trials, the following results :—

from a single isolated seedling.....				11.3	shoots
,,	2 seedlings planted together... . .			12.8	,,
,,	3	,,	,,	,,	14.2	,,
,,	5	,,	,,	,,	16.5	,,
,,	8	,,	,,	,,	19.4	,,
,,	10	,,	,,	,,	20.7	,,

Although these figures show a gradual increase in the number of shoots, yet the increase is not proportionate to the number of seedlings planted. There is seen, on the contrary, rather a relative diminution in the number of shoots with the increased number of seedlings contained in a batch. This relative diminution must arise from the inefficiency of the assimilation process, since the more seeds a single batch contains the greater must be the deficiency of manure, air, and light for a single seed. On these data, I propose to develop a method of calculating the number of shoots that grow from a given number of seedlings planted in a batch.



Suppose, in the above diagrams, that the small circle (A) is the plot of land occupied by one seedling, and that the large concentric circle (B) denotes the cross section of the imaginary cylinder, the surface of which is equal to the actual surface of assimilation in the plant. In the case of figure I, we may suppose, that assimilation takes place at every point in the circumference of the circle (B), while in figure II or III, where 2 or 3 seedlings are planted together, assimilation can take place only in the arcs (a b c) and (c d a) or (a b c) (c d e) and (e f a), respectively, and not in the other arcs of the circles such as (a e c) and (c f a) or (a g c), (c k e) and (e h a), where air and light, are entirely cut off by the outer arcs.

As every new particle in the body of a plant is always produced by assimilation, the number of shoots that spring from a seedling must necessarily be proportional to its surface area of assimilation, thus :—

$$\overbrace{\begin{pmatrix}\text{from 1 seedling}\\ \text{planted single}\end{pmatrix} : \begin{pmatrix}\text{from 2 seedlings}\\ \text{planted together}\end{pmatrix} : \begin{pmatrix}\text{from 3 seedlings}\\ \text{planted together}\end{pmatrix}}^{\text{The number of shoots sent forth}} : \&c.$$

$$= \begin{pmatrix}\text{figure I,}\\ \text{circle B}\end{pmatrix} : \begin{pmatrix}\text{figure II, arcs}\\ \text{a b c+c d a}\end{pmatrix} : \begin{pmatrix}\text{figure III, arcs}\\ \text{a b c+c d e+e f a}\end{pmatrix} : \&c.$$

Taking the circumference of the circle (B) as 1, the corresponding length of the arcs (a b c+c d a), (a b c+c d e+e f a), etc, are as follows :

The assimilation surface of one seedling planted single....	1.
The assimilation surface of 2 seedlings planted together.	2–2C
,, ,, ,, ,, 3 ,, ,, ,,	2.5–3C
,, ,, ,, ,, 4 ,, ,, ,,	3.0–4C
,, ,, ,, ,, 5 ,, ,, ,,	3.5–5C
,, ,, ,, ,, 6 ,, ,, ,,	4.0–6C

,,	,,	,,	,, 7	,,	,,	,,	4.0–6C
,,	,,	,,	,, 8	,,	,,	,,	4.5–7C
,,	,,	,,	,, 9	,,	,,	,,	5.0–8C
,,	,,	,,	,,10	,,	,,	,,	5.0–8C
,,	,,	,,	,,&c.	,,	,,	,,	&c.

Now we can easily calculate the number of shoots that spring from a given number of seedlings planted together, by multiplying the number of shoots produced from one isolated seedling by the sum of the corresponding arcs. The factor (C) is equal to $\frac{\text{arc, cos. } \frac{r}{R}}{\pi}$, in which r denotes the radius of the small circle (A), and (R) that of the larger one (B). Its numerical value must, of course, vary according to the kind of rice, climate, soil, manure, etc., and is found out by experiments carried on, on the same ground, after the same method. If, for instance, 11 shoots are produced from a single isolated seedling, and 20 shoots from 10 seedlings planted together, the value of the factor can be calculated from the equation,

$$\frac{1}{5-8C} = \frac{11}{20}$$

I here quote the number of shoots calculated in accordance with the principle above explained, and the number actually observed at the Tōkyō Agricultural Station during the years 1892 and 1893; and a comparision of the two will enable us to form an estimate of the value of the theory above enunciated.

Name of Rice.	Homura.			Zaruya.			Ōtsubu.			Shiratama.		
Number of seedlings in a batch.	Number of shoots			Number of shoots			Number of shoots			Number of shoots		
	observed.	calc'd.	diff.	observed.	calc'd.	diff.	observed.	calc'd.	diff.	observed.	calc'd.	diff.
1	9.8	9.8	0	13.8	13.8	0	11.7	11.7	0	11.3	11.3	0
2	11.2	11.3	+0.1	15.5	15.5	0	14.7	14.4	−0.3	12.8	13.6	+0.8
3	13.0	12.1	−0.9	18.2	16.3	−1.9	16.3	15.7	−0.6	14.2	14.8	+0.6
4	12.3	12.9	+0.6	16.3	17.2	+0.9	17.8	17.1	−0.7	—	16.0	—
5	13.0	13.6	+0.6	17.8	18.0	+0.2	17.0	18.4	+1.4	16.5	17.2	+0.7
6	14.0	14.4	+0.4	18.2	18.9	+0.7	18.2	19.8	+1.6	—	18.4	—
7	13.8	14.4	+0.6	17.9	18.9	+1.9	20.3	19.8	−0.5	—	18.4	—
8	15.2	15.2	0	19.7	19.7	0	21.7	21.1	−0.6	19.4	19.5	+0.1
9	15.7	15.9	+0.2	23.2	20.5	−2.7	22.2	22.5	+0.3	—	20.7	—
10	15.9	15.9	0	20.5	20.5	0	22.5	22.5	0	20.7	20.7	0
Value of factor C.	0.422			0.439			0.385			0.396		

Name of Rice.	Shina.			Kyō.			Yōrō.		
Number of seedlings in a batch.	Number of shoots			Number of shoots			Number of shoots		
	observed.	calc'd.	diff.	observed.	calc'd.	diff.	observed.	calc'd.	diff.
1	16.9	16.9	0	11.1	11.1	0	14.0	14.0	0
2	20.5	20.4	−0.1	11.8	13.4	+1.6	14.8	16.1	+1.3
3	23.4	22.1	−1.3	13.8	14.5	+0.7	15.3	17.1	+1.8
4	—	23.9	—	—	15.6	—	—	18.1	—
5	25.9	25.6	−0.3	14.4	16.8	+2.4	19.0	19.2	+0.2
6	—	27.3	—	—	17.9	—	—	20.2	—
7	—	27.3	—	—	17.9	—	—	20.2	—
8	27.7	29.1	+1.4	18.4	19.0	+0.6	22.0	21.3	−0.7
9	—	30.8	—	—	20.2	—	—	22.3	—
10	30.8	30.8	0	20.2	20.2	0	22.3	22.3	0
Value of factor C.	0.397			0.398			0.426		

A glance at this table shows at once how close the coincidence between the numbers observed and calculated is. It must, however, be remarked that the increase in the number of shoots with the increase of seedlings contained in a batch, is subject to a certain limit, beyond which there is no increase. This is not to be wondered at, when we bear in mind the limitation of manure on which the plant chiefly depends, in opposition to the ample supply of air and light. This law of constancy is also clear from the experiments made at the Tōkyō Agricultural Station, tabulated below :

Name of Rice.	Tsurugi.			Saikoku.			Ōmi.			Sawada.		
Number of seedlings in a batch.	Number of shoots			Number of shoots			Number of shoots			Number of shoots		
	observed.	calc'd.	diff.	observed.	calc'd.	diff.	observed.	calc'd.	diff.	observed.	calc'd.	diff.
1	16.3	16.3	0	20.8	20.8	0	29.0	26.5	−2.5	20.3	20.5	+0.2
2	18.5	19.9	+1.4	24.8	24.8	0	27.3	26.5	−0.8	19.8	20.5	+0.7
3	21.7	21.7	0	26.8	26.2	−0.6	24.0	26.5	+2.5	19.3	20.5	+1.2
4	25.0	23.5	−1.5	26.0	26.2	+0.2	21.3	26.5	+5.2	—	20.5	—
5	25.5	25.2	−0.3	25.0	26.2	+1.2	25.8	26.5	+0.7	22.3	20.5	−1.8
6	24.8	25.2	+0.4	26.3	26.2	−0.1	27.8	26.5	−1.3	—	20.5	—
7	26.2	25.2	−1.0	23.8	26.2	+2.4	29.3	26.5	−2.8	—	20.5	—
8	22.7	25.2	+2.5	26.0	26.2	+0.2	25.8	26.5	+0.7	21.9	20.5	−1.4
9	26.7	25.2	−1.5	27.8	26.2	−1.6	26.3	26.5	+0.2	—	20.5	—
10	25.5	25.2	−0.3	27.5	26.2	−1.3	28.0	26.5	−1.5	19.3	20.5	+1.2
value of factor C.	0.300			0.404			—			—		

Thus far I have reasoned on the assumption that the number of shoots produced from a certain number of seedlings of a certain kind of rice planted in a certain soil under similar conditions and treatment is constant. There remains, however, one fact, which is rather of high importance, viz :—

The shoots produced from seedlings obtained from a large ear grown on the main shoot of the mother plant, are always fewer than those produced from seedlings from smaller ears on the side shoots of the same plant. This fact, I observed from the experiment made by me at Komaba in 1893, the method of which will be described in a paper entitled "On the Selection of Seeds." I here quote only the result of the experiment :—

Number of shoots produced.					
From 10 seedlings planted together.				From 1 seedling planted single.	
On a sufficiently manured field. (Average of 16 trials).		On an unmanured field. (Average of 16 trials).		On an unmanured field. (Average of 8 trials).	
Using the seed taken from large ear 1)	Using the seed taken from small ear 2)	Using the seed taken from large ear 1)	Using the seed taken from small ear 2)	Using the seed taken from large ear 1)	Using the seed taken from small ear 2)
17.67	21.75	13.44	14.50	4.25	5.25

1) Average total weight of the seeds taken from one large ear =2.381 gr.

2) Average total weight of the seeds taken from one small ear =0.765 gr.

On "The Saltwater Selection" Method of Seeds.

BY

T. Yokoi. *Nōgakushi.*

Professor of Agriculture.

A method of selecting seeds by specific gravity has been long in use in Japan and China. In China a famous author[1] already speaks of the so-called "water selection" method. It is stated that those seeds that float on water are of a poor quality and should be rejected. In Japan, an unknown author of an unknown date but who is supposed to have written in the period of Genroku (1688—1703) mentions the same method of selection and even goes into the details of the operation with special reference to rice seed and states furthermore that it is the method said to have been followed from olden times. Thus inasmuch as its details were known, it may fairly be concluded that the method was of a much remoter origin. Indeed, it is not without reason to suppose that when Roman farmers steeped their seeds in various solutions and extracts, and when farmers of Asiatic countries[2] steeped their rice seeds in water, they threw off the light and immature seeds floating on the surface of the liquid. But this kind of selection which is without an aim, is called by Darwin "unconscious selection" and differs from those methods of selection which are now so widely in use in civilized countries,—systematic selection.

Whether the quality of seeds has any relation with their specific gravity or not is a question which has been much discussed of late.

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(1) Nung-ching-ts'iuen-shú, first published in 1639.

(2) An erroneous but unfortunately often quoted statement of S. Julien as to a ceremony said to be established by the Emperor Chin-nung in which the sowing of five kinds of grains is the chief observance must be here pointed out. This statement even led De Candolle to conclude that rice is probably the native of China. The ceremony established by the Emperor was certainly not of this kind. Indeed in the so-called five grains (hemp[?]), common and glutinous millets, barley and soy bean) the sownig of which was established as a ceremony in a much later time than Chin-nung, rice was not included. According to a reliable Chinese authority, rice was excluded from the "five grains" in remote ages and only in later periods it was included, because men of literature in ancient China mostly lived in the northern provinces where rice was then not cultivated. In my opinion, rice is probably not indigenous to China.

From the existing literature on the subject, it may be concluded that the quantity of nutriment contained in a seed has no intimate relation to its specific gravity. So far as specific gravity of the constituents of seed alone is concerned, it is not without reason to infer that those seeds which are rich in mineral matter have a higher specific gravity; that those rich in starch have a higher specific gravity than those rich in albuminoids and those rich in oil lighter than those rich in albuminoids. But there is still another constituent or rather accidental ingredient having a much lower specific gravity than even oil, viz. free air. The specific gravities of the various constituents of seeds may be seen from the following table[3]:—

Starch	1.479–1.630	Resin	0.93–1.220
Palm starch	1.450	Fat	0.892–0.999
Cellulose	1.25–1.45	Etherial oils	0.740–1.140
*Lignose	1.460–1.534	Extractive matter	about 1.300
Plant mucilage	1.300–1.600	Ash constituents	about 2.5
Cane sugar	1.404–1.606	Atmospheric air	0.001293
Gluten of wheat pulv	1.297	Carbonic acid	0.001978
Gluten air dried	1.036	Nitrogen	0.001267
Legumin pulv	1.360	Oxygen	0.001432
Legumin, compact	1.285	Water	1.00
Wax	0.941–0.999		

As there is no seed which does not contain more or less free air, and as the quantity of air contained must be variable with the number and size of the cavities and spaces within, the quantity of air contained must be, within certain limits, the principal or the most influential factor in determining the specific gravity of seeds. Thus it naturally follows that seed containing larger quantity of starch may be lower in specific gravity than one rich in albuminoids, as can be seen in the case of "mealy" and "glassy" sorts of cereals. Indeed when we carefully examine the tables of analysis we see that the relation between the percentage of the various constituents and the specific gravity of a seed is rather irregular, and even with seeds having almost the same weight the one containing more nutriments is not necessarily the one having a greater specific gravity; nor do those having a higher specific gravity necessarily contain more mineral matter and less nutriment.

(3) Harz, Landwirth. Samenkunde pp. 243 Vol. I, 1885, Berlin.

* According to Rumford the lower figure here given represents the specific gravity of the oak, and the higher, that of the maple.

There is still another question which has not yet been investigated, and to which no author has yet given an answer;—in what ratio should the various constituents, mineral matter, albuminoids, carbohydrates, be contained in the best seed? Or is there no rule as to their relative quantities to determine the quality of a seed? At least within certain limit, there must certainly be some rule in this matter, and I am inclined to think that here also that "Law of minimum" holds true. As this important question has not yet been answered—nor likely that it could be answered easily—the question of the quality of seed can be answered safely only by direct experiments.

Many investigations have been made on the quality of seeds in relation to their specific gravity. The experiments of F. Haberlandt, Church, C. Trommer, H. Haberlandt, Th. Dietrich and many others besides myself have all given similar results and have gone to prove that those seeds which have a higher specific gravity are more productive. These experimenters, however, have all fallen into the same mistake, viz. that of sorting their seeds according to their specific gravity regardless of their weight,—a mistake which has detracted much from the value of their experiments and has entailed unreliable results for ascertaining the quality of seeds.

It seems that H. Hellriegel was the first who found out this mistake and renewed his experiment, the results of which are given in his "Beiträge zu den naturwissenschaftlichen Grundlagen des Ackerbaus." From his results, it may be seen that specific gravity by itself, when seeds of similar weight be selected according to their specific gravity, has no regular relation with the quantity of produce obtained with the seeds. Similar results have been obtained by E. Wollny conducted on a larger scale in the field.[4]

Experiments were conducted in 1894 by H. Ando, a student of our College. He selected barley seeds of similar specific gravity with a solution of sodium bromide, and from the selected seeds, he took 14 grains all of nearly the same weight. They were sown in Wagner's cylinder, filled with garden loam, 7 grains in each cylinder making 4 series in all and ascertained the length of the stalks and leaves developed in a week. The result was as follows:—

(4) Saat und Pflege der landwirth Kulturpflanzen. Berlin 1885.

TABLE I.

BARLEY ; SORT, GOLDEN MELON Sp. gr. 1.255.

Weight of one grain.	Length of stalks and leaves, average of 14 plants in m. m.			
m. gr.	1st day of sprouting.	2nd day.	3rd day.	4th day.
Over 55	26.65	40.00	51.55	69.60
45—50	19.25	34.65	43.35	58.35
35—40	19.25	30.20	40.85	51.75
Below 30	17.60	26.43	37.40	42.10

When seeds of different specific gravities but of the same weight were selected from the same sample, the result was as follows, the weight of a seed being 52.5 milligrams :—

TABLE II.

	Length of stalks and leaves, average of 14 plants in m. m.			
Sp. gr.	1st day of sprouting.	2nd day.	3rd day.	4th day.
Over 1.30 *	23.30	35.45	47.80	65.40
1.255	25.25	33.65	43.35	57.50
1.205	21.25	31.55	42.30	55.70
1.155	21.05	31.60	40.30	55.85

He again experimented in 1895 with barley and naked barley by letting the seeds germinate in Liebenberg's germination apparatus. Observations made two weeks after germination gave the following results :—

* Weight of a seed used in this case was over 55 mg. as grains of less weight could not be obtained.

TABLE III.

NAKED BARLEY ; SORT, JŌSHŪ-HADAKA.

Sp. gr.	Weight of a grain. m gr.	No. of plants.	Length of leaves and stalks av. m. m.	Width of leaves av. m. m.	Total length of roots of one plant av.m.m.	No. of roots of one plant av.	Weight of produce av. of one plant.		
							green.	dried at 100° C. 6 hours.	
								With chaff.	Without chaff.
1.375	28—32	5	11.4	6.8	191.8	4.0	167.5	18.2	14.8
	26—28	6	112.2	6.2	197.0	3.9	166.0	17.2	14.1
	20—28	6	96.7	6.0	163.8	3.5	121.0	13.4	11.2
	Below 20	7	85.4	5.6	163.1	3.3	108.6	12.2	9.9
1.365	24—28	10	109.6	6.1	181.0	3.9	154.1	16.9	13.7
	20—24	8	89.9	6.0	145.8	3.5	114.6	13.1	11.1
	Below 20	10	90.1	5.5	159.2	3.7	108.2	10.9	8.8

BARLEY ; SORT, GOLDEN-MELON.

Sp. gr.	Weight of a grain. m. gr.	No. of plants.	Length of leaves and stalks av. m. m.	Width of leaves av. m. m.	Total length of roots of one plant. av.m.m.	No. of roots of one plant av.	Weight of produce of one plant av.		
							green.	Dried at 100 °C. 6 hours.	
								With chaff.	Without chaff.
1.255	Over 55	7	178.6	6.4	260.0	5.9	298.6	37.4	25.5
	45- 50	10	146.8	5.5	247.8	5.5	198.3	25.6	16.7
1.205	Over 55	9	178.9	6.3	271.1	6.4	304.4	36.9	24.7
	45—50	7	142.8	5.4	248.1	6.9	238.8	33.4	18.6
	35—40	7	171.1	5.0	289.6	6.3	210.0	21.6	16.2

From this it may be seen that the absolute weight of a seed has an intimate relation with its productive power but the latter has almost no relation with its specific gravity. Moreover, the results above recorded confirm those obtained by Hellriegel, Wollny and other experimenters.

But then the question naturally arises, why do the results of those experimenters who took the specific gravity of a seed as the sole standard regardless of its weight all or almost all without exception, agree? In 1882 I tried to use a solution of common salt, which can be obtained cheap anywhere in our country, as the medium for the selection of rice seeds and got good results. I have named the method the "salt water (or rather salt solution, strictly speaking) selection" method.[5] Thereafter the method has been tried with good results and applied to various seeds, being now widely used especially for rice in our country. The results I obtained in Chikuzen, where I first tried it may be summed up as follows, the aim of the experiments having been to know the comparative merits of the method in question and the "water selection" method :—

TABLE IV.

COMPARATIVE RESULTS OF THE "SALT WATER" AND THE "WATER SELECTION."[6]

Method of selection.	Paddy per tan, koku.	Weight of paddy per koku, kwan.	Husked rice per tan, koku.	Weight of rice per koku, kwan.	Straw per tan. kwan.	Length of straw, shaku.
"Salt water"	5.571	26.36	2.615	40.81	101.165	3.81
"Water"	4.999	25.80	2.403	40.02	99.455	3.74
Extra produce of the former.	0.572	0.56	0.212	0.79	1.710	0.07

According to this table, the produce obtained with the "salt water selection" in the form of paddy or unhusked rice was 146.850 *kwamme*, which when husked gave 100.710 *kwamme* while with the "water selection" the paddy weighed 128.970 *kwamme*, which when husked gave 96.170 *kwamme*—thus giving a result in favour of the former.

Practically the method is carried on in the following manner. A certain weighed quantity of common salt of impure sort is put into a large wooden tub with water, and the water is then stirred to

(5) Wolffenstein used already in 1877 specific gravity for the selection of seeds though with a quite different aim. His work was, however, not known to me at that time. See Anleitung zur Getreidezüchtung by Dr. K. Rümker, Berlin 1889.

(6) Fesca, Beiträge zur Kenntniss der Japanischen Landwirthschaft, Sp. Th. Tokio 1892.

hasten the dissolution of salt and when the salt is comparatively dissolved, the seeds that are to be selected are put into the solution, well stirred and the imperfect grains floating on the surface of the solution are quickly scooped off, the solution is again stirred to make those imperfect grains which have subsided with good grains to float and the floating grains are again scooped off, the operation being repeated until no grain is left floating. When this is over, the seed is transferred on to a "zaru," a shallow bell with a rounded bottom made of bamboo strips with irregular meshes—placed on a tub and the solution is filtered off into the tub to be again used for the same purpose.

The strength of the solution used should of course be different with the kind of seed and even with the same sort, the specific gravity of the seed differing more or less with locality, the kind of weather when harvested, with the methods of cultivation and so forth; and the strength of the solution must therefore be accommodated to each particular case. Practically the right strength of a solution is tested in the following manner:—A small quantity of seed is put into the solution and when nearly all the grains show an inclination to float up—which in the case of cereals can be known from the grains standing up in an oblique position, as the centre of specific gravity is excentric and lies nearer one extremity than another—the strength of the solution in question may be decided as fitted for the purpose.

The proportions of salt and water we have hitherto used are stated below. These must of course be greatly varied especially with different sorts of seeds; for example, with some sorts of barley seed the strength of the solution is to be similar to that for wheat. The figures given are about the number of grams of salt to a litre of water.

Rice	208–312
Barley	208–396 (or *nigari*)
Italian millet	167–208
Buckwheat	187–229
Rape	104–208
Tsukena (a kind of Chinese cabbages.)	104–250
Radish	83–124
Turnip	124-208

For naked barley and wheat and also for some sorts of barley for example some European sorts, a good *nigari*,—a name given to the mother liquor of, or drippings from impure, common salt, with

the specific gravity varying from 1.200 to 1.280—is used. According to my experiment made some years ago the specific gravity of *nigari* varies with the number of days passed after it has been produced, a new one having a higher specific gravity than old one with a dark colour and dirty sediments. This is probably due to the fact that during standing the salt in solution gradually crystallises out on the bottom of the containing vessel. Thus when a liquor with a high specific gravity is required a good new *nigari* is preferred, as for naked barley and wheat. The reason why I have tried to use these instead of various salts which are obtainable from the apothecary and which could easily be managed to get any required specific gravity is simply that the latter are generally too costly for general use by small peasants. Our farmers have already learned and tried the method and it is now widely practiced especially for rice seeds either common salt solution or *nigari* diluted with water being used for the purpose.

Now the question is why does the "specific gravity method" of selection give generally such good result? Why did those experimenters who selected the grains by their specific gravity regardless of their weight give also good results when specific gravity is not a measure of the quality of seed? This question has now to be answered, and the main object of our experiments has been to solve this important question.

Certainly it is one thing to be used as a standard for the valuation of quality, and another to be used as a medium of selection. As a measure of quality, specific gravity is surely not to be relied upon as scientifically accurate; but as a medium for selection, it can be used as sufficiently accurate for practical purposes though not scientifically so. And our experiments tend to show that at least for some cereals "specific gravity method of selection" can be applied with sufficient accuracy.

As absolute weight has been clearly shown to be a sufficiently correct measure of the quality of a seed, and as the quality of a seed improves with the increase of its weight, the object of our experiments has been first to find out whether the specific gravity has any or no relation with the absolute weight of a seed.

According to Schertler[7] the specific gravity of a seed increases with its size except in the case of abnormally large grains, which

(7) Schertler, die Anwendung des specifischen Gewichtes als Mittel zur Werthbestimmung der Kartoffeln, Cerealien und Hülsenfrüchte sowie des Saatgetreides, Wien 1873.

have less specific gravity than middle sized ones. On the other hand, according to the results obtained by Marek[8] and others, it seems that smaller grains have a greater specific gravity than larger grains, but not very regularly.

Ando's results obtained in 1895 tend to show that with some seeds their absolute weight does increase with their specific gravity. He separated the seed of various crops according to their absolute weights, and then determined their specific gravities by means of the pycrometer with alcohol.

Kind of Crops.	Weight of a grain. mgr.	No. of grains.	Weight of total grains. mgr.	Average weight of a grain. mgr.	Sp. gr.
Rice ; sort, *Skiratama.*	Over 32	50	1649.6	32.99	1.2241
	28—32	50	1521.0	30.42	1.2151
	24—28	50	1325.8	26.52	1.1812
	20—24	50	1110.2	22.20	1.1201
	Below 20	50	847.4	16,95	0.9912
Barley ; sort, Golden melon.	Over 60	50	3176.2	63.52	1.2932
	55—60	50	2886 0	57.52	1.2851
	50—55	50	2661.8	53.24	1.2603
	45—50	50	2425.2	48.50	1.2644
	40—45	50	2149.6	42.99	1.2573
	35—40	50	1886.4	37.73	1.2300
	30—35	50	1642.2	32.84	1.2418
	Below 30	50	1286.4	25.73	1.1993
Barley ; sort, *Hozoroi.*	Over 45	30	1457.0	48.57	1.2856
	40—45	30	1289 4	42.98	1.2658
	35—40	30	1140.8	38.03	1.2762
	30—35	30	1018.2	33.94	1.2520
	Below 30	30	781.6	36.05	1.2375

(8) Marek, Das Saatgut und dessen Einfluss auf Menge und Güte der Ernte, Wien 1875.

Kind of Crops.	Weight of a grain. mgr.	No. of grains.	Weight of total grains. mgr.	Average Weight of a grain. mgr.	Sp. gr.
Naked barley ; sort, *Jōshū-awo.*	Over 32	50	1697.5	33.92	1.3572
	28—32	50	1517.2	30.34	1.3767
	24—28	50	1369.0	27.38	1.3686
	20—24	50	1131.0	22.62	1.3458
	Below 20	50	844.0	16.88	1.3097
Naked barley ; sort, *Hōnen.*	Over 35	50	1862.5	37.31	1.3578
	32—35	50	1660.8	33.22	1.3874
	28—32	50	1499.4	29.98	1.3830
	24—28	50	1319.2	26.38	1.3608
	20—24	50	1127.6	22.55	1.3608
	Below 20	50	998.8	19.98	1.2778
Wheat ; sort, Fultz.	Over 50	20	1049.2	52.86	1.3603
	45—50	20	954.4	47.72	1.3551
	40—45	20	852.0	42.60	1.3673
	35—40	20	771.6	38.58	1.3550
	30—35	20	654.8	32.73	1.3489
	Below 30	20	536.4	26.82	1.3509
Wheat ; sort, *Kyūshū.*	Over 33	20	691.6	34.58	1.3378
	30—33	20	643.6	32.18	1.3109
	25—30	20	566.4	28.32	1.3124
	20—25	20	446.6	22.32	1.3404
	Below 20	20	318.6	15.93	1.3349

When we examine the above table, it may be seen that with rice and barley, both of which have light and porous husks, their specific gravities vary with their weights very regularly, with a few exceptional cases.

On the other hand in the case of wheat and naked barley both destitute of any husk their specific gravities do not show a regular relation with the weights as in the case of rice and barley.

These facts naturally suggest that light and porous husk has a great influence upon the relation of weight and specific gravity. The husk of rice and barley is formed before the development of seed and the development of seed has little influence upon that of the husk; and the weight of the latter must have great influence upon the specific gravity of the grain. There must be a great difference in their specific gravity, according as the seed is well developed and fills the inside of the husk, or is little developed and lies loosely within the husk. As the husk is light and porous enclosing within it a large quantity of air, its specific gravity is very small—smaller than that of water—and if it be comparatively well developed it will naturally decrease the specific gravity of a grain. Moreover when the space between the husk and the seed be wide apart and encloses a large quantity of air it will lessen the specific gravity of the whole. If this be so, it is no wonder that in the case of rice and barley, grains which are covered with light and porous husks, their specific gravities should have a regular relation to their weight. The results obtained by Ando on the absolute and percentage weight of the husk are shown in the following table, the specimens examined being in each case those used for the determination of their specific gravities:—

RICE; SORT, SHIRATAMA.

Weight of a grain. mgr.	Weight of 50 grains. mgr.	Sp. gr.	Weight of husk. mgr.	Per cent of husk.
Over 32	1649.6	1.2241	272.7	16.53
28—32	1521.0	1.2151	247.5	16.93
24—28	1325.8	1.1811	225.8	17.03
20—24	1110.2	1.1203	200.7	18.08
Below 20	847.4	0.9912	176.1	20.78

BARLEY ; SORT, HOZOROI.

Weight of a grain. mgr.	Weight of 30 grains. mgr.	Sp. gr.	Weight of husk. mgr.	Per cent of husk.
Over 45	1457.0	1.2856	130.5	8.92
40—45	1289.4	1.2658	134.7	10.45
35—45	1140.8	1.2762	123.6	10.83
30—35	1018.2	1.2520	122.7	12.05
Below 30	781.6	1.2375	115.6	14.79

From these tables it is obvious that the percentage of husk has more or less influence upon the specific gravity of rice and barley.

In the case of wheat and naked barley, it is natural from the reason above given that specific gravity and absolute weight can have scarcely any or no relation with each other. Moreover these seeds contain air cavities formed by the folding of the testa and the size of these must have a great influence upon the specific gravity of the seed, but the size of the air cavities undoubtedly can have no relation with the size and weight of the grain.

Notwithstanding these facts, Ando's experiments tend to show that even with these grains some relation does exist between specific gravity and weight, and that the specific gravity can be used safely as a means of selection. He separated seeds of naked barley besides rice and barley according to their specific gravities with a solution of sodium bromide and sodium chloride and weighed a certain number of grains air-dried. The results, as given in the following table show that the average weight of the seed increases with its specific gravity.

NAKED BARLEY.

Sp. gr.	Weight of 100 grains in mgr.	
	Sort, Jōshiu.	Sort, Hōnen.
Over 1.380	2558.0	2868.0
1.375—1.380	2238.2	2506.6
1.370—1.375	1963.8	2154.8
1.365—1.370	1847.8	2077.0
1.360—1.365	1752.6	——
1.355—1.360	——	——
1.350—1.355	1561.7	1704.4
1.345—1 350	1342.0	——
1.340—1.345	——	1366.0

RICE.

	Sort, Shiratama.	Sort, Sekitori.
Over 1.235	3196.0	2931.2
1.20—1.21	3155.8	2744.4
1.15—1.16	2888.7	2551.1
1.00—1.03	2152.4	2126.4

BARLEY.

	Sort, Golden melon.	
Over 1.30	5497.0	
1.25—1.26	5220.3	
1.20—1.21	4875.4	
1.15—1.16	4417.2	
1.00—1.10	2940.0	

Thus it may be seen that as to cereals weight and specific gravity have a certain relation with each other and grains with a higher specific gravity are generally also heavier. Ando has proved this for rice by weighing each grain and counting the number of grains of similar weights within a certain space as shown in the following table :—

RICE; SORT, SHIRATAMA.

Weight mgr. / Sp. gr.	Number of grains.									
	Below. 20	20—22	22—24	24—26	26—28	28—30	30—32	32—34	34—36	36—38
1.00—1.03	28	39	16	3	7	2	5	0	0	0
1.15—1.16	0	2	3	16	26	27	21	5	0	0
1.20—1.21	0	0	0	0	12	16	41	29	2	0
Over 1.235	0	0	0	0	3	10	55	23	7	2

SORT; SEKITORI.

1.00—1.03	42	26	12	9	1	8	1	1	0	0
1.15—1.16	1	3	14	39	29	8	5	1	0	0
1.20—1.21	0	1	5	30	27	28	7	0	0	0
Over 1.235	0	0	0	7	25	20	37	6	5	0

Thus it may be seen that the seed with a higher specific gravity contains a larger number of heavier grains, and if we take those grains which sink in a solution with a high specific gravity as for example in the case 1.21, and reject those grains which float on it, then surely we shall obtain the largest and best grains.

So far with Ando's results. In this direction Y. Ida, another student of our college, has also examined various sorts of rice and made elaborate experiments in our laboratory in 1896. His results are embodied in the following table, which shows the distribution of grains of various weights under each fixed specific gravity. The number of grains is shown in percentage.

NUMBER OF GRAINS IN PER CENT.

Wt. in mgr. / Sp. gr.	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	24-25	25-26	26-27	27-28	28-29	29-30	30-31	31-32	32-33	33-34
SORT, JAVA.																					
Below 1.00	—	—	7	21	19	25	17	11													
1.00—1.05											23	56	11								
1.05—1.10												6	32	38	18	4	2				
1.10—1.15														16	43	40	0	1			
1.15—1.20															9	87	4				
Over 1.20																39	43	10	8		
SORT, YAMADA.																					
Below 1.00	1	9	11	19	15	14	17	9	5												
1.00—1.05								8	20	32	21	13	4	2							
1.05—1.10										2	16	27	29	16	8	2					
1.10—1.15													10	26	32	15	18	0	1		
1.15—1.20														3	10	27	18	11	6	1	
Over 1.20																8	21	30	25	14	2

SORT, SHIRATAMA.

Below 1.00	—	—	1	18	22	26	21	10	2												
1.00—1.05								8	18	19	33	15	6	1							
1.05—1.10										2	11	9	28	22	19	9					
1.10—1.15														14	25	53	8				
1.15—1.20															1	11	51	21	14	2	
Over 1.20																		18	30	37	15

SORT, SEKITORI.

Below 1.00	—	—	6	14	11	20	21	20	8												
1.00—1.05								19	24	26	21	9	1								
1.05—1.10										10	17	40	15	12	5	1					
1.10—1.15											2	15	27	36	16	4					
1.15—1.20													3	18	26	28	16	6	3		
Over 1.20															3	17	30	25	16	6	3

GLUTINOUS SORT, ZAKKOKU.

Below 1.00	—	—	12	43	17	15	8	3	2												
1.00—1.05						1	10	33	24	18	9	5									
1.05—1.10										3	37	29	21	8							
1.10—1.15												2	21	39	28	9	1				
Over 1.15														12	22	52	13				

As may be clearly seen, these results fully confirm those obtained by Ando and show that the heaviest and best grains are mainly included in the lots with higher specific gravities. Ida's carefull observations also show that the percentage of husk has more or less influence upon the specific gravity of the grain; and this seems to confirm our view with regard to the question of the relation of the weight and the specific gravity of a grain with its husk. Ida's results may be tabulated as follows :—

Sp. gr.	Average weight of a grain in mgr.	Average weight of husk of a grain in mgr	Ratio of husk to grain taking husk as	Per cent of husk.
		SORT, JAVA.		
Below 1.00	17.50	4.90	1 : 3.51	28.4
1.00—1.05	24.30	5.06	1 : 4.80	20.5
1.05—1.10	25.90	5.13	1 : 5.00	20.0
1.10—1.15	27.80	5.20	1 : 5.35	18.7
1.15—1.20	28.40	5.20	1 : 5.46	18.3
Over 1.20	29.00	5.20	1 : 5.77	17.3
		SORT, YAMADA.		
Below 1.00	17.40	4.30	1 : 4.05	24.6
1.00—1.05	22.40	4.30	1 : 5.21	19.2
1.05—1.10	24.90	4.20	1 : 5.93	16.8
1.10—1.15	27.00	4.20	1 : 6.43	15.5
1.15—1.20	29.60	4.30	1 : 6.88	14.5
Over 1.20	30.90	4.40	1 : 7.00	14.4
		SORT, SHIRATAMA.		
Below 1.00	18.30	3.80	1 : 4.82	20.7
1.00—1.05	23.30	4.20	1 : 5.55	18.6
1.05—1.10	25.80	4.20	1 : 6.14	16.2
1.10—1.15	28.30	4.60	1 : 6.15	16.2
1.15—1.20	29.40	4.80	1 : 6.13	16.2
Over 1.20	31.50	4.80	1 : 6.65	15.0

SORT, SEKITORI.

Below 1.00	19.50	3.80	1 : 5.13	19.4
1.00—1.05	22.30	3.80	1 : 5.87	17.3
1.05—1.10	24.40	4.10	1 : 5.95	16.8
1.10—1.15	26.10	4.40	1 : 5.93	16.8
1.15—1.20	27.80	4.80	1 : 5.79	17.2
Over 1.20	29.80	4.90	1 : 6.08	16.4

SORT, ZAKKOKU-MOCHI (glutinous).

Below 1.00	16.30	3.80	1 : 4.30	23.2
1.00—1.05	20.90	4.00	1 : 5.23	19.1
1.05—1.10	23.80	4.30	1 : 5.53	18.0
1.10—1.15	26.30	4.60	1 : 5.72	17.4
Over 1.15	28.30	4.80	1 : 5.90	16.9

Thus it is seen that in the case of grains with a low specific gravity the ratio of husk to seed is greater, that is, they have more husk in proportion to the weight of the seed, and thus it may be concluded that the husk of a grain has a great influence upon its specific gravity.

From these results we can see the reason why those experimenters who have selected their grains by means of their specific gravities regardless of their weight, have almost without exception obtained good results. Indeed they have selected unconciously good, plump and heavy grains by taking specific gravity as the standard of selection. The reason why the "specific gravity selection" method is so widely used especially for rice with good results can also be seen. Though we can not say that a heavy grain has always a high specific gravity, heavy grains of cereals have *on the average* a higher specific gravity, and when the seeds are selected by specific gravity those light and immature grains can be effectively got rid of and fairly good and plump seeds can be obtained; and when grains with the highest specific gravities are selected, we obtain the largest number of the best grains. If seeds could be selected practically by their weights so accurately that only the best grains could be obtained, then the "specific gravity

selection" method should be abandoned as an inaccurate method of selection; but those small farmers especially here in Japan might profitably use this method as a convenient method of selection especially for cereals.

With regard to leguminous grains, it seems that specific gravity has scarcely any relation to weight and the "specific gravity selection" method would not give good results. This fact has been shown by C. Ikeda of this College, whose results are given in the following table. The grains used were those of the soy bean but similar results can probably be got with other leguminous grains which often contain a large quantity of air.

Sp. gr.	Number of grains with weight more than 160.0 mgr.	Number of grains with weight less than 160.0 mgr.
Below 1.15	56%	44%
1.15 —1.175	64 „	36
1.175—1.20	65 „	35
1.20 —1.225	64	36
1.225—1.25	64	36

Rape seed has also been examined by C. Kobayashi of this College, whose results are given in a separate paper. It seems from his result that the "salt water selection" can also be used for its selection.

On the Selection of Rape Seed.

BY

C. Kobayashi, *Nōgakushi.*

The quality of a seed is one of the important factors to be considered for attaining a good and rich harvest, and the quality of a seed is determined by precisely observing its size, weight, purity, genuineness, germinative energy, germination percentage, &c.

Several facts has hitherto been found by many foreign investigators on these points but there are still some questions as to the relation between the size and weight of a seed and its specific gravity that needs to be cleared up. For cereals and especially for rice and barley some of our investigators, foremost of whom is Prof. T. Yokoi of the Agricultural College, have found that seeds of high specific gravity are generally heavier and have more germinative and vegetative energy and those of lower specific gravity the reverse. Upon this fact the so-called "salt-water selection" or better "specific gravity selection" method was devised in which the good seeds were separated from the bad by floating and skimming off the latter in a saline solution of a moderate specific gravity. It is, however, allowable to doubt if this method can be applied with equal success to rape seeds, which furnish oil. Our object in the cultivation of the rape lies chiefly in getting seeds which are rich in oil; and for sowing seeds rich in oil must be selected. Further trials were therefore necessary to determine whether seeds rich in oil can be selected by the same method as was applied to cereals or not.

The object of my investigation was to find out the relation between the physical and chemical characters of rape seed and its quality, and to devise some practical method for the selection of rape seed.

The results can be summed up under the following headings:—

I. The relation between the absolute weight and the specific gravity of rape seed.

II. The relation between the absolute weight and specific gravity of rape seed and its germination.

III. The relation between the specific gravity of rape seed and its oil content.

I. The Relation between the Absolute Weight and the Specific Gravity of Rape Seed.

For experiment five different sorts of rape seeds were taken and in the first place their average specific gravity and absolute weight were determined, the former by means of the pycnometer and then they were separated into eight lots of different specific gravities with the solution of common salt. The results were as follows :—

Sorts.	Average specific gravity.	Average weight of one grain.
Chōsen	1.1225	3.11 mg.
Okuna from Gumma	1.1120	3.21
Hiroshima	1 1103	3.22
Hamburg	1.1580	3.15
Colza	1.1090	2.69

The seeds were first selected with the solution of common salt of the specific gravity of 1.145, the floating portion was separated and successively selected with the solutions of the specific gravity of 1.125, 1.105, 1.085, 1.065, 1.045 and 1.025. In this way a series of seeds having different specific gravities was obtained :—

Series.	Specific gravity.
I	1.145 and more.
II	1.145—1.125
III	1.125—1.105
IV	1.105—1.085
V	1.085—1.065
VI	1.065—1.045
VII	1.045—1.025
VIII	1.025 and less.

Of a given quantity of rape seeds thus divided, those of I having the highest specific gravity, were least in number and the grains were irregular in shape and size ; those of II were about

equal in number to I, but a little more numerous, those of III and specially IV and V were of a more regular shape and size and still more numerous, while those of VI and especially VII and VIII were again of irregular shape and size, mixed moreover with light and immature ones, and were less numerous.

The absolute weight of 100 grains of each series were then determined and were found to be as follows :—

TABLE A.

Series.	Sp. gr.	Chōsen.	Hiro-shima.	Okuna.	Colza.	Hamburg.	Tōkyō wase.
I	1.145 and more.	346.0 mg.	—mg.	—mg.	—mg.	—mg.	—mg.
II	1.145—1.125	403.0	376.0	348.0	—	318.0	—
III	1.125—1.105	420.0	395.2	392.0	306.4	—	412.0
IV	1.105—1.085	447.0	451.0	421.0	325.5	407.0	421.0
V	1.085—1.065	435.0	400.0	373.6	—	—	—
VI	1.065—1.045	424.0	399.0	376.0	322.4	407.6	402.0
VII	1.045—1 025	406.0	398.0	354.0	—	—	—
VIII	1.025 and less.	372.0	377.0	330.0	316.0	311.0	377.0

Thus, the weight of rape seed does not increase or decrease proportionately with its specific gravity, but the seeds of medium specific gravity are always heavier on the average and consist of the grains of a more regular shape. Then the grains belonging to each lot were weighed and classified into four groups for examining the contents of each lot. The result was as follows :—

SORT, CHOSEN.

	Sp. gr.	No. of grains weighing 3 mg. & less.	No. of grains weigh. 3–4 mg.	No. of grains weigh. 4–5 mg.	No. of grains weigh. 5 mg. & more.	Total no. of grains.
I	1.145 and more.	46	40	14	0	100.
II	1.145—1.125	29	46	25	0	100.
III	1.125—1.105	22	44	34	0	100.
IV	1.105—1.085	0	51	39	10	100.
V	1.085—1.065	0	48	44	8	100.
VI	1.065—1.045	13	47	34	6	100.
VII	1.045—1.025	16	44	36	4	100.
VIII	1.025 and less.	42	36	22	0	100.

SORT, HIROSHIMA.

	Sp. gr.	No. of grains weighing 3 mg. & less.	No. of grains weigh. 3–4 mg.	No. of grains weigh. 4–5 mg.	No. of grains. weigh. 5 mg. & more.	Total no. of grains.
I	1.145 & more.	—	—	—	—	0
II	1.145—1.125	38 grains	43 grains	19 grains	--	100
III	1.125—1.105	—	—	—		100
IV	1.105—1 085	—	31	55	14	100
V	1.085—1.065	18	46	24	12	100
VI	1.065—1.045	20	52	29	—	100
VII	1.045—1.025	30	40	30	—	100
VIII	1.025 & less.	28	40	32	—	100

SORT, OKUNA.

	Sp. gr.	No. of grains weighing 3 mg. & less.	No. of grains weigh. 3-4 mr.	No. of grains weigh. 4-5 mg.	No. of grains weigh. 5 mg. & more.	Total no. of grains.
I	1.145 & more.	—	—	—	—	0
II	1.145—1.125	44 grains	32 grains	24 grains.	—	100
III	1.125—1.105	—	—	—	—	0
IV	1.105—1·085	7	42	44	7	100
V	1.085—1.065	—	—	—	—	0
VI	1.065—1.045	25	42	26	7	100
VII	1.045—1.025	—	—	—	—	0
VIII	1.025 & less.	33	45	22	—	100

SORT, HAMBURG.

	Sp. gr.	No. of grains weighing 3 mg. & less.	No. of grains weigh. 3-4 mg.	No. of grains weigh. 4-5 mg.	No. of grains. weigh. 5 mg. & more.	Total no. of grains.
I	1.145 & more	—	—	—	0	0
II	1.145—1.125	50	38	12	0	100
III	1.125—1.105	—	—	—	0	0
IV	1.105—1.085	26	32	42	0	100
V	1.085—1.065	—	—	—	0	0
VI	1.065—1.045	14	39	39	8	100
VII	1.045—1.025	0	0	0	0	0
VIII	1.025 & less.	54	32	14	0	100

Thus we see that seeds of greater average weight contain on the whole more heavy grains.

It was stated by Marek that seeds of greatest absolute weight are the best in quality and yield the largest crops ; but the absolute weight of any seed has no constant relation to its specific gravity. Hellriegel, Lehmann, Wollny, Marek and others have found that although the weight of a seed varies under various conditions, the heaviest and largest seeds produce the largest and best crops and are best for sowing. As regards the specific gravity, opinions are divided, Hellriegel, Wollny and Marek being of the opinion that the specific gravity of a seed and its quality do not always go together. The results obtained by many workers of our College show, however, that in cereals especially those which have hulls, such as rice, barley except the naked sort, etc., the specific gravity and absolute weight and consequently the quality have a certain close relation with each other.

I have furthermore examined the average specific gravity of rape seed, classed in three groups of different weight. 200–250 grains were taken from each group and the specific gravity determined by means of the pycnometer :—

TABLE B.

	Weight of one grain.	Sp. gr. of the sort Chōsen.	Sp. gr. of the sort Okuna.	Sp. gr. of the sort Hamburg.
Heaviest.....	4.5 & more mg.	1.105	1.093	1.136
Medium	3.0 – 4.0	1.121	1.098	1.151
Lightest.....	3.0 and less.	1.135	1.105	1.160

In the above, the seeds are but roughly classified ; e. g. in the heaviest group there are of course, included several grains, whose specific gravity are less than 1.08 or even 0.025, while lightest group include also those of 1.145 and more. It would therefore, be erroneous to conclude from the above table that the seeds which have a smaller specific gravity have the greatest absolute weight. On the contrary the above results agree quite well with those of Table A, and we may state that the results always agree quite well whether the absolute weight was measured for seeds of different specific gravities or whether the specific gravity was determined for seeds of different absolute weights. In either case the seeds which had a medium specific gravity had the greatest absolute weight.

Thus, in the Chōsen rape, seeds of the specific gravity 1.105–1.085 had the greatest absolute weight and the results were about the same both with Okuna and Hamburg rape. It is interesting to compare my figures with those of Wollny which are very similar, and are as follows :—

	Weight of 100 grains.	Specific gravity.
Heaviest rape seed.	0.554 gram.	1.0593
Medium ,, ,,	0.429	1.1004
Lighest ,, ,,	0.336	1.1141

As has been proved by several investigators the heaviest seeds are the best, and if this rule also holds good with rape, which is cultivated for oil we must select those having a medium specific gravity viz., those with the greatest absolute weight ; and it will be very interesting in this connection to know whether the oil content of rape seed has any relation with specific gravity or not.

II. The Relation between the Absolute Weight and Specific Gravity of Rape Seed and its Germination.

The experiments under this category were carried out with reference to the following three points :—

a.) Relation of the specific gravity of seed to its germination.

b.) Relation of the absolute weight of seed to its germination.

c.) Relation of the different absolute weight of seeds arranged in a series according to specific gravity to their germination.

The seeds employed for experiments were divided into four groups of different specific gravities, as follows :—

1.)	Seeds of specific gravity	1.125 & more
2.)	,, ,, ,, ,,	1.105—1.085
3.)	,, ,, ,, ,,	1.065—1.045
4.)	,, ,, ,, ,,	1.025 & less

a.) Relation of the Specific Gravity of Seed to its Gemination.

The rape seeds used in this experiments were of five sorts : Chōsen, Okuna, Hiroshima, Colza and Hamburg. They were germinated in a germination apparatus, all under the same condition. The germinative energy and germination percentage observed were as follows :—

TABLE I.

SORT CHŌSEN.

		Seeds of specific gravity of				
Days.		Original sample. (120 grains)	1.125 & more. (100 grains)	1.105—1.085 (100 grains)	1.065—1.045 (100 grains)	1.025 & less. (100 grains)
I	Germinated.	3	4	3	2	0
II	,,	12	18	16	11	5
III	,,	39	39	43	51	42
IV	,,	29	21	25	19	19
V	,,	14	5	7	10	13
VI	,,	15	10	5	4	14
VII	,,	3	0	1	1	2
VIII	,,	1	1	—	0	0
IX	,,	1	0	—	0	0
X	,,	0	0	—	0	0
XI	,,	1	0	—	0	0
Total	,,	108	98	100	98	95
Germination percentage.		90%	98%	100%	98%	95%

SORT OKUNA.

		Seeds of specific gravity of				
Days.		Original. sample. (100 grains)	1.125 & more. (100 grains)	1.105—1 085 (100 grains)	1.065—1.045 (100 grains)	1.025 & less. (100 grains)
I	Germinated.	2	2	3	2	7
II	,,	11	17	14	18	14
III	,,	53	51	67	52	45
IV	,,	3	15	7	4	6
V	,,	10	13	6	5	3
VI	,,	15	0	1	1	10
VII	,,	2	0	1	1	5
VIII	,,	0	0	0	0	1
IX	,,	0	1	0	1	2
X	,,	0	0	0	0	1
XI	,,	0	0	0	0	1
XII	,,	0	0	0	0	1
XIII	,,	0	0	0	0	0
XIV	,,	0	0	0	0	0
XV	,,	0	0	0	0	1
Total	,,	96	99	99	98	97
Germination percentage.		96%	99%	99%	98%	97%

SORT HIROSHIMA.

		Seeds of specific gravity of				
Days.		Original sample. (100 grains)	1.125 & more. (58 grains)	1·105—1.085 (100 grains)	1.065—1.045 (100 grains)	1.025 & less. (100 grains)
I	Germinated.	0	0	0	0	0
II	,,	0	0	7	2	0
III	,,	40	14	54	37	33
IV	,,	31	17	16	21	17
V	,,	13	14	18	29	27
VI	,,	9	6	1	9	9
VII	,,	1	0	1	0	7
VIII	,,	0	1	0	0	0
IX	,,	0	0	0	0	2
X	,,	2	0	1	0	0
XI	,,	0	0	0	1	1
XII	,,	0	1	0	1	1
XIII	,,	0	0	0	—	1
XIV	,,	0	1	0	—	0
Total	,,	96	54	98	100	98
Germination percentage.		96%	93%	98%	100%	98%

SORT HAMBURG.

		Seeds of specific gravity of			
Days.	Original sample. (100 grains)	1.125 & more. (100 grains)	1.105—1.085 (100 grains)	1.065—1.045 (100 grains)	1.025 & less. (100 grains)
I Germinated.	5	8	5	2	7
II ,,	21	15	18	18	24
III ,,	32	33	48	37	32
IV ,,	6	12	12	16	9
V ,,	18	23	10	14	16
VI ,,	5	2	3	1	4
VII ,,	3	0	1	6	2
VIII ,,	2	0	1	1	1
IX ,,	1	0	0	0	1
X ,,	1	0	0	0	0
XI ,,	1	0	0	0	1
XII ,,	1	0	0	0	0
XIII ,,	1	0	0	0	0
XIV ,,	0	0	0	0	0
XV ,,	1	0	0	0	0
Total ,,	98	93	98	95	97
Germination percentage.	98%	93%	98%	95%	97%

SORT COLZA.

		Seeds of specific gravity of			
Days.	Original sample. (100 grains)	1.125 & more. (58 grains)	1.105—1.085 (100 grains)	1.065—1.045 (100 grains)	1.025 & less. (100 grains)
I Germinated.	0	0	0	0	0
II ,,	13	12	22	22	13
III ,,	38	22	52	50	56
IV ,,	22	12	20	22	22
V ,,	7	5	3	3	5
VI ,,	6	6	1	0	1
VII ,,	3	0	1	0	0
VIII ,,	0	0	0	0	0
IX ,,	0	1	0	0	0
X ,,	0	0	0	0	1
XI ,,	0	0		0	1
Total ,,	89	58	99	97	99
Germination percentage.	89%	96%	99%	97%	99%

In the above experiment the germination was very irregular owing to the low temperature of the season. It was, however, observed that the germination percentage was always better in the seeds of mediun specific gravity. After three weeks of germination the seedlings were carefully measured and weighed and their dry matter determined. The following results were obtained :—

TABLE II.

SORT CHŌSEN.

	Germination percentage.	Height of plants. (average of 12 plants.)	Breadth of leaves. (average of 12 plants.)	Weight of plants.	Dry matter of plants.
Original sample.	90%	11.500 bu.*	0.98 -bu.	30.03 mg.	1.570 mg.
Seeds of sp. gr. 1.125 & more.	98%	—	—	—	2.004
,, ,, 1.105—1.085	100%	12.950	1.24	36.31	2.244
,, ,, 1.065—1.045	98%	13.590	1.13	34.12	2.083
,, ,, 1.025 & less.	95%	12.600	1.10	30.06	2.061

SORT OKUNA.

	Germination percentage.	Height of plants. (average of 12 plants.)	Breadth of leaves. (average of 12 plants.)	Weight of plants.	Dry matter of plants.
Original sample.	96%	11.700 bu.	1.020 bu.	32.93 mg.	1.720 mg.
Seeds of sp. gr. 1.125 & more.	99%	12.125	1.120	37.51	1.610
,, ,, 1.105—1.085	99%	14.365	1.415	43.66	2.180
,, ,, 1.065—1.045	98%	14.320	1.330	46.91	1.930
,, 1.025 & less.	97%	12.700	1.040	24.74	1.540

SORT HIROSHIMA.

	Germination percentage.	Height of plants. (average of 12 plants.)	Breadth of leaves. (average of 12 plants.)	Weight of plants.	Dry matter of plants.
Original sample.	96%	13.745 bu.	1.566 bu.	31.74 mg.	1.896 mg.
Seeds of sp. gr. 1.125 & more.	93%	12.875	1.215	26.91	1.460
,, ,, 1.105—1.085	98%	—	—	29.42	1.830
,, ,, 1.065—1.045	100%	17.717	1.325	31.39	1.805
,, ,, 1.025 & less.	98%	16.190	1.105	28.19	1.440

* one bu = 0.333 cm.

SORT HAMBURG.

	Germination percentage.	Height of plants. (average of 12 plants.)	Breadth of leaves. (average of 12 plants.)	Weight of plants.	Dry matter of plants.
Original sample,	98%	12.930 bu.	1.155 bu.	—	1.970 mg.
Seeds of sp. gr. 1.125 & more.	93%	14.133	1.000	—	1.900
,, ,, 1.105—1.085	97%	16.515	1.290	—	2.568
,, ,, 1.065—1.045	95%	15.770	1.400	—	2.455
,, ,, 1.025 & less.	97%	14.080	1.350	—	2.130

SORT COLZA.

	Germination percentage.	Height of plants. (average of 12 plants.)	Breadth of leaves. (average of 12 plants.)	Weight of plants.	Dry matter of plants.
Original sample.	89%	10.300 bu.	1.110 bu.	27.75 mg	1.470 mg.
Seeds of sp. gr. 1.125 & more.	96%	11.400	1.480	31.25	1.340
,, ,, 1.105—1.085	99%	12.700	1.130	38.33	1.630
,, ,, 1.063—1.045	97%	11.400	1.080	31.30	1.980
,, ,, 1.025 & less.	99%	11.430	1.010	—	1.530

The above table shows that the seedlings from seeds of medium specific gravity, which are heavy and regular in shape, generally gave superior results as regards their height and the breadth of their leaves, as well as their weights and their dry matter. Marck's results show that seeds of different size, do not differ in their germination percentage and energy but that the seedlings from large seeds have always longer leaves and stalks and are heavier than the seedlings obtained from small seeds. These results and those obtained by me prove that heavy seeds are always superior.

b.) Relation of the Absolute Weight of Seed to its Germination.

For this experiment seeds of the Chōsen rape were used and five lots, each containing 30 grains, of different absolute weights were made to germinate. The following results was obtained :—

TABLE I.

		Seeds of the absolute weight of			
Days.	Dates.	3 mg. & less.	3—4 mg.	4—5 mg.	5 mg. & more.
I	19 March.	0	0	0	0
II	20 ,,	18	27	26	22
III	21 ,,	7	3	3	7
IV	22 ,,	3	—	0	0
V	23 ,,	1	—	1	0
VI	24 ,,	0	—	—	0
VII	25 ,,	0	—	—	0
VIII	26 ,,	0	—	—	1
IX	27 ,,	0	—	—	—
Total no. germinated.		29	30	30	30
Germination percentage.		96.7%	100%	100%	100%

After three weeks of germination, the plants were carefully measured and weighed and their dry matter determined. The results were as follows :—

TABLE II.

Absolute weight of a seed.	Height of plants. (average of 12 plants)	Weight of plants.	Weight of dry matter.	Length of root.
3 mg. & less.	14.55 Bu.	22.91 mg.	1.227 mg.	14.54 Bu.
3—4 mg.	13.31	38.80	2.103	21.38
4—5 mg.	13.56	43.81	3.193	28.08
5 mg. & more	14.42	48.04	—	24.89

The above tables show that the germinative energy are irregular in the case both of heavy and light grains but that the germination percentage was inferior for lighter seeds. The height of seedlings were also irregular, but the plants from lighter seeds were always much weaker; they were also lighter and contained less dry matter than those obtained from heavy seeds. Thus there exists a definite relation between the weight of a seed and the rigor of the seedling. The experiments made by Marek and those at the Laboratory of Plant-physiology at Halle as regards the germination of large and small grains of beans, peas, wheat, linseed, and beet gave similar results to the above. In these experiments, all the peas and beans germinated both light and heavy grains, and with wheat, linseed, and beet the germination percentage of the smaller grains was rather inferior. The results of the measurements of the seedlings of both grains, which have grown out only of their reserve matters, made by Marek also agree with those of mine.

c.) Relation of the different Absolute Weight of Seeds arranged in a Series according to Specific Gravity to their Germination.

Three sorts of rape seed—Chōsen, Okuna, and Hiroshima—were taken and arranged in a series according to different specific gravities and the seeds of a given specific gravity were again arranged in the order of their absolute weights. The results were shown in the following tables :—

TABLE I.

SORT CHŌSEN.

Days.	Date. / Ab. wt.	Seeds of sp. gr. 1.125 & more.			Seeds of sp. gr. 1.105—1.085			Seeds of sp. gr. 1.065—1.045				Seeds of sp. gr. 1.025 & less..		
		3 mg. & less. (30 grains)	3—4 mg. (30 grains)	4—5 mg. (30 grains)	3—4 mg. (30 grains)	4—5 mg. (30 grains)	5 mg. & more. (18 grains)	3 mg. & less (30 grains)	3—4 mg. (30 grains)	4—5 mg. (30 grains)	5 mg. & more. (5 grains)	3 mg. & less. (30 grains)	3—4 mg. (50 grains)	4—5 mg. (30 grains)
I	17 April.	0	0	0	0	0	0	1	0	1	0	0	0	0
II	18 ,,	1	2	2	2	8	1	3	0	6	1	9	12	8
III	19 ,,	14	18	23	21	16	17	17	21	20	3	20	17	22
IV	20 ,,	11	10	5	7	6	—	9	7	3	1	0	1	—
V	21 ,,	3	—	—	—	—	—	—	1	—	—	1	—	—
VI	22 ,,	0	—	—	—	—	—	—	1	—	—	—	—	—
Total.		29	30	30	30	30	18	30	30	30	5	30	30	30
Germination percentage.		96.7%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

SORT OKUNA.

	Seeds of sp. gr. 1.125 & more.			Seeds of sp. gr. 1.105—1.085				Seeds of sp. gr. 1.065—1.045				Seeds of sp. gr 1.025 & less.		
Days. Date. / Ab. wt.	3 mg. & less. (30 grains)	3—4 mg. (30 grains)	4—5 mg. (30 grains)	3 mg. & less. (30 grains)	3—4 mg. (30 grains)	4—5 mg. (30 grains)	5 mg. & more. (23 grains)	3 mg. & less. (30 grains)	3—4 mg. (30 grains)	4—5 mg. (30 grains)	5 mg. & more. (20 grains)	3 mg. & less. (30 grains)	3—4 mg. (30 grains)	4—5 mg. (30 grains)
I 13 May.	2	3	4	3	3	1	1	3	5	5	1	5	6	3
II 14 ,,	26	27	23	0	24	28	19	24	25	24	17	25	24	25
III 15 ,,	2	—	2	25	3	1	2	1	—	1	1	—	—	2
IV 16 ,,	—	—	0	2	—	—	1	2	—	—	1	—	—	—
V 17 ,,	—	—	0	—	—	—	—	—	—	—	—	—	—	—
VI 18 ,,	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Total.	30	30	30	30	30	30	23	30	30	30	20	30	30	30
Germination percentage.	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

SORT HIROSHIMA.

Days..	Date. / Ab. wt.	Seeds of sp. gr. 1.125 & more.			Seeds of sp. gr. 1.105—1.085			Seeds of sp. gr. 1.065—1.045			Seeds of sp. gr. 1.025 & less.		
		3 mg. & less. (30 grains)	3—4 mg. (30 grains)	4—5 mg. (30 grains)	3—4 mg. (30 grains)	4—5 mg. (30 grains)	5 mg. & more. (14 grains)	3 mg. & less. (30 grains)	3—4 mg. (30 grains)	4—5 mg. (30 grains)	3 mg. & less. (30 grains)	3—4 mg. (30 grains)	4—5 mg. (30 grains)
I	30 April.	1	4	1	3	7	0	1	1	0	2	2	1
II	1 May.	25	25	26	26	23	14	29	27	28	28	28	29
III	2 ,,	2	1	2	0	—	—	—	2	0	—	—	—
IV	3 ,,	0	—	1	0	—	—	—	—	2	—	—	—
V	4 ,,	0	—	—	0	—	—	—	—	—	—	—	—
VI	5 ,,	0	—	—	0	—	—	—	—	—	—	—	—
VII	6 ,,	0	—	—	1	—	—	—	—	—	—	—	—
VIII	7 ,,	0	—	—	—	—	—	—	—	—	—	—	—
IX	8 ,,	1	—	—	—	—	—	—	—	—	—	—	—
Total.		29	30	30	30	30	14	30	30	30	30	30	30
Germination percentage.		96.7%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

TABLE II.

SORT CHOSEN.

Sp. gr. / Ab. wt.	Germination percentage.				Height of plants (12 plants)				Length of roots (12 plants)				Weight ef plants.				Dry matter of plants.			
	1.025 & less.	1.065–1.045	1.105–1.085	1.125 & more.	1.025 & less.	1.065–1.045	1.105–1.085	1.125 & more.	1.025 & less.	1.065–1.045	1.105–1.085	1.125 & more.	1.025 & less.	1.065–1.045	1.105–1.085	1.125 & more	1.025 & less.	1.065–1.045	1.105–1.085	1.125 & more.
					bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	mg.	mg.	mg.	mg.	mg.	mg.	mg.	mg.
3 mg. & less.	100%	100%	—	96.7%	13.600	13.808	—	14.491	14.816	15.241	—	17.275	15.853	17.828	—	24.150	1.373	1.325	—	1.553
3—4 mg.	100%	100%	100%	100%	15.232	16.167	16.029	15.797	17.550	16.642	15.717	16.033	24.913	28.500	31.519	32.286	2.196	2.363	2.272	2.233
4—5 mg.	100%	100%	100%	100%	16.849	16.466	17.817	17.450	17.766	16.250	16.642	16.475	40.540	31.293	37.262	32.774	2.653	2.733	2.575	2.653
5 mg. & less.	—	100%	100%	—	—	—	17.352	—	—	—	16.350	—	—	24.880	28.682	—	—	—	2.861	—
Total.	—	—	—	—	45.680	46.441	51.198	44.738	50.132	48.133	—	49.783	81.306	102.501	107.463	89.210	6.222	6.421	7.708	6.439
Average.	100%	100%	100%	98.9%	15.226	15.480	17.066	15.913	16.710	16.044	16.047	16.594	27.102	25.625	35.821	29.736	2.074	2.1403	2.5693	2.1463

SORT OKUNA.

Sp. gr. / Ab. wt.	Germination percentage.				Height of plants. (12 plants)				Length of roots. (12 plants)				Weight of plants.				Dry matter of plants.			
	1.025 & less.	1.065–1.045	1.105–1.085	1.125 & more.	1.025 & more.	1.065–1.045	1.105–1.085	1 125 & more.	1.025 & less.	1.065–1.045	1.105–1.085	1.125 & more.	1.025 & less.	1.065–1.045	1.105–1.083	1.125 & more.	1.025 & less.	1.065–1.045	1.105–1.085	1,125 & more.
					bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	mg.	mg.	mg.	mg.	mg.	mg.	mg,	mg.
3 mg. & less.	100%	100%	100%	100%	14.000	13.517	13 920	16.512	15.378	16.025	15.897	17.008	25.200	21.526	22.406	28.574	1.552	1.620	1.553	1.580
3–4 mg.	100%	100%	100%	100%	15.391	15.995	15.114	16.386	16.941	16.609	17.350	17.786	32.950	33.313	34 673	30.153	2.213	2.350	2.276	2.297
4—5 mg.	100%	100%	100%	100%	15.187	15.825	16.795	16.444	16.650	18.980	17.158	15.922	41.566	40.493	36.075	40.689	3.010	2.680	2.824	2.969
5 mg. & more.	—	100%	100%	100%	—	17.433	15.967	—	—	17.175	17.217	—	—	44.600	41.36ε	—	—	3.135	3.143	—
Total.	—	—	—	—	44.578	62.768	61.795	49.342	48.968	68.789	67.620	50.715	99.716	139.932	134.519	99.416	6.775	9.785	9.896	6.846
Average.	100%	100%	100%	100%	14.860	15,692	15.449	16.447	16.323	17.197	16.905	16.905	33.238	34.983	33.630	33.138	2.258	2.446	2.474	2.283

SORT HIROSHIMA.

Sp. gr. / Ab. wt.	Germination percentage.				Height of plants. (12 plants)				Length of roots. (12 plants)				Weight of plants.				Dry matter of plants.			
	1.025 & less.	1.065–1.045	1.105–1.085	1.125 & more.	1.125 & more.	1.065–1.045	1.105–1.045	1.125 & more.	1.025 & less.	1.065–1.045	1.105–1.085	1.125 & more.	1.025 & less.	1.065–1.045	1.105–1.085	1.125 & more.	1.025 & less.	1.065–1.045	1.105–1.085	1.125 & more.
					bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	mg.	mg.	mg.	mg.	mg,	mg.	mg:	mg.
3 mg. & less.	100%	100%	—	96.7%	14.308	14.308	—	14.91	15.233	13.567	—	13.490	33 420	30.133	—	34.280	1.835	1.606	—	1.544
3—4 mg.	100%	100%	100%	100%	17.707	16 840	17.257	19.820	15.143	14.391	16.311	15.244	40.800	40.146	37.593	37.944	2.333	2.380	2.383	2.241
4—5 mg.	100%	100%	100%	100%	19.098	17.928	18.822	17.365	15.572	16.107	20.995	15.727	47.146	43.459	46.614	41.979	2.696	2.942	2.942	2.675
5 mg. & more.	—	—	100%	—	—	—	19.625	—	—	—	19.188	—	—	—	55.628	—	—	—	3.328	—
Total.	—	—	—	—	51.113	48.920	55.704	52.095	45.948	44.066	55.599	44.461	121.366	113.738	139.835	114.203	6.864	6.928	8.653	6.460
Average.	100%	100%	100%	98.9%	17.038	16.307	18.568	17.365	15.316	14.688	18.533	14.820	40.455	37.913	46.612	38.068	2.288	2.309	2.884	2.153

These results show that the germination energy and percentage are about the same in the seeds of different specific gravities and absolute weights, but that, for a given specific gravity, the length of the shoots and roots and the dry matter of their seedlings increase proportionately with the weight of the seeds, and that when we compare seeds of the same absolute weight but of different specific gravities the results are found to be in favour of the seeds of medium specific gravity on the average. In the preceding chapter it has been proved that the seeds of medium specific gravity have also, on the average, greater absolute weight than those of maximum and minimum specific gravities and consist mainly of heavy grains. Thus it may be stated that as large heavy seeds produce good seedlings and best crops, seeds of medium specific gravity should be selected in the case of rape. For the selection of rape seed, however, its oil content must primarily be taken into account and it is very important to ascertain whether the seeds which have strong germination power and which consequently promise a better growth and superior crops always contain more oil than the weaker or not. The results of my experiments on this point will be described in the next chapter.

III. The Relation between the Specific Gravity of Rape Seed and its Oil Content.

The object of this experiment was to find out the specific gravity which should be taken as the criterion for the so-called "specific gravity selection," by means of which rape seeds richest in oil could be separated and to determine which sorts of rape are comparatively rich in oil. Thus the experiments were divided into two groups :—

a.) Those directed to determine the relative richness of different sorts in oil.

b.) Those pertaining to the relation of the oil content to the specific gravity of seed.

Soxlet's method of fat estimation was followed in this investigation.

a.) Relative Richness of different Sorts in Oil.

Four sorts of rape seed were taken and their specific gravities were determined, and the percentage of water and oil was then measured ; thus :—

		Air-dry matter.		
Sorts.	Specific gravity.	Water.	Fat.	Fat in dry matter.
Colza	1.109	7.82%	43.77%	47.48%
Okuna	1.112	7.96	42.32	45.98
Chōsen	1.123	8.36	41.27	45.03
Hamburg	1.158	8 04	40.11	43.62

The oil content differs much with differents sorts. Colza, which has the lowest specific gravity, has been found to be richest in oil, then follows Okuna and the oil content increases with the decrease of the specific gravity. The results obtained by Wollny with Dutch rape agrees with mine and is as follows :—

	Weight of 100 grains.	Sp. gr.	Fat & oil.
a.) Large seed	0.554	1.0393	49.51%
b.) Medium seed	0.429	1.1004	49.03
c.) Small seed	0.336	1.1141	46.77

b.) Relation of the Oil Content to the Specific Gravity of Seed.

Three different sorts were used for experiment. The percentage of water and oil was determined for their original samples as well as for each of the four groups, into which the seeds were divided according to specific gravity. The results were as follows :—

	CHŌSEN.			OKUNA.			HAMBURG.		
	Air dry.			Air dry.			Air dry.		
	Water.	Fat in dry matter.	Fat in dry matter.	Water.	Fat in dry matter.	Fat in dry matter.	Water.	Fat in dry matter.	Fat in dry matter.
Original sample.	8.37%	41.27%	45.05%	7.96%	42.32%	45.98%	8.04%	40.11%	43.62%
Seeds of Sp. gr. 1.105 and more.	6.94	39.54	42.50	7.09	40.29	43.35	9.16	38.46	42.63
,, ,, 1.105—1.085	7.86	42.87	46.51	7.05	43.91	47.23	8.48	41.90	45.77
,, ,, 1.065—1.045	7.14	42.02	45.26	6.35	44.00	47.01	8.64	41.26	45.22
,, ,, 1.025 and less.	8.32	40.98	44.69	9.59	40.15	44.40	7.52	40.38	43.65

For each sort seeds of medium specific gravity are generally richer in oil, and we see from the above that the seeds whose specific gravity lies between 1.105 and 1.085, are richest in oil, and these are followed by those of the specific gravity of 1.065–1.045; but that the seeds whose specific gravity is greater than 1.105 or less than 1.025 are poorer in oil. It has also been observed that the group richest in oil cansists as a rule of large and plump grains of regular size. The results obtained in some experiments made at the Central Experiment Station at Nishigahara near Tōkyō agree tolerably well with mine and may be quoted for comparison :—

	CHŌSEN.			HAMBURG.		
	Air-dry.			Air-dry.		
	Water.	Fat.	Fat in dry matter.	Water.	Fat.	Fat in dry matter.
Seed which floated on the distilled water of 30°C.	10.63%	33.40%	37.37%	11.80%	31.50	35.69%
Seed which floated on the well water of 15°C.	10.75	43.25	48.46	11.50	40.35	45.59
Seed which floated on the salt water of sp. gr. 1.05	11.60	44.20	50.00	11.10	40.90	46.01
Seed which floated on the salt water of sp. gr. 1.10	10.60	43.99	49.20	11.80	41.20	45.71
Seed which sunk in the salt water of sp. gr. 1.10	11.40	37.95	42.82	12 30	36.35	41.45

According to Marek and Wollny large seeds contain generally both absolutely and relatively more oil than small ones. The results obtained by these investigators were follows :—

MAREK.

Beans.	large seed.	2.59% oil in dry matter.
	small seed.	2.32
Peas.	large seed.	4.07
	small seed.	3.87

Wheat.	large seed.	2.58
	small seed.	2.49
Flax.	large seed.	32.52
	small seed.	23.76
Rübsen.	large seed.	48.92
	small seed.	44.35

WOLLNY.

Winter rape.	large seed	49.44% oil in dry matter.
	medium seed.	49.26
	small seed.	46.30

Marek has also obtained 1.468 grams of fat from 100 large grains of peas while only 0.524 gram was contained in small ones. Wollny's experiment on oats and rape gave the following results :—

		Weight of 100 grains	Specific gravity.	Water.	Fat.
Oats.	large seed.....	3.49 gram.	1.3364	9.12%	5.22%
	medium seed.....	2.82	1 3386	9.34	5.35
	small seed	1.93	1 3298	9.41	5.78
Rape.	large seed	0.554	1.0393	5.62	49.51
	medium seed.....	0.429	1 004	5.69	49.03
	small seed.....	0.336	1.1141	5.92	46.77

Thus, the results of investigators all go to show that large and consequently heavy seeds are rich in oil. My results, as already mentioned, also lead to the same conclusion, and they also show that with rape, plump grains of regular size always have a medium specific gravity. Marek attributes the richness in oil of large seeds to the transformation of starch into oil in the process of ripening since large seeds are always fully ripened ones, while small ones are more or less immature. This hypothesis, however, seems to me to need further investigation.

CONCLUSION.

The results of my experiments may be briefly summarized as follows :—

1.) As to the relation of the specific gravity and the absolute weight of rape seed, grains of medium specific gravity

a.) Have a regular shape and are large and plump.

b.) Are heaviest.

c.) Consist mainly of heavier grains when compared with those having maximum or minimum specific gravity.

2.) The relations of the specific gravity and absolute weight of rape seed to germination are as follows :—

a.) Seeds of medium specific gravity are always superior in their germinating capacity and produce more vigorous seedlings, when compared with seeds which have much higher or lower specific gravity.

b.) Heavy seeds produce longer and heavier seedling than lighter ones.

c.) When for a given sort of rape, seed grains are divided into several groups according to their specific gravity and absolute weight, heavier ones give always better results in germination, and on the whole those of medium specific gravity are the best for sowing.

3.) Results of the estimation of fat in rape seed.

a.) Of several sorts of rape, Colza which has the least average specific gravity is richest in oil, then follows Okuna, and then Chōsen and Hamburg, the seeds of which latter have a grater specific gravity than those of the preceding two.

b.) For a given sort of rape, seeds of medium specific gravity are richest in oil.

Generally it has been found that the groups of lower specific gravity always contain many immature grains and those of higher specific gravity smaller grains, while those of medium specific gravity are richest in oil and consist of heavy grains of superior germinative power and promising better harvest. Thus, it is evident that in the case of rape, seeds of medium specific gravity should be selected for sowing. For this purpose, lighter seeds and foreign matters must be separated from the heaviest ones first by means of fanning mills ; the latter must then be passed through

sieves in order to get rid of irregular grains of higher specific gravity, and the lighter ones must be skimmed off in a solution of common salt having the specific gravity of 1.045. The large, heavy and regularly shaped grains of the medium specific gravity of about 1.045–1.105 left after these selective processes must alone be employed for sowing.

TŌKYŌ, JUNE, 1896.

On the Effect of Steeping on Rice-seeds.

BY

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Professor of Agriculture.

When seeds are steeped in water, the nutriment they contain must necessarily be more or less dissolved out, the quantity dissolved being different in different kinds of seeds, the length of steeping and the temperature and quantity of the water used. According to an experiment of F. Haberlandt[1] the following quantities of dry matter were dissolved out from various seeds, during 24 hours of steeping.

Wheat	1.14%	Field bean	2.58%
Rye	1.35 ,,	Kidney bean	6.48 ,,
Barley	1.33 ,,	Red clover	11.11 ,,
Oats	2.06 ,,	Linseed	13.22 ,,
Maize	1.05 ,,	Hemp	1.09 ,,
Pea	5.03 ,,	Poppy	2.00 ,,

On the influence of temperature, A. Zoebl's experiment has given the following results.[2]

		Loss of dry substance: maize.	barley.
after 5 days.	in cold water of 7°C.	4.34%	3.26%
	in warm ,, ,, 18°C.	5.45 ,,	4.52 ,,
after 30 days.	in cold ,, ,, 7°C.	26.04 ,,	19.44 ,,
	in warm ,, ,, 18°C.	33.70 ,,	27.12 ,,

(1) Der allgem. landwirthschaftl. Pflanzenbau. Wien 1879.

(2) Ibid. and Wollny's Saat und Pflege der landwirthschaftl. Kalturpflanzen, Berlin 1885. It is rather remarkable that Zoebl's figures show such a regular and decisive effect of the length of time on the percentage of dissolved matter. Unfortunately we can not get access to the original literature.

Zoebl's analysis has moreover shown that not only ash constituents but also nitrogenous and non-nitrogenous organic substances are considerably dissolved out during steeping:

The injurious effect of long continued steeping especially in warm water is certainly attributable to this fact and partly also to the multitude of bacteria which prosper in water.

Notwithstanding these injurious effects of steeping especially in warm water, our farmers have been in the custom of steeping their rice seeds for a number of days, generally 3 weeks and in some cases for 100 days or more without, however, such detrimental effect as has been observed in the case of wheat, barley and other seeds, so long as water of low temperature was used.

As to the effect of length of steeping on the productive power of rice, our experiments[3] for many years, have gone to show that long steeping does comparatively little injury to rice seeds, while when sown without steeping its germination is rather prolonged—thus entailing only a drawback. According to our experience, with large quantities of seed, however, steeping for about 120 days destroys, even in favorable cases, the vital power of some 20 or 30 per cent of the grains; and those that survive germinate with difficulty.

From these facts, it must be concluded that rice seed has a remarkable power of withstanding the action of water and bacteria. Indeed this would not be any wonder when we reflect that rice, when in the wild state, must have been in the habit of shedding its seed in marshes, in which they could retain their vital power for a long time. We shall now proceed to examine more minutely some of the effect of long steeping on rice seeds.

Our experiment was commenced on January 20, 1895 with 114.812 grams of seed steeped in 3 litres of pure water, and was concluded on April 23 of the same year,—the seed having lain in water for 100 days, when the seed was taken out from water and each grain was carefully wiped with blotting paper to deprive it of the water adhering to it. The whole seed was found to weigh 140.8992 grams, the increase being due to the water absorbed during steeping.

After drying at about 97°C for some hours, the weight decreased to 106.1896 grams.

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(3) M. Fesca in his Beiträge zur Kenntniss der Japanischen Landw. Sp. Theil, state only the two results of my experiments executed in Chikuzen where the experiments on a larger scale were prolonged for many years. The results of these experiments are stated in the text.

On analysis we found the composition of the original and the steeped seed to be as follows :—

	The original seed.	The seed after steeping.
Water	10.0762	14.4600
Total dry matter	89.9238	85.5400
	100.0000	100.0000
Organic matter	85.9066	81.2580
Ash	4.0172	4.2820
Nitrogen	1.1068	0.9329

Thus it may be seen that the percentage of dissolved matter by weight amounts only to 12.018% of the total dry matter, containing

* Organic matter	11.955%
Ash	0.063 ,,
* Nitrogenous matter	1.696%
Non-nitrogenous ,,	10.259 ,,

This result when compared with the result of A. Zoebl, with barley and maize, shows strikingly the power of rice seed to withstand the dissolving action of water. The fact becomes more remarkable when we take into consideration not only the time of steeping but the temperature of water during the interval. The bottle with the seed was placed in a cool room; but as the room was daily warmed during the latter half of the experiment, the water must also have become somewhat warmer. Daily observation of the temperature of the water, showed that the lowest temperature observed was 1.0°C. and the highest 16°C. both these temperatures having been observed only twice during the whole experiment. Aside from these two extreme cases the temperature of the water was in general over 3°C. and below 10°C. during the first 69 days, and above 10°C. and below 16°C. during the latter 31 days—being on the average lower than that of Zoebl's warm water and higher than that of his cold water.

Another fact which struck us during the experiment was the small quantity of bacteria found in the water. The water was remarkably clear even after many days of steeping and did not show such brown or dark brown colouration found almost directly after steeping in the case of barley and other grains. Bacteria were found forming a thin film on the surface of the water; hence it is perhaps not unreasonable to suppose that rice seed contains some ingredient detrimental to the growth of bacteria.

It is rather curious that our steeped seed remained without germination in water with the temperature above the minimum for germination so long as 31 days.[4] Indeed as has already been stated, very long steeping, according to our experience, seems to make the seed germinate with difficulty. We have also tested our long steeped seed as to its power of germination. 200 grains each of steeped seed and the seed without steeping were transfered on to the Liebenberg's germination apparatus and the result was as follows :—

Dates of observation.		Number of germinated grains. Seed, steeped.	Seed, not steeped.
April.	23	—	—
,,	24	—	—
,,	25	163	—
,,	26	13	7
,,	27	9	84
,,	28	5	76
,,	29	1	26
,,	30	2	1
May.	1	1	1
,,	2	1	—
	Total.	195	195

From this result, it may be seen that the number of grains that germinated was exactly the same in both lots (97.5%). But the seed which had not been steeped germinated one day later and the germination was at first very irregular when compared with the steeped seed. This fact is undoubtedly to be attributed to the difficulty with which the seed absorbs water in the apparatus, and if the seed had been steeped for 24 hours or so before the experiment, the result would probably have been otherwise. However, when we take number of germinated grains during the first 4 days after the commencement of germination in each case, we get 190 and 193, which is calculated in percentage 95% and 96.5% respectively—thus showing the germinating power slightly in favour of the seed which had not been steeped. On the whole it seems that though rice seed has such a remarkable power of withstanding the action of water and although the result of the germination experi-

(4) The minimum temperature for germination of rice seed, according to Haberlandt is 10–12°C, and rice seed is capable of germinating under water.

ment does not show a decided effect, the steeping so long as 100 days is not without influence and the germinating power of the seed is more or less damaged by it.[5]

As a conclusion, we may state thus: rice seed has a remarkable power of withstanding the action of water when steeped, and this fact is probably to be attributed to the comparatively small solubility of its nutriment and its power of preventing to a certain degree the growth of bacteria so hurtful to the germinating power of seeds.

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(5) A curious fact was observed during the experiment; the five grains which did not germinate in the steeped seed were taken out without moulding, which was not the case with the seed which was not steeped.

On the Aborption of Water by Rice-Seed.

BY

H. Andō, *Nōgakushi.*

The time required for saturation with water is different with different kinds of seed, the quality of water, and the temperature during steeping. Our farmers have from a very old time been in the practice of steeping rice seed for days, weeks or even more than 3 months; 3 weeks being general. They generally select cool places, especially in warm regions, so that the seeds remain without sprouting; but the question is whether such a long time is required for rice seeds to absorb sufficient quantity of water for germination.

To solve the question I have undertaken a series of experiments in 1894–1895. Various samples of rice seeds were steeped in water and the increase of their weight was observed from time to time until it became fairy constant.

EXPERIMENT I.

This experiment was made in April 1894, when the daily temperature of the atmosphere stood between 10° and 16°C. On the sixth day of steeping, some of the grains began to germinate, and thereafter the increase of weight was no more observed. The result is shown in the following table :—

30 grains weighing 921.2 gr. when dry.			
Hours after steeping.	Weight of grains after steeping in mgr.	Increase of weight in mgr.	Increase of weight in % of the original.
2.5	966.2	45.0	4.88
5.	980.8	59.2	6.43
7.	989.4	68.2	7.40
25.	1042.2	121.0	13.14
29.	1055.6	134.4	14.59
49.	1084.2	163.0	17.69
99.	1134.6	213.4	23.16
120.	1136.6	215.4	23.38

EXPERIMENT II.

The second experiment was made in May of the same year, with the daily temperature varying between 15°–18°C. Germination began on the 5th day of steeping and on the 7th day the number of germinated grains was more than one-third of the whole. The results were as follows :—

LOTS I AND II.

30 grains in each lot weighing 920.8 and 888.4 mgr. respectively.

Hours after steeping.	Weight after steeping in mgr.		Increase of weight in mgr.		Increase of weight in % of the original wt.	
	Lot 1	Lot 2	Lot 1	Lot 2	Lot 1	Lot 2
1	955.0	922.6	34.2	34.2	3.71	3.86
2	963.2	934.2	42.4	45.8	4.80	5.11
3	966.6	939.0	45.8	50.6	4.97	5.70
4	972.8	943.6	52.0	55.2	5.64	6.21
5	978.8	950.0	58.0	61.6	6.30	6.93
6	988.4	956.0	67.6	67.6	7.34	7.61
24	1052.5	1016.6	131.8	128.2	14.31	14.32
30	1063.2	1028.6	142.4	140.2	15.46	15.78
48	1086.6	1054.0	165.8	165.6	18.00	18.65
54	1096.0	1057.0	175.2	168.6	19.02	18.98
72	1106.8	1073.0	186.0	184.6	20.19	20.78
78	1117.4	1078.0	196.6	184.2	21.34	21.35
96	1127.2	1087.4	206.4	199.0	22.41	22.41
102	1128.2	1088.0	207.4	199.6	22.51	22.47
120	1129.0	1093.2	208.2	204.6	22.66	23.04

LOTS III AND IV.

(30 grains)

Hour after steeping.	Wt. of seed before steeping in mgr.		Wt. of seed after steeping in mgr.		Increased wt. by steeping in mgr.		Increased wt. in % of total original wt.	
	Lot 3	Lot 4	Lot 3	Lot 4	Lot 3	Lot 4	Lot 3	Lot 4
1.	896.0	905.0	934.0	940.8	38.0	35.8	4.24	3.95
2.	908.8	942.4	955.0	976.4	46.2	34.0	5.08	3.60
3.	952.4	912.6	1004.2	954.8	51.8	42.2	5.44	4.62
4.	951.2	921.2	1005.2	972.0	52.0	50.8	5.46	5.51
5.	914.0	898.6	972.0	960.8	58.8	62.2	6.39	6.92
6.	924.8	925.2	985.6	989.0	60.8	63.8	6.58	6.90
8.	943.0	919.8	1009.6	995.0	66.6	75.2	7.06	8.17
12.	917.8	876.2	1002.0	967.2	84.2	91.0	9.17	10.38
15.	927.6	879.0	1017.4	960.6	89.8	81.6	9.67	9.28
18.	927.6	904.6	1026.8	1011.0	99.2	106.4	10.69	11.75
24.	917.6	893.2	1037.6	1008.4	120.0	115.2	13.07	12.90
30.	901.6	895.0	1025.6	1019.6	124.0	124.6	13.74	13.92
36.	886.4	903.2	1017.4	1037.4	131.4	134.2	14.83	14.86
42.	937.6	917.0	1094.0	1077.3	156.4	160.3	16.67	17.42
48.	941.8	934.6	1102.3	1100.2	161.0	165.6	17.09	17.71
54.	956.2	887.8	1133.0	1044.8	176.8	157.0	18.49	17.68
60.	890.8	877.0	1062.2	1047.4	171.4	170.4	19.23	19.43
66.	945.4	926.2	1128.0	1110.6	182.6	184.4	19.32	19.91
72.	905.6	895.2	1125.0	1076.2	219.4	181.0	24.21	20.22
78.	913.0	899.2	1102.6	1080.6	189.6	181.4	20.76	20.17
96.	938.2	929.8	1141.2	1129.0	203.0	199.2	21.64	21.42
102.	896.0	867.2	1085.8	1060.0	189.8	192.8	21.18	22.23

EXPERIMENT III.

The experiment was carried out in May 1895. In this case, the seeds did not germinate on account of the lower temperature and the time required to saturate them with water was somewhat longer. The result may be summed up as follows :—

(50 grains.)

Hour of steeping.	Wt. of seed after steeping in mgr.		Increased wt. by steeping in mgr.		Increased wt. in % of total original wt.	
	Lot 1	Lot 2	Lot 1	Lot 2	Lot 1	Lot 2
0	1562.0	1588.6	—	—	—	—
1	1640.0	1653.4	78.0	64.8	4.99	4.08
2	1660.0	1671.4	98.0	82.8	6.27	5.21
3	1680.0	1687.8	118.0	99.2	7.55	6.18
4	1693.4	1703.4	131.4	114.8	8.41	7.23
5	1704.2	1718.4	142.2	129.8	9.10	8.15
24	1785.2	1787.0	223.2	198.4	14.29	12.49
48	1845.8	1846.8	283.8	258.2	18.17	16.25
72	1899.0	1911.6	337 0	323.0	21.32	20.33
90	1911.4	1927.0	349.4	338.4	22.37	21.32
168	1918.5	1944.9	356.5	356.3	22.82	22.43
240	1922.1	1944.1	360.1	355.5	23.05	22.38

CONCLUSION.

From the figures above tabulated, it may be seen that on the average 22.57 % of water by weight is required to saturate a certain quantity of rice seeds with water—neglecting the small quantity of dry matter dissolved out during steeping. This quantity of water seems more than sufficient for germination and to absorb this quantity it requires at a low temperature 240 hours and in a high temperature 102-120 hours. From these results, it may be seen that 5–7 days of steeping are sufficient for rice seeds to absorb enough water to facilitate germination.

On the Specific Gravity of Rice Seeds in Different Stages of Ripening.

BY

H. Andō, *Nōgakushi.*

It is a well known fact that the specific gravity of seeds varies in different stage of ripening, but the results obtained by previous investigators do not agree with one another. According to Marek[1] and Nowacki,[2] the specific gravity of wheat and rye decreases as the seed ripens ; but the result obtained by Lucanus[3] is opposed to that of those two authors. Such a contradiction is not to be wondered at when we consider that the specific gravity of seeds varies with various circumstances, e. g. the conditions in which seeds are produced and with different kind and varieties of plants.

As regards rice seed, which is covered with a light, porous husk, it is exceedingly probable that its specific gravity should vary according to different laws from those obtained in other cereals. To get an insight into the matter, I selected, in 1895, some rice seeds at 5 different stages of ripening and determined their specific gravities both in the fresh state and after after-ripening.

Period I. Milk-ripe :—both grain and straw still green, seeds yielding a white milky juice easily pressed out between fingers.

Period II. Green-ripe :—husk and straw beginning to become yellowish, endosperm already full, though still very soft.

Period III. Yellow-ripe :—husk and most straw yellowish ; seed tolerably hard.

Period IV. Full-ripe :—husk and straw tolerably dry and of a pale yellow colour, seed very hard.

Period V. Dead-ripe :—husk and straw entirely dry and of a yellowish white colour.

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(1) and (3) Harz, Samenkunde, Vol. I. p. 515.

(2) Nowacki, Getreidebau, p, 235–239.

The results of my observations are summed up in the following table :—

Sorts.	Stage of ripening.	Dates of harvest.	Specific gravity.		
			Fresh grains.(1)	Ditto,(2) air dried.	After-ripen.
Shiratama.	Milky.	Oct. 15th.	1.1087	0.7408	0.8291
	Green.	20th.	1.1885	0.9934	1.0174
	Yellow.	22nd.	1.2765	1.2060	1.2022
	Full.	Nov. 6th.	1.2225	1.2107	1.2069
Sekitori.	Milky.	Oct. 18th.	1.1383	0.8264	0.8730
	Green.	20th.	1.2006	0.9549	1.0214
	Yellow.	25th.	1.2579	1.2020	1.1919
	Full.	Nov. 6th	1.2218	1.2040	1.1851
	Dead.	Dec. 13th.	—	—	1.2083
Java.	Milky.	Oct. 18th.	1.1236	0.7228	0.8490
	Green.	22nd.	1.2373	1.0156	1.0901
	Yellow.	25th.	1.2351	1.1293	1.2028
	Full.	Nov. 6th.	1.2346	1.1712	1.2313
Hiye-mochi.	Milky.	Oct. 12th.	1.1325	0.7613	0.9074
	Green.	18th.	1.1704	0.9293	0.9838
	Yellow.	22nd.	1.2368	1.1564	1.1799
	Full.	Nov. 1st.	1.1917	1.1627	1.1608
Zakkoku-mochi.	Milky.	Oct. 12th.	1.1924	0.8214	0.9144
	Green.	18th.	1.2138	0.9714	0.9968
	Yellow.	23rd.	1.2511	1.1455	1.1206
	Full.	Nov. 1st.	1.2137	1.1712	1.1422

(1) and (2) are of same sample.

Erom the above table, it can clearly be seen that the specific gravity of rice seed increases with ripening. On the other hand, the specific gravity is less when air dried than in the fresh state.

These changes are probably to be attributed mainly to the fact that the light and porous husk which is first formed does not change in size with the development of the seed inside, and is moreover relatively heavier in the milky and green stages than when fully ripe, and that with drying the seed shrinks up by losing much water, leaving much space between the seed and the husk, the space necessarily being larger in the milky and green stages than when fully ripe.

The following table shows these relations clearly :—

Stage of ripening.	Weight of seed. (20 grains)	Weight of husk.	Husks in % of total weight of seed.
Milky	265.8 mgr.	88.8 mgr.	33.41 %
Green	452.0	92.6	20.57
Yellow	582.4	96.6	16.60
Full	503.1	101.5	16.83

On the Development of the Plumule and Radicle of Rice-Seed with Various Quantities of Water in the Germinating Medium.

BY

T. Yokoi, *Nōgakushi.*

Professor of agriculture.

With Plates XVI—XVII.

It has already been shown by F. Haberlandt that some kinds of seed germinates under water deprived of air.* Our experiments have also shown that rice seed is one of them. Indeed, rice seed germinates freely under water with or without air. Yet it has been observed that in the case of germination under water the plumule alone elongates long before the radicle appears. It has also been observed in the case of other grains, that in media with different quantities of moisture the plumule and the radicle develop in different proportions.

To show the matter clearly I allowed 10 grains of rice to germinate under water and on sand with different quantities of moisture. The sand selected was found on examination to have the water holding capacity of 31.5 % by weight. On germination, the lengths of the plumule and the radicle were determined, sketches of an average specimen having been taken each time.

The result may be seen from the following tables and sketches (Plates XVI–XVII). The first experiment was made in July 1895, and in May 1896 the experiment was repeated.

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* Der allgem. landwirthschaftl. Pflanzenbau. Wien, 1879.

EXPERIMENT I.

TABLE I.

Per cent of water in sand.		Length of plumule and radicle in milimeter.							
		1st day.		2nd day.		3rd day.		4th day.	
No.		plum.	rad.	plum.	rad.	plum.	rad.	plum.	rad.
I	Water without sand covering seed.	3.03		6.36	—	18.48	0.60	27.27	4.64
II	Superfluous water in sand covering seed.	3.33		7.57	—	22.72	0.60	30.30	0.01
III	30 %	2.30	3.33	4.24	11.81	9.69	27.57	18.78	31.87
IV	27 „	0.90	7.27	1.81	13.63	4.54	16.06	7.57	21.51
V	24 „	0.30	3.03	0.90	6.06	2.36	15.75	4.54	19.69
VI	20 „	—	—	—	4.54	1.87	12.12	2.72	13.63
VII	18 „	—	—	—	1.36	0.90	3.93	1.21	4.54
VIII	15 „	—	—	—	—	—	2.72	0.60	4.24
IX	12 „	—	—	—	—	—	0.90	0	1.87
X	7.5„	—	—	—	—	—	0.60	0	0.90

TABLE II.

Per cent of water in sand.		Calculated ratio of plumule to radicle.			
		1st day.	2nd day.	3rd day.	4th day.
No. I	Water without sand covering seed.	—	—	1 : 0.0032	1 : 0.013
II	Superfluous water in sand covering seed.	—	—	1 : 0.0026	1 : 0.015
III	30 %	1 : 1.44	1 : 2.78	1 : 2.84	1 : 1.69
IV	27 „	1 : 8.08	1 : 7.53	1 : 3.53	1 : 2.86
V	24 „	1 : 10.10	1 : 6.73	1 : 6.67	1 : 4.35
VI	20 „	—	—	1 : 6.48	1 : 5.00
VII	18 „	—	—	1 : 4.39	1 : 3.75
VIII	15 „	—	—	—	1 : 7.07
IX	12 „	—	—	—	—
X	7.5 „	—	—	—	—

EXPERIMENT II.

TABLE I.

No.	Per cent of water in sand.	Length of plumule and radicle in milimeter.																	
		1st day.		2nd day.		3rd day.		4th day.		5th day.		6th day.		7th day.		8th day.		9th day.	
		p.	r.	p.	r.	p.	r.	p.	r.	p.	r.	p.	r.	p.	r.	p.	r.	p.	r.
I	Water without sand covering seed.	2.42	—	6.06	—	10.90	—	15.75	5.15	19.99	6.66	21.18	9.89	24.54	15.45	25.45	20.60	28.78	31.90
II	Superfluous water in sand covering seed.	0.90	—	3.03	—	5.75	--	14.42	—	20.00	4.84	21.79	7.57	23.23	11.51	27.27	19.09	30.30	24.54
III	30 %	2.12	—	3.96	3.03	4.54	6.36	6.91	10.90	10.6	26.66	13.63	3.39	18.48	45.45	24.54	54.54	33.33	69.69
IV	27 „	0.90	—	2.11	1.51	3.33	4.54	5.15	8.18	6.66	14.81	9.39	18.18	13.93	23.63	15.75	25.15	21.18	33.33
V	24 „	—	—	1.21	3.03	2.42	6.98	3.93	13.33	6.66	16.36	8.18	17.87	9.69	19.69	11.81	26.96	15.75	30.30
VI	20 „	—	—	1.21	1.51	2.72	3.93	4.54	7.57	6.06	13.33	7.87	18.48	9.09	23.93	10.00	25.45	12.72	28.78
VII	18 „	—	—	0.60	—	1.51	2.42	2.72	5.15	4.24	11.21	5.45	14.54	6.96	18.18	8.48	23.23	10.66	27.87
VIII	15 „	—	—	0.60	—	1.51	2.72	2.42	6.96	3.93	12.12	4.84	16.66	5.75	20.30	7.57	29.69	9.09	33.33
IX	12 „	—	-	—	1.81	1.21	5.75	1.81	8.18	2.42	12.72	3.33	16.96	4.21	21.81	6.66	30.30	8.48	39.39
X	7.5 „	—	—	—	—	—	2.42	0.60	8.48	2.12	14.84	3.33	17.87	4.84	23.03	6.06	33.33	7.57	42.42

TABLE II.

Percent of water in sand.		Calculated ratio of plumule to radicle.								
		1st day.	2nd day.	3rd day.	4th day.	5th day.	6th day.	7th day.	8th day.	9th day.
No.		p. r.	p. r.	p. r.	p. r.	p. r.	p. r.	p. r.	p. r.	p. r.
I	Water without sand covering seed.	—	—	—	1 : 0.32	1 : 0.33	1 : 0.46	1 : 0.62	1 : 0.80	1 : 1.10
II	Superfluous water in sand covering seed.	—	—	—	—	1 : 0.24	1 : 0.34	1 : 0.49	1 : 0.80	1 : 0.71
III	30 %	—	1 : 0.74	1 : 1.40	1 : 1.57	1 : 2.51	1 : 2.24	1 : 2.45	1 : 2.22	1 : 2.09
IV	27 „	—	1 : 0.71	1 : 1.39	1 : 1.58	1 : 2.22	1 : 1.93	1 : 1.69	1 : 1.59	1 : 1.57
V	24 „	—	1 : 2.50	1 : 2.88	1 : 3.39	1 : 2.45	1 : 2.18	1 : 2.04	1 : 2.28	1 : 1.92
VI	20 „	—	1 : 1.25	1 : 1.44	1 : 1.66	1 : 2.20	1 : 2.34	1 : 2.63	1 : 2.54	1 : 2.26
VII	18 „	—	—	1 : 1.60	1 : 1.88	1 : 2.69	1 : 2.66	1 : 2.61	1 : 2.73	1 : 2.61
VIII	15 „		—	1 : 1.80	1 : 2.87	1 : 3.08	1 : 3.44	1 : 3.53	1 : 3.92	1 : 3.66
IX	12 „	—	—	1 : 4.75	1 : 4.51	1 : 5.26	1 : 5.09	1 : 5.03	1 : 4.54	1 : 4.64
X	7 5„	—	—	—	1:14.14	1 : 7.00	1 : 5.36	1 : 4.75	1 : 5.50	1 : 5.60

From these figures and the subjoined sketches, it may clearly be seen that the quantity of water in the sand has a great influence upon the relative development of the plumule and radicle; when allowed to germinate under water with or without sand, the plumule alone develops 2 or 3 days before the radicle could be clearly recognised. On the contrary, when the quantity of water contained in the sand is scanty (between 15 %—7.5 %) the radicle develops before the plumule. When the percentage of water falls below 27 or in one case 24 germination is greatly retarded and with it the whole development of seedling, and some irregularities are observed in the ratio of the plumule to the radicle; but carefully comparing the figures, it may clearly be seen that with the decrease of the percentage of water, the difference becomes greater, that is to say the redicle develops comparatively faster than the plumule. It has also been observed that when the radicle is surrounded with abundant quantity of water very few or no root hairs could be found on it.

Such a phenomenon seems to be very natural as the main function of the radicle is the absorption of water, and to absorb a

sufficient quantity of water from a scanty source the radicle must develop faster, (and produce more root hairs) to enlarge the absorbing surface, than when there is abundant supply. We see, however, when we examine the figures in each of the two experiments and compare similar cases, that the ratio is seen to be more or less different. This fact is probably to be attributed mainly to the difference of temperature in the two experiments.

It has been the custom in our country from remote ages to let out the water of rice-fields in the morning, after the rice seeds have been sown, and let it in the evening. One good effect of this procedure is of course the warmth imparted to the fields by sunshine in the daytime and protection from cold or even frost at night. Another explanation of this procedure has often been sought in the necessity of exygen during germination. Indeed, in the warmer parts of our country, the contrary procedure is sometimes observed, water being let in in the morning and let out in the evening. Where the field has an inclination to dry out when the water is drained off, there we observe that farmers are in the custom of draining off the water when the seedlings are striking out the roots, saying that by this means the roots become "firm."

Now since as we have seen from the result of the above experiments, rice seeds though covered with the water of irrigation will not be much in want of oxygen but will freely germinate under water, the explanation hitherto given as to the benefit of letting out water in giving the oxygen to the germinating seed, must be withdrawn. The true explanation is undoubtedly to be sought in the benefit due to the acceleration in the growth of roots so necessary to the normal development of the seedlings. Thus it must be suggested to the farmers to irrigate the field after sowing in such a manner that water shall not be much more than sufficient to saturate the soil till the seedlings sufficiently strike the rootlets into it, at the same time avoiding the exposure of seeds to dryness, which of course will greatly injure their germinating power.

On the Formation of Proteids and the Assimilation of Nitrates by Phænogams in the Absence of Light.

BY

U. Suzuki, *Nōgakushi.*

The question whether nitrates can be assimilated and proteids can be produced by Phænogams in the dark, still meets with contradictory answers. *Kinoshita* concluded that nitrates can thus give rise to some asparagine. He experimented with young barley plants 20 cm. high, and found that ammonium salts yield much more asparagine than nitrates.[1] From experiments with *Lemna, Hansteen* inferred that ammonium salts are more easily assimilated in darkness, when some cane sugar is present, nitrates however but little.[2] *Ishizuka* observed that nitrates stored up in the roots of *Batatus edulis*, *Nelumbo nucifera*, *Lilium tigrinum*, *Helianthus tuberosus*, *Capsicum longum*, *Eutrema wasabi*, *Colocasia antiquorum*, tubers of *Solanum tuberosum*, and in the fruits of *Cucurbita pepo*, gradually decrease, when kept for several weeks in the dark, while the amount of asparagine increases.[3] In my experiments with etiolated shoots of the potato, I also observed the conversion of nitrates into asparagine, when some sugar was present; but generally ammonium salts and urea were more easily assimilated.[4] *Godlewski* concluded from his experiments on wheat that nitrates can be assimilated in darkness, whereby *amido compounds* are produced (whose nature he did not investigate) but no *Proteids.*[5] *Laurent*, on the contrary asserts that neither ammonium salts nor nitrates can be assimilated in darkness.[6] I have for some time devoted my attention to this interesting question. My first

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(1) Bulletin of college of Agriculture. Tokyo Vol. II. No. 4. (1895).
(2) Ber. d. bot. Ges. 14, 368 (1896).
(3) Bulletin of Coll. of Agriculture. Tokyo. Vol. II. No. 7.
(4) Bulletin of College of Agriculture. Vol. II. No. 7.
(5) Auzeiger der Akademie der Wissenschaften in Krakau. März 1897.
(6) Bull. de l'Akademie royale de Belgique 32. No. 2. (1896).

Experiment I.

	1st Day.	*2nd Day*	*3rd Day*	*4th Day*
No I				
No II				
No III				
No IV				
No V				
No VI				
No VII				
No VIII				
No IX				
No X				

Experiment II.

experiments failed to prove any assimilation of nitrates in darkness, but the consideration that the reduction of nitrates might require larger quantities of sugar, led me to increase the latter from 1 per cent. in the first experiments to 10 per cent. in my final experiments. The results then turned out quite differently.

I. EXPERIMENT WITH ETIOLATED SHOOTS OF BARLEY (*Hordeum distichon.*)

Shoots of barley 15 cm. high, grown in the dark in moist saw dust, were nourished with a 0.2% solution of sodium nitrate as well as with other necessary mineral matters[1] (from October 7 to 14) until the shoots attained the average height of 28 cm., thus allowing time to store up some of the nitrate. Hereupon, one portion of the plants was dried and analyzed, while the other portion was carefully removed from the saw dust, well washed and put in a 10% solution of cane sugar half saturated with gypsum. On the fourth day the plants were transferred to a solution of containing 0.1% mono- and di-potassium phosphate and as much of magnesium sulphate. The plants were left in a perfectly dark room for 7 days, during which time the temperature was Min. 10°C. and Max. 20°C. The solution was renewed every day; no bacterial turbidity was observed, the plants remained very healthy and grew 3–4 cm. On October 21 the plants were taken out from the solution and dried for analysis. The plants nourished with the nitrate until the 14, contained a moderate quantity of nitrates, as shown by the diphenylamine reaction. But the plants further kept in the 10% sugar solution *showed no trace of nitrates*, diphenylamine entirely failing to call forth the reaction. This experiment suffices to prove that the assimilation of nitrates can take place in the dark, provided there be sufficient sugar present. The quantitative analysis shows the result more clearly.

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(1) Solution containing 0.1% K_2HPO_4, 0.1% KH_2PO_4, 0.1% $MgSO_4$, half saturated with $CaSO_4$.

Total dry weight of 100 shoots :—

Plants treated with N_aNO_3 until the 14th ... ...1.365 g.
Plants kept in 10% sugar solution from the 14th to the 21st. ... ...1.650 g.
Increase of dry matter during experiment... ... ...0.285 g.=21%.

IN 100 PARTS OF DRY MATTER.

	Plants treated with nitrate.	
	Before nourishment with sugar (a)	After nourishment with sugar (b)
Total nitrogen.	4.22	3.53
Albuminoid nitrogen.....	1.85	1.85
Asparagine nitrogen	1.26	1.00
Nitrates nitrogen.	**0.32**	**0**
Other nitrogen.	0.79	0.68
Proteids (Alb. Nx 6.25).	11.56	11.56
Asparagine (water free).	5.94	4.71

As the plants kept in the sugar solution increased very much in dry matter, the percentage of nitrogen is lower, and no inference as to the formation of proteids can directly be drawn from these numbers. Therefore we have to recalculate the numbers with reference to the total amount of nitrogen, and also the absolute amount of nitrogen contained in every 100 shoots.

IN 100 PARTS OF TOTAL NITROGEN :—

	(a)	(b)
Albuminoid nitrogen.	**44.00**	**52.40**
Asparagine nitrogen.....	30.00	28.30
Nitrates nitrogen	**8.00**	**0**
Other nitrogen	18.00	19.30

EVERY 100 SHOOTS CONTAIN :—

	(a)	(b)
Total nitrogen.	0.0576 g	0.0582
Albuminoid nitrogen.	**0.0252**	**0.0305**
Asparagine nitrogen	0.0172	0.0166
Nitrates nitrogen.	**0.0044**	**0.000**
Other nitrogen.	0.0108	0.0112
Proteids (Alb. Nx 6.25)	0.1575	0.1906
Asparagine (water free).	0.0811	0.0778

0.0331 grams or 20% of Proteids increased during the experiment!

It is therefore evident that, a considerable increase of albuminoid nitrogen has taken place in the plants treated with 10% suger solution; and this increase almost coincides with the decrease of nitrates nitrogen.

II. SECOND EXPERIMENT WITH ETIOLATED SHOOTS OF BARLEY (*Hordeum distichon*).

On Oct. 7, when the etiolated shoots of barley, kept in saw dust, grew to the height of 15 cm., a portion of them was removed from the saw dust, washed well, dried and analyzed. The other portion was divided into 4 parts, and put in the following solutions :—

1) Half saturated gypsum solution.
2) 0.2% soduim nitrate, half saturated with gypsum.
3) 2% cane sugar half saturated with gypsum.
4) 2% cane sugar and 0.2% sodium nitrate, half saturated with gypsum.

Once in every 4 days, all these plants were transferred for a

whole day in solutions containing 0.1% KH_2PO_4. 0.1% K_2HPO_4. 0.1% $MgSO_4$ half saturated with gypsum.[1]

They were kept in perfect darkness from the 7th to the 20th., the temperature during this time being Min. 7°C. and Max. 21°C. The solutions were renewed every day, and no bacterial turbidity was allowed to appear. The plants were very healthy and their average height at the end of the experiment was 28 cm. After careful washing and drying, they were analyzed, with the following result:

IN 100 PARTS OF DRY MATTER.

	Plants dried on the 7th (a)	Plants kept in $CaSO_4$ 7th–20th (b)	Plants kept in $NaNO_3$ and $CaSO_4$ 7th–20th (c)	Plants kept in suger and $CaSO_4$ 7th–20th (d)	Plants kept in sugar, $NaNO_3$ and $CaSO_4$ 7th–20th (e)
Total nitrogen	3.88	4.13	4.22	3.75	4.30
Albuminoid nitrogen	2.03	1.85	1.85	1.76	2.40
Asparagine nitrogen.	0.68	1.62	1.26	1.12	0.96
Nitrates nitrogen	0	0	0.32	0	0.10
Other nitrogen	1.17	0.66	0.79	0.87	0.84
Proteids (Alb. Nx 6.25)	12.69	11.56	11.56	11.00	15.00
Asparagine (water free)	3.21	7.64	5.94	5.28	4.53

IN 100 PARTS OF TOTAL NITROGEN.

	(a)	(b)	(c)	(d)	(e)
Total nitrogen	100.0	100.0	100.0	100.0	100.0
Albuminoid nitrogen	**52.3**	44.8	**44.0**	47.0	**55.8**
Asparagine nitrogen	1.75	39.2	30.0	30.0	22.3
Nitrates nitrogen	0	0	**8.0**	0	**2.4**
Other nitrogen	30.2	16.0	18.0	23.0	19.5

(1) The separation of solutions was necessary to prevent bacterial growth as far as possible.

	(a)	(b)	(d)	(e)
Dry weight of 100 shoots.	1.300 g	1.240	1.300	1.310

EVERY 100 SHOOTS CONTAIN THEREFORE:—

	(a)	(b)	(d)	(e)
Total nitrogen.	0.0504 g	0.0512	0.0488	0.0563
Albuminoid nitrogen	0.0264	0.0229	0.0229	0.0314
Asparagine nitrogen	0.0088	0.0201	0.0146	0.0126
Nitrates nitrogen	0	0	0	0.0013
Other nitrogen	0.0152	0.0082	0.0113	0.0110
Proteids (Alb. NX 6.25)	0.1650	0.1431	0.1431	0.1963
Asparagine (water free).	0.0435	0.0948	0.0688	0.0594

Thus we see that during 14 days, about 15% of nitrogen was absorbed in the form of sodium nitrate, and that in the plants nourished with sodium nitrate and sugar, almost all the nitrates absorbed were converted into proteids; while in the plants nourished with soduim nitrate alone, without addition of sugar, nearly half or more of the nitrates absorbed remained unchanged on further cultivation. We observe further no increase of albuminoid nitrogen in the plants nourished with sugar alone. We can therefore say that sugar is absolutely necessary for the reduction of nitrates for plants kept in the dark.

III. EXPERIMENT WITH *Phaseolus multiflorus*.

On Sept. 22 young plants 10–15 cm. high were removed from the field, carefully washed and put in a 0.2% solution of sodium nitrate half saturated with gypsum. They were kept in diffuse day light for 2 days to allow them store up some nitrates. Then, one portion of them was directly dried and analyzed, while the other was again divided into 2 parts and put in the following solutions:—

1) 1% cane sugar, half saturated with gypsum.
2) 10% cane sugar, half saturated with gypsum.

Once in every 4 days the plants were transferred for a whole

day in solutions containing. 0.1% KH_2PO_4. 0.1% K_2HPO_4. 0.1% $MgSO_4$, and half saturated with $CaSO_4$.

As the solutions were renewed every day, no bacterial turbidity was allowed to appear. The plants were kept in perfect darkness for 4 days,[1] during which the temperature varied between 11°C. and 22°C.

Analysis after careful washing and drying gave the following results :—

IN 100 PARTS OF DRY MATTER.

	Control dried on 24th	Dark 1% sugar dried on 28th	Dark 10% sugar dried on 28th
Total nitrogen	5.12	5 12	4.07
Albuminoid nitrogen	2.80	2.15	2.12
Asparagine nitrogen	0.82	1.40	0.62
Nitrates nitrogen	**0.36**	**0.26**	**0.13**
Other nitrogen	1.14	1.31	1.20
Proteids.	17.50	13.44	13.25
Asparagine	3.87	6.60	2.92

IN 100 PARTS OF TOTAL NITROGEN.

	Control dried on 24th	Dark 1% sugar dried on 28th	Dark 10% sugar dried on 28th
Total nitrogen	100.0	100.0	100.0
Albuminoid nitrogen	54.7	42.0	52.1
Asparagine nitrogen	16.0	27.3	15.2
Nitrates nitrogen	**7.0**	**5.0**	**3.3**
Other nitrogen	22.3	25.7	28.4

We observe here a gradual decrease of nitrates nitrogen, depending much upon the quantity of cane sugar present. But the

(1) I could not keep them longer, as they began to show signs of suffering.

nitrates assimilated apparently served in this case only for the production of amido-compounds.

IV. EXPERIMENT WITH YOUNG BARLEY PLANTS.

On March 6, some young barley plants were taken from the field, and put in a 0.2% solution of soduim nitrate, in diffuse day light for 7 days at temperature of Min. 5°C and Max. 15°C. Thus the plants had sufficient time to store up some nitrate. On the 13th the plants were removed from the solution, washed well, and one portion of the plant was directly dried for analysis, while the other portion was divided into 2 parts. One of these was exposed to day light, and the other kept in the dark, both being put in a 1% glucose solution half saturated with gypsum and once in every 4 days, they were transferred in solutions containing 0.1% KH_2PO_4 0.1% $MgSO_4$, half saturated with gypsum. During the experiment the temperature was Min. 8°C. and Max. 15°C. After 7 days, the plants were removed from the solutions, washed well, and dried for analysis.

IN 100 PARTS OF DRY MATTER.

	Control plants dried on 13th	Plants in day light dried on 20th	Plants in dark dried on 20th
Total nitrogen	5.18	5.34	6.19
Albuminoid nitrogen	2.26	1.71	1.49
Nitrates nitrogen	0.25	0.17	0.39
Proteids	14.13	10.69	9.31

IN 100 PARTS OF TOTAL NITROGEN.

	Control plants dried on 13th	Plants in day light dried on 20th	Plants in dark dried on 20th
Total nitrogen.....	100.0	100.0	100.0
Albuminoid nitrogen	43.6	32.0(1)	24.1(1)
Nitrates nitrogen.....	**4.8**	**3.2**	**3.1**

The nitrates nitrogen of the control plants being taken as 100 the following numbers are obtained:

	Control plant	Plants in day light	Plants in dark
Nitrates nitrogen	100.	68.	76.

This result shows that the formation of proteids from nitrates does not take place in darkness when the amount of sugar present is very small.

V. EXPERIMENT WITH POTATO PLANTS.

(a). Young potato plants tolerably rich in nitrates, were carefully removed from the field and washed. One portion of it was directly dried, while the other was put in a 1% sugar solution half saturated with $CaSO_4$, from which it was put into the mineral solution mentioned above once in every three days and left in it for a whole day; the plants being kept all the while in the dark. The experiment lasted from May 12 to 18. The temperature varied from 8°C. to 15°C.

(1) As the plants were kept in a warm house, the growth was considerable in both cases, and the decomposition of proteids was consequently also considerable.

IN 100 PARTS OF DRY MATTER:—

	Control plants dried on 12th	Plants kept in dark dried on 18th
Total nitrogen.	3.92	4.11
Nitrates nitrogen.	0.18	0.14

IN 100 PARTS OF TOTAL NITROGEN.

	Control plants dried on 12th	Plants kept in dark dried on 18th
Total nitrogen.	100.0	100.0
Nitrates nitrogen.	**4.6**	**3.6**

A little decrease of nitrogen in the plants kept in the dark was observed here, but as the sugar solution applied was too dilute, the reduction proceeded rather slowly.

(b) The same experiment was repeated with the same potato plants.

Time of experiment May 13–18.
Temperature Min. 8°C. Max. 15°C.

IN 100 PARTS OF DRY MATTER.

	Control plants dried on 13th	Plants in dark dried on 18th
Total nitrogen.	4.97	5.05
Nitrates nitrogen.	0.54	0.42

IN 100 PARTS OF TOTAL NITROGEN.

	Control plants dried on 13th	Plants in dark dried on 18th
Total nitrogen.	100.0	100.0
Nitrates nitrogen.	**10.9**	**8.3**

In this case also, a little decrease of nitrates nitrogen in the plants kept in the dark, was observed.

SUMMARY AND CONCLUSIONS.

1) Nitrates can be assimilated by Phaenogams in *perfect darkness*.

2) Sugar has great influence upon the reduction of nitrates. When the available amount of sugar is insufficient, the nitrates are not assimilated. This is one of the reasons why contradictory results have been obtained by various authors.

3) *Proteids can be formed from nitrates in perfect darkness* when the conditions are favorable, that is, when much sugar is present in the plant cells.

4) The intermediate product between nitrates and proteids is most probably, asparagine, which accumulates when the conditions for protein formation are imperfect.

5) The reason, why my results differ from those of *Godlewski*, is, that *he did not cultivate his plants in sugar solution.* He found that the nitrates can be converted into non-albuminous nitrogen compound, but he did not ascertain what compound it was.

6) *Laurent's* results have been subjected to some critical remarks by *Godlewski* with whom I agree.

7) After this investigation was finished *Zaleski* published some preliminary results, showing also the possibility of protein formation *in darkness*. (Ber. Botan. Gesellschaft. (1897) **75** 536).

ANALYTICAL DATA.

Total nitrogen was determined according to *Kjeldahl's* method.

Albuminoid nitrogen, according to *Stutzer's* method.

Asparagine nitrogen by that of *Sacchsse*.

Nitrates nitrogen by that of *Tiemann* and *Schulz*.

I. EXPERIMENT ETIOLATED SHOOTS OF BARLEY.

TOTAL NITROGEN.

		Dry matter used	Baryta water replaced	Nitrogen found
		Gram.	c. c.	Gram.
Control plants	1.	0.470	11.3	0.01984
	2.	,,	11.5	
Sugar plants.	1.	0.434	8.7	0.01531
	2.	,,	8.8	

ALBUMINOID NITROGEN.

		Dry matter used	Baryta water replaced	Nitrogen found
		Gram.	c. c.	Gram.
Control plants	1.	0.470	4.9	0.0087
	2.	,,	5.1	
Sugar plants.	1.	0.434	4.6	0.0080
	2.	,,	4.6	

ASPARAGINE NITROGEN.

		Dry matter used	Baryta water replaced	Nitrogen found
		Gram.	c. c.	Gram.
Control plants	1.	0.470	1.6	0.0030
	2.	,,	1.8	
Sugar plants.	1.	0.434	1.25	0.0022
	2.	,,	1.25	

1 c. c. baryta solution = 0.00174 gram. nitrogen.

NITRATES NITROGEN.

		Dry matter used	Temperature	Pressure	Vol. of NO. gas	Nitrogen found
		Gram.	°C.	m. m.	c. c.	Gram.
Control plants	1.	0.940	7.	756	4.8	0.0030
	2.	,,	,,	,,	4.6	
Sugar plants	1.	0.868	,,	,,	0	0
	2.	,,	,,	,,		

II. EXPERIMENT WITH ETIOLATED SHOOTS OF BARLEY.

TOTAL NITROGEN.

		Dry matter used	Baryta water replaced	Nitrogen found
		Gram.	c. c.	Gram.
Plants dried on the 7th	1.	0.466	10.5	0.0181
	2.	,,	10.4	
$CaSO_4$	1.	0.451	10.7	0.0186
	2.	,,	10.8	
$NaNO_3$ and $CaSO_4$	1.	0.470	11.3	0.0198
	2.	,,	11.5	
Sugar and $CaSO_4$	1.	0.464	9.8	0.0174
	2.	,,	10.2	
Sugar, $NaNO_3$ and $CaSO_4$	1.	0.469	11.6	0.0212
	2.	,,	11.7	

1 c. c. baryta solution = 0.00174 gram. nitrogen.

ALBUMINOID NITROGEN.

		Dry matter used	Baryta water replaced	Nitrogen found
		Gram.	c. c.	Gram.
Plants dried on the 7th	1.	0.466	5.4	0.0095
	2.	,,	5.5	
Plants kept in :— (7th–20th) CaSO$_4$	1.	0.451	4.7	0.0084
	2.	,,	4.9	
NaNO$_3$ and CaSO$_4$	1.	0.470	5.0	0.0087
	2.	,,	5.1	
Sugar and CaSO$_4$	1.	0.464	4.7	0.0082
	2.	,,	4.7	
Sugar, NaNO$_3$ and CaSO$_4$	1.	0.469	5.5	0.0096
	2.	,,	5.5	

ASPARAGINE NITROGEN.

		Dry matter used	Baryta water replaced	Nitrogen found
		Gram.	c. c.	Gram.
Plants dried on the 7th	1.	0.466	0.8	0.00157
	2.	,,	1.0	
Plants kept in :— (7th–20th) CaSO$_4$	1.	0.451	2.1	0.0037
	2.	,,	2.0	
NaNO$_3$ and CaSO$_4$	1.	0.470	1.7	0.0030
	2.	,,	1.7	
Sugar and CaSO$_4$	1.	0.464	1.4	0.0026
	2.	,,	1.6	
Sugar, NaNO$_3$ and CaSO$_4$	1.	0.469	1.3	0.0023
	2.	,,	1.4	

NITRATES NITROGEN.

		Dry matter used	Temperature	Pressure	Vol. of NO. gas	Nitrogen found
		Gram.	°C.	m. m.	c. c.	Gram.
Plants kept in :— (7th-20th)	$NaNO_3$ and $CaSO_4$.	1. 0.940	7	756	4.6	0.0030
		2. ,,	,,	,,	4.8	
	$NaNO_3$, sugar and $CaSO_4$	1. 0.938	,,	,,	1.7	0.0009
		2. ,,	,,	,,	1.7	

III. EXPERIMENT WITH *PHASEOLUS MULTIFLORUS*.

TOTAL NITROGEN.

		Dry matter used	Baryta water replaced	Nitrogen found
		Gram.	c. c.	Gram.
Control plants (24th)		1. 0.452	13.3	0.0231
		2. ,,	13.3	
Plants kept in :— (24th-28th)	1% sugar	1. 0.445	13.0	0.0228
		2. ,,	13.2	
	1% sugar	1. 0.444	10.3	0.0181
		2. ,,	10.4	

1 c. c. baryta solution = 0.00174 gram. nitrogen.

ALBUMINOID NITROGEN.

		Dry matter used	Baryta water replaced	Nitrogen found
		Gram.	c. c.	Gram.
Control plants (24th)	1.	0.452	7.2	0.0127
	2.	,,	7.4	
Plants kept in :— (24th–28th) 1% sugar	1.	0.445	5.5	0.0096
	2.	,,	5.5	
Plants kept in :— (24th–28th) 1% sugar	1.	0.444	5.3	0.0094
	2.	,,	5.5	

ASPARAGINE NITROGEN.

		Dry matter used	Baryta water replaced	Nitrogen found
		Gram.	c. c.	Gram.
Control plants (24th)	1.	0.904	2.1	0.0038
	2.	,,	2.3	
Plants kept in :— (24th–28th) 1% sugar	1.	0.863	3.3	0.0059
	2.	,,	3.5	
Plants kept in :— (24th–28th) 1% sugar	1.	0.888	1.6	0.0028
	2.	,,	1.6	

NITRATES NITROGEN.

		Dry matter used	Temperature	Pressure	Vol. of NO. gas	Nitrogen found
		Gram.	°C.	m. m.	c. c.	Gram.
Control plants (24th)	1.	0.904	23	761	5.5	0.0032
	2.	,,	,,	,,	5.6	
Plants kept in :— (24th–28th) 1% sugar	1.	0.890	24	,,	4.0	0.0023
	2.	,,	,,	,,	4.1	
1% sugar	1.	0.888	,,	,,	2.2	0.0012
	2.	,,	,,	,,	2.0	

IV. EXPERIMENT WITH YOUNG BARLEY PLANTS.

TOTAL NITROGEN.

		Dry matter used	Baryta water replaced	Nitrogen found
		Gram.	c. c.	Gram.
Control plants	1.	0.468	12.4	0.0243
	2.	,,	12.4	
Plants in day light	1.	0.480	13.0	0.0256
	2.	,,	13.2	
Plants in dark	1.	0.461	14.5	0.0286
	2.	,,	14.7	

1 c. c. baryta solution = 0.001955 gram. nitrogen.

ALBUMINOID NITROGEN.

		Dry matter used	Baryta water replaced	Nitrogen found
		Gram.	c. c.	Gram.
Control plants	1.	0.468	5.4	0.0106
	2.	,,	5.4	
Plants in day light	1.	0.480	4.1	0.0082
	2.	,,	4.3	
Plants in dark	1.	0.461	3.4	0.0068
	2.	,,	3.6	

NITRATES NITROGEN.

		Dry matter used	Temperature	Pressure	Vol. of NO. gas	Nitrogen found
		Gram.	°C.	m. m.	c. c.	Gram.
Control plants	1.	0.936	18	760	4.0	0.0023
	2.	,,	,,	,,	4.1	
Plants in day light	1.	0.959	,,	,,	2.7	0.0016
	2.	,,	,,	,,	2.8	
Plants in dark	1.	0.921	,,	,,	3.0	0.0017
	2.	,,	,,	,,	2.9	

V. EXPERIMENT WITH POTATO PLANTS.

(*A*).

TOTAL NITROGEN.

		Dry matter used	Baryta water replaced	Nitrogen found
		Gram.	c. c.	Gram.
Control plants	1.	0.468	10.0	0.0183
	2.	,,	10.1	
Plants in dark	1.	0.469	10.4	0.0193
	2.	,,	10.6	

NITRATES NITROGEN.

		Dry matter used	Temperature	Pressure	Vol. of NO. gas	Nitrogen found
		Gram.	°C.	m. m.	c. c.	Gram.
Control plants	1.	0.936	24	758	3.1	0.0017
	2.	,,	,,	,,	2.9	
Plants in dark	1.	0.937	,,	,,	2.4	0.0014
	2.	,,	,,	,,	2.8	

1 c. c. baryta solution = 0.00183 gram. nitrogen.

(*B*).

TOTAL NITROGEN.

		Dry matter used	Baryta water replaced	Nitrogen found
		Gram.	c. c.	Gram.
Control plants	1.	0.476	12.8	0.0237
	2.	,,	13.0	
Plants in dark	1.	0.469	12.9	0.0237
	2.	,,	12.9	

NITRATES NITROGEN.

		Dry matter used	Temperature	Pressure	Vol. of NO. gas	Nitrogen found
		Gram.	°C.	m. m.	c. c.	Gram.
Control plants	1.	0.952	27	758	8.9	0.005
	2.	,,	,,	,,	9.0	
Plants in dark	1.	0 937	,,	,,	7.0	0.004
	2.	,,	,,	,,	6.9	

1 c. c. baryta solution = 0.00183 gram. nitrogen.

On the Properties of Cocoons of the Various Silkworm Races of Japan.

BY

Jiro Kawara, *Nōgakushi.*

The largest and most important production in Japan is raw silk, and the sum of exportation from our country to America and Europe amounts, at present, to nearly 40,000,000 *yen.*[1] The method of silkworm culture has been known to us for more than two thousand years, and in nearly every province of our empire there are planted large numbers of mulberry trees, and silkworms are raised in innumerable numbers year after year by many practical and competent raisers. The principal varieties of cocoons raised are two:—white (Siromayu) and green (Kimayu)[2],—of which the former is extensively and largely cultivated, while the latter is very few, and cultivated only in a limited district. The white variety is again subdivided into a few hundred races, which are distinguished from each other by different raisers. These so-called races can, however, be reduced into a few principal ones.

The object of my investigation was to examine the properties of the thread of the cocoons of these principal races with the view of determining which of them can be raised with the greatest advantage.

The principal races whose cocoons have been subjected to examination are 12 aboriginal, 1 Chinese, and 1 Italian:—

Annuals

1. Akabiki (white)
2. Awobiki (,,)
3. Onichijirà (,,)
4. Koishimaru (,,)
5. Matamukashi (,,)

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(1). *Yen* is equal to 2 francs 75 cent.

(2). Kimayu means "yellow cocoon," but it is really green, as Europeans call it.

6. Kimayu (green)
7. Hakuriu (white)
8. O-setsu (,,)
9. Koishimaru, produced at Hokkaido (white)
10. Chosan (white)

Bivoltins

11. Kumako (white)
12. Natsuko (,,)

Foreign races

13. Chinese (white)
14. Italian (,,)

O-setsu is quite new race produced by our silkworm raisers. Its eggs do not change their colour after deposition, and remain a light yellow till they hatch in the following year. The eyes of the moths are not tinged with black, but light greyish yellow. Chosan is a race which has been produced in our Agricultural College. It was derived from Akabiki by feeding the worms with the leaves of Broussonetia papyrifera twice a day for the last three years.

The properties of the cocoons of each of the above mentioned races were examined with reference to the following ten points :—

1. Length of the filament of a single cocoon... ... (L.F.)
2. Weight ,, ,, ,, ... (W.F.)
3. Weight in deniers ,, ,, ,, ... (W.D.)
4. Diameter ,, ,, ,, ... (D.)
5. Tenacity ,, ,, ,, ... (T.)
6. Ductility (Elasticity) ,, ,, ,, ... (Duc.)
7. Knots ... ... (K.)
8. Ruptures... ... ... (R.)
9. Feature of the unwinding of the filament of a single cocoon ... ... (Unw.)
10. Weight of flocks of a single cocoon ... ... (W.Fl.)

The weight of the filament and that of flocks were taken in the air-dry condition. Knots were counted in the first 238 meters of the filament, and ruptures in its whole length. The feature of unwinding was classified into three divisions indicated respectively by the letters A, B, C, of which A indicates very good, B good, and C tolerable. Flocks are those parts which form the extreme outer and inner layers of a cocoon and can not be reeled.

The results of examination are shown in the following table :—

Races.	No.	L. F. in m.	W. F. in m. grams.	W. D.
Akabiki.	1	631	173	2.45
	2	893	239	2.40
	3	833	199	2.11
	aver.	785	204	2.32
Awobiki.	1	619	133	1.92
	2	690	146	1.90
	3	833	186	2.00
	aver.	714	155	1.95
Onichijira.	1	809	199	2.20
	2	928	213	2.05
	3	797	197	2.21
	4	738	186	2.26
	5	678	149	1.97
	aver.	790	189	2.14
Koishimaru.	1	476	143	2.70
	2	440	138	2.80
	3	655	138	1.89
	aver.	524	140	2.46
Matamukashi.	1	571	120	1.87
	2	512	133	2.33
	3	571	117	1.84
	4	476	106	2.00
	5	488	122	2.24
	aver.	524	120	2.05

D in μ.	T in grams.	Duc. in %.	K.	R.	Unw.	W. Fl. in m. grams.
30.5	12.3	13.1	0	0	A	
31.4	12.7	13.8	1	0	,,	
29.4	10.4	12.9	3	1	,,	
30.4	11.8	13.2	1.3	0.3		44
29.7	7.4	9.7	0	0	A	
28.3	8.6	13.3	1	3	,,	
29.4	8.2	11.4	5	2	,,	
29.1	8.1	11.5	2	1.7		35
27.7	9.5	12.8	4	3	B	
25.8	11.5	12.9	3	15	,,	
26.3	8.1	10.1	4	3	,,	
28.3	10.4	13.3	3	8	,,	
28.0	9.5	12.2	13	7	,,	
27.2	9.8	12.3	5.4	7.2		16
25.8	9.2	12.3	4	0	A	
26.3	9.7	12.8	8	1	,,	
25.2	8.6	12.5	4	2	,,	
25.8	9.2	12.5	6	1		27
24.9	6.4	11.2	2	3	A	
26.9	8.3	12.1	3	1	,,	
25.2	8.7	11.4	2	3	,,	
26.3	9.4	12.5	2	2	,,	
26.3	8.2	11.0	1	1	,,	
25.9	8.2	11.6	1.8	2		11

Races.	No.	L. F. in m.	W. F. in m. grams.	W. D.
Kimayu.	1	655	186	2.54
	2	512	149	2.60
	3	690	223	2.89
	4	619	159	2.31
	5	655	170	2.33
	aver.	626	177	2.54
Hakuriu.	1	536	213	3.55
	2	738	223	2.71
	3	571	239	3.74
	4	678	202	2.66
	5	619	213	3.07
	aver.	628	218	3.11
O-setsu.	1	536	173	2.89
	2	417	159	3.43
	3	666	180	2.50
	4	583	228	3.52
	aver.	551	186	3.09
Koishimaru, produced in Hokkaidō.	1	500	138	2.48
	2	476	143	2.70
	3	—	—	—
	aver.	488	141	2.59
Chosan.	1	512	146	2.56
	2	655	159	2.18
	3	607	133	2.00
	4	702	120	1.52
	5	595	146	2.20

D. in μ.	T. in grams.	Duc. in %.	K.	R.	Unw.	W. Fl. in m. grams.
28.6	8.2	12.7	3	2	A	
29.1	9.6	13.5	3	1	,,	
29.4	10.1	13.7	4	1	,,	
27.7	7.8	10.3	4	1	,,	
28.6	8.9	11.8	2	0	,,	
28.7	9.1	12.2	3.2	1		21
31.4	13.1	14.6	3	1	A	
30.2	11.5	12.2	2	8	,,	
32.2	13.7	15.9	21	1	,,	
29.7	10.9	12.4	5	2	,,	
31.1	12.3	13.9	14	1	,,	
30.9	12.3	13.8	9	2.6		64
27.7	10.1	10.8	3	1	A	
29.7	10.2	10.5	0	0	,,	
28.6	10.7	9.4	2	6	,,	
30.7	11.1	13.6	1	1	,,	
29.5	10.6	11.6	1.5	2		21
25.5	9.3	13.2	1	1	A	
26.9	9.7	12.4	3	1	,	
24.6	8.3	11.9	0	0	,,	
25.7	9.1	12.5	1.4	0.7		32
27.2	8.9	12.9	6	0	A	
25.8	8.6	12.3	3	3	,,	
24.6	8.4	11.8	2	2	,,	
23.5	7.9	12.3	2	4	B	
26.9	9.1	13.6	2	0	,,	

Races.	No.	L. F. in m.	W. F. in m. grams.	W. D.
	aver.	614	141	2.06
Kumako, the first breed.	1	464	80	1.54
	2	369	80	1.93
	3	369	93	2.29
	4	393	85	1.94
	aver.	399	84	1.90
Kumako, the second breed.	1	482	80	1.48
	2	476	66	1.25
	3	440	53	1.08
	4	524	106	1.82
	5	536	93	1.56
	aver.	492	80	1.45
Natsuko, the first breed.	1	437	146	3.14
	2	381	93	2.19
	3	357	86	2.13
	aver.	384	110	2.53
Natsuko, the second breed.	1	250	53	1.90
	2	452	80	1.58
	3	428	80	1.67
	4	357	66	1.67
	5	363	93	2.29
	aver.	370	74	1.78
Chinese.	1	559	170	2.72
	2	619	173	2.38
	3	571	159	2.50
	4		120	2.25

D. in μ.	T. in grams.	Duc. in %.	K.	R.	Unw.	W. Fl. in m. grams.
25.6	8.6	12.6	3	1.8		11
23.5	5.3	7.9	0	0	A	
24.1	7.5	10.4	1	0	,,	
24.9	7.6	12.1	2	0	,,	
23.8	5.8	11.3	2	0	,,	
24.1	6.5	10.4	1.3	0		27
26.2	7.2	10.5	2	0	A	
25.1	6.8	9.4	2	0	,,	
24.3	5.9	6.2	1	0	,,	
27.3	6.1	10.7	1	0	,,	
25.4	5.6	9.3	0	0	,,	
25.7	6.3	9.8	1.2	0		19
26.6	8.4	10.9	2	0	A	
24.6	6.5	10.6	3	1	,,	
24.9	7.8	10.2	2	0	,,	
25.4	7.6	10.6	2.3	0.3		11
27.3	7.3	12.5	2	1	B	
25.1	6.2	9.4	0	1	A	
25.7	6.8	10.7	3	0	,,	
25.9	6.7	10.1	0	0	,,	
26.4	7.9	11.6	1	0	,,	
26.1	7.0	10.9	1.2	1.4		16
27.2	8.5	10.2	2	4	A	
26.3	9.6	10.1	2	1	,,	
26.0	8.7	10.4	2	3	,,	
25.5	6.4	8.3	1	1	,,	

Races.	No.	L. F. in m.	W. F. in m. grams.	W. D.
	5	655	146	2.00
	aver.	576	154	2.39
Italian.	1	690	213	2.76
	2	488	186	3.41
	3	595	191	2.88
	aver.	591	197	2.97

It is a general belief among silk manufacturers, that the size and weight of the filament of a cocoon is proportional to its weight in deniers, that is to say, if a cocoon is larger and its filament heavier, then its weight in deniers is greater, while on the contrary if a cocoon is smaller and its filament lighter, then its weight in deniers is smaller. But my researches show that this is by no means always the case but that the contrary may happen. For example, the filament of a cocoon of the races Awobiki, Akabiki, Onichijira, etc. which measures more than 700 metres weighs less in deniers than that of Koishimaru, Matamukashi, etc., which measures less than 550 metres. In particular the filament of an Awobiki cocoon weighs only as much as 1.92 Deniers. The heaviest filament is, so far I have examined that of the Hakuriu rece, whose filament weighs 3.75 deniers. In view of the facts detailed above, I do not hesitate to say, that the length of the filament is not always proportional to the weight in deniers, and similarly, the weight in deniers of a single filament is not always proportional to the diameter of the same. The weight in deniers and the diameter of a filament of Hakuriu race, which are the highest and largest of the filaments I have examined, are 2.11 and 30.9 respectively. But the filament of the Akabiki race which weighs 2.32 denier measurs 30.4 μ in diameter which is very nearly equal to that of Hakuriu. Furthermore, although the denier of the filament of Koishimaru is reckoned 2.46, which is higher than that of Akabiki, its diameter measures only 25.8 μ. Similar observations were also made in the Laboratoire de la ver à soie in Lyon in 1885. The results obtained in that laboratory were as follows :—

D. in μ.	T. in grams.	Duc. in %.	K.	R.	Unw.	W. Fl. in m. grams.
24.6	7.2	10.2	4	1	A	
25.9	8.1	9.9	2.2	2		24
30.8	8.5	11.6	5	2	C	
32.2	9.6	12.1	1	2	,,	
30.8	8.7	11.9	3	1	,,	
31.3	8.9	11.5	3	1.7		37

Races.		Diameter.	Weight in Deniers.
Cevenne	(yellow)	23.7 μ	2.46
,,	(,,)	,,	2.83
Valleraugue	(white)	32.2 μ	2.54
,,	(,,)	,,	2.98
Milan	(,,)	30.2 μ	2.59

If the results which I have obtained on the relation of the weight in deniers with the diameter of a filament, and those obtained in the Laboratoire de la ver à soie in Lyon be correct then I do not hesitate to say, that this disagreement between the weight in deniers of a filament and its diameter is due to the specific gravity or hygroscopic property of the filament, which may be different in cocoons of different races. Later I expect to spend more time in accurate experiments on these two points, viz. the specific gravity and the hygroscopie property of a filament, and to publish my results in a subsequent number of this bulletin.

Further I may add some remarks on the properties of the filaments examined by me as detailed above. It is commonly known that the longer the filament of a cocoon is the greater is its diameter; thus the filament of a cocoon of an Akabiki, whose length is 785 metres on the average, measures 30.4 μ in diameter, while the filament of a cocoon of a Koishimaru, Matamukashi, and of some bivoltin races, etc., whose length is less than 550 metres, measurs only 26 μ in diameter. In general, the worms of the Akabiki race are much larger in size than those of Koishimaru, Matamukashi, and others; and when the worms are larger in size, their silk-glands must also be larger than those of the smaller

worms, and further, the opening of the spinning process on the labium of the former must also be wider than that of the latter. These differences seem to be closely correlated to the length and diameter of the filament of the cocoons of the various races.

The strength of the filament of a cocoon is proportional to its diameter, but there are exceptions to this rule. Thus by comparing the strength and diameter of the filament of Awobiki, which are 8.1 grams and 29.1 μ respectively, with those of Koishimaru which are 9.2 grams and 25.8 μ., it will be found that notwithstanding the smaller diameter of the latter its strength, which is estimated at 9.2 grams, is far superior to that of Awobiki, estimated at 8.1 grams. Filament of smallest strengths are found among the bivoltins. Thus the filament of the second breed of Kumako (bivoltins) which measurs 25.7 μ in diameter (nearly equal to that of Koishimaru and Matamukashi) has the strength of 6.3 grams only, which is far inferior to that of Koishimaru and Matamukashi whose strengths are respectively 9.2 and 8.2 grams. Filament of the smallest strength and diameter I have observed in the second breed of Natsuko (bivoltins), while filament of the greatest strength and diameter is to be find in Hakuriu, the strength and diameter of the latter being respectively 13.7 grams and 32.2 μ.

The degree of ductility of a filament has some relation to its diameter, but this relation is not so remarkable as that between the strength and the diameter of a filament. It may, however, be said that the ductility depends upon the strength of a filament. Thus, the diameter of the filament in relation to its ductility and tenacity in our aboriginal races examined, is as follows :—

Races	Diameter of filament	Ductility	Tenacity
Awobiki	29.1 μ.	11 5%	8.1 grams
Matamukashi	25.9 ,,	11.6 ,,	8.2 ,,
Onichijira	27.2 ,,	12.2 ,,	9.8 ,,
Koishimaru	25.8 ,,	12.5 ,,	9.2 ,,
Kimayu	28.7 ,,	12.2 ,,	9.1 ,,

THE PROPERTIES OF RAW SILK.

For the examination of the properties of raw silk I took samples from our principal races. Each thread of raw silk is composed of 5 or 6 filaments, and reeled with Zaguri (Japanese hand reel). The results obtained were as follows :—

Races.	Number of filaments.	Number of cocoon in 1shō.(1)	Weight of silk obt. from 1shō of cocoon in momme.(2)	Weight in deniers.	Tenacity in grams.	Ductility in %.	Unwinding.	Weight of flocks obt. from 1shō of cocoons in momme.
Akabiki.	5	250	12.45	14.80	48	19.4	A	2.50
,,	6	,,	12.54	17.00	57	20.7	,,	,,
Awobiki.	5	260	10.48	14.08	47	21.9	B	,,
,,	6	,,	12.10	16.23	58	23.4	A	,,
Onichijira.	5	,,	11.57	10.24	38	21.8	,,	3.00
Koishimaru.	5	280	11.78	11.84	43	21.1	,,	2.50
Matamukashi.	5	340	9.90	12.16	40	20.5	,,	,,
,,	6	,,	10.24	12.60	45	20.9	,,	,,
Hakuriu.	5	260	14.90	14.24	47	21.9	,,	,,
,,	6	,,	14.00	14.60	55	22.3	,,	,,
Osetsu.	5	270	9.96	15.80	49	21.9	,,	2.75
,,	6	,,	10.51	18.40	57	22.1	,,	,,
Koishimaru, produced in Hokkaidō.	5	280	8.41	10.50	39	19.4	,,	2.50
,,	6	,,	9.47	15.28	46	20.6	,,	,,
Kumako, the first breed.	5	320	7.69	10.00	32	18.5	,,	4.00
Natsuko, the first breed.	5	340	6.85	10.80	39	19.8	,,	5.00
Kimayu.	5	280	11.27	13.10	45	24.7	B	5.00

(1) 1 shō = 2 litres. (2) 1 momme = 3.7565 grams.

These figures show that the larger the cocoons are the larger quantity of raw silk they furnish, and vice versa. The O-setsu, however, whose cocoons are of a nearly equal size to those of Akabiki, furnish an exceptionally small quantity of silk.

As I have stated before, the aboriginal races of silkworms, count a few hundreds, but the more widely distributed and cultivated races are, so far I have examined, not more than eight. It will not be entirely useless to compare the properties (diameter, tenacity, and ductility) of these eight races with those of some foreign races mentioned in the report of the Laboratoire de la ver à soie in Lyon. The comparison of the filaments is as follows :—

Races	Diameter	Tenacity	Ductility
Akabiki.	30.4 μ	11.8 grams	13.2%
Awobiki.	29.1 ,,	8.1 ,,	11.5 ,,
Onichijira.	27.2 ,,	9.8 ,,	12.3 ,,
Koishimaru.	25.8 ,,	9.2 ,,	12.5 ,,
Matamukashi.	25.9 ,,	8.2 ,,	11.6 ,,
Kimayu.	28.7 ,,	9.1 ,,	12.2 ,,
Kumako, (second breed.)	25.7 ,,	6.3 ,,	9.8 ,,
Natsuko, (,, ,,)	26.1 ,,	7.0 ,,	10.9 ,,
Yellow, (French race)	29.6 ,,	9.4 ,,	12.1 ,,
,, (Italian race)	30.8 ,,	9.7 ,,	13.6 ,,
,, (Chinese race)	26.3 ,,	7.2 ,,	9.5 ,,
White, (French race)	30.5 ,,	8.5 ,,	11.2 ,,
,, (Italian race)	30.2 ,,	8.8 ,,	12.8 ,,
,, (Chinese race)	25.9 ,,	7.5 ,,	10.6 ,,

This table shows us that the filament of the cocoons of our aboriginal races is not thicker than that of the European races; and the Chinese races which are regarded as giving finer filaments do not show any difference on this point when compared with Koishimaru, Matamukashi, etc.; and only a few bivoltin races, such as Kumako and Natsuko, produce filaments of inferior quality.

In conclusion, I do not hesitate to say that our races of silkworms afford filaments equal in quality to those of any other race; and the fact that some of our filament are of an inferior quality seems to be due mainly to reeling, an incomplete selection of cocoons, and some other causes.

I must here express my hearty thanks to Prof. Sasaki, under whose direction this investigation has been carried out.