MERRILL

The Effect of Fertility on the Transpiration of the Oat Plant

Agronomy

M. S.

1908

THE EFFECT OF FERTILITY ON THE TRANSPIRATION OF THE OAT PLANT

BY

AMOS NEWLOVE MERRILL, B.S.
(AGR. COLLEGE OF UTAH '96)

THESIS

SUBMITTED IN PARTIAL FULFILLMENT of the requirements FOR THE

DEGREE OF MASTER OF SCIENCE

IN

AGRONOMY

IN THE

GRADUATE SCHOOL

OF THE

UNIVERSITY OF ILLINOIS

1908

1908
MSS

UNIVERSITY OF ILLINOIS

June 1, 1908

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Amos Newlove Merrill

ENTITLED The Effect of Fertility on the Transpiration of the Oat Plant.

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Master of Science

Cyril G. Hopkins
Instructor in Charge.

APPROVED: Cyril G. Hopkins

HEAD OF DEPARTMENT OF Agronomy

6

Table of Contents.

Part I

Part II

Part I

REVIEW OF LITERATURE

The Effect of Soil Fertility
on the
Transpiration of the Oat Plant.

Introduction.

In the arid and semi-arid regions of America, effort is being made to find out ways and means of conserving in the soils of the tillable areas the largest possible amount of water that falls in the form of rain and snow.

The experimentation described and discussed in this thesis was undertaken with the intention of collecting additional data that would be of value in the solution of this problem.

The writer is indebted to Dr. Cyril G. Hopkins, under whose direction the work was carried on, for the many helpful suggestions he has given, and to others who, in minor ways, assisted in working out the experiment.

Escape of Water from Soils.

All water that finds its way to a soil that is producing crops leaves that soil in three ways, namely, by drainage, by evaporation from the surface of the soil, and by transpiration of the plants. It is very evident that the greater part of this water must escape from the soil if a water-logged condition is to be avoided. It is equally important, however, that the time, rate, and manner of escape should, so faras possible, be under control.

Influence of Fertilizers
On the Evaporation of Water from the Soil.

W. H. Beal[1] of the United States Department of Agriculture says: "The belief is common that the moisture conditions of soils may be materially modified by the use of appropriate fertilizers, more especially the application of common salt. It is claimed that, by the use of such substances, the power of the soil to collect and retain moisture can be increased to such an extent as to make this means of controlling the water supply of the soil of practical utility."

J. T. Willard[33] of the Kansas Experiment Station applied in pot experiments potassium chloride, super-phosphate, potassium sulphate, sodium chloride, magnesium chloride, kainite, and carnallite at the rate of 904 pounds per acre, lime at the rate of 12 bushels per acre, and barnyard manure at the rate of 28 tons per acre; and in plot experiments kainite, magnesium chloride, super-phosphate, potassium chloride, sodium chloride, plaster of paris, potassium sulphate, potassium nitrate, sodium nitrate, and ammonium sulphate at the rate of 500 pounds per acre; lime and unleached ashes at the rate of 2000 pounds per acre, leaf mold and barnyard manure at the rate of 40,000 pounds per acre.

The evaporation from the pots was ascertained by weighing daily for 100 days, and in the plot experiment, by sampling twice a week from October 19 to November 2. In consideration of the data obtained the author concludes that "Experiments with soil in pots, tried under the most rigid conditions available, showed that the rate of evaporation of water from soils is not sensibly affected by the addition to the soil of relatively large amounts of the substances ordinarily used as fertilizers, nor by certain others. Experiments with outdoor

plots, where both evaporation and drainage came into play, showed no decided effect from the fertilizers, except with the plots to which unleached ashes were applied, which lost water more rapidly than any of the others."

Wollny,[32] a German investigator, from a number of years' experiments with the various kinds of salts used by the Kansas station, concluded that the application of the soluble salts increased the water supply of the soil and lessoned the amount of water transpired by the plants, but in his opinion, the plants received no benefit from the increase of soil moisture as the salts stimulated the growth and a corresponding demand for water which in some cases, at least, is more than the soil actually gains. He suggests, also, that in dry seasons the soil water may become so concentrated by evaporation as to partially or completely prevent the taking up of water by the roots of the plants. It appears, therefore, that the benefits which, on theoretical grounds, would be expected from the saving of the moisture are not, as a rule, realized in practice.

M. Maercker[19] placed in vegetative pots soil already rich in potassium salts. Before growing his plants, more potassium salts were added. The pots were now placed in the greenhouse and the plants allowed to develop. From his experiment, he concluded that the beneficial effects of these fertilizers, under such conditions, was without doubt, due to the conservation of moisture in the soil, and that the action was not only confined to the soil, but extended to the plant as well. As it becomes rich in salts, it is less subject to the loss of water by transpiration.

Von Seelhorst,[25] in 1900, confirmed the resultsof the majority of those who have investigated this question. He found that pots which were not treated with fertilizers lost water more rapidly than those

which were treated, and that potassium and nitrogen fertilizers had a more retarding effect upon evaporation than phosphorus. Indeed, the effect of phosphorus fertilizer is very little. Under field conditions, nitrogen caused the plants to make a rank growth and, as a result, the soil was left in a more exhausted condition than when nitrogen was not applied. When potassium and phosphorus were added this effect was not noticed. To this conclusion Hollring and Kravkov add the weight of their investigations.

In this connection, however, it will be well to bear in mind that while nitrogenous manures accelerate the development of the parts above ground, at the same time, according to E. Gain[4], it stimulates the development of roots as well and thus enables the plants to draw water from the subsoil; and also the conclusion that King[7] of Wisconsin drew from his experiments. He found that the capillary movement of moisture upward was 22.84 per cent greater under the influence of .08 per cent of potassium nitrate than it was under the influence of distilled water.

The writer just cited, about 1892, began to investigate the effect of barnyard manure on the water in the soil. He found that heavy applications of barnyard manure disturbed, for a few months, the upward flow of capillary water and allowed the surface soil to become dryer than when manure was not added. From several years'experiments, however, he found that the manure had but little effect on the amount of water retained in the first six feet of soil; but the amount in the first three feet was 34.41 tons per acre, or 1.09 per cent greater than was found in soils not manured.

From the fact that the manure had the effect of concentrating the moisture in the first three feet of soil lead to the belief that, possibly, the evaporation from the manuredsoil would be greater. To test this, he sank two cylinders 18 inches in diameter and 42

inches deep into the soil of the field plots and in each of these he placed about 600 pounds of soil. These were treated in every respect the same, save that in one just 6 inches from the surface a one-inch layer of manure was placed and 5 inches of soil placed on it. At the end of 105 days by actual weight he found that the manured cylinder of soil had lost by evaporation 4.98 pounds per square foot more than the unmanured cylinder. This amounted to 108.5 tons per acre. Yet, in spite of this loss, the manured soil produced a far larger amount of corn than the unmanured, and at harvest time was only a fraction of one per cent dryer.

In another experiment the wetting of the surface of sand with leachings from barnyard manure decreased the rate at which water was lifted 16 inches, and evaporated from the surface 49.65 per cent.

M. Whitney[81] of the Maryland Experiment Station offers this explanation in accounting for the effect of fertilizers on soil moisture:

"There is little doubt that the surface tension of soil moisture is very low, much lower than that of pure water. Salt and kainite, on the other hand, increases the surface tension of water very considerably and raises it far above that of the soil extract. This probably explains the fact which has been often commented on, that an application of salt or kainite tends to keep the soil more moist. By increasing the surface tension of soil moisture they increase the power the soil has of drawing water up from below in a dry season. Ammonia and urine lower the surface tension of water considerably below that of soil extract, and far below that of pure water. This, probably, also explains another common observation that the injudicious use of excessive quantities of organic matter is liable to 'burn out' a soil in a dry season, because, by reducing the surface tension, water can less rapidly be drawn up from below."

Influence of Soil Humidity on the Rate of Evaporation.

From the data obtained in extended field investigations under a system of irrigation where the amount of water applied to the plots was accurately measured, Dr. Widtsoe[34] of the Utah Station formulated the following law:

"The rate of loss of water from soils varies directly with the initial per cent of moisture in the soil."

Dr. Livingston[13] of the Carnegie Institute, in his studies on the water relations of the desert plants, had occasion to investigate this same subject. The following table is taken from data published by him.

Percent of Soil Moisture.	Loss in Grams.
10	6.95
20	12.62
30	17.69
40	19.58

In connection with the total loss of water by evaporation, he determined, also, the rate of evaporation at the beginning and at the end of his experiment. The soil with a 10 percent moisture content lost water very fast at the beginning but at the end of the experiment the evaporation was very little. The soil with the 20 pér cent of moisture was quite uniform but grew gradually feebler, while the soils with the 30 and 40 per cents of moisture lost almost the same at the end of the experiment as at the beginning.

Effect of Fertilizers on Transpiration.

Those who have worked on this question have grown plants, either in distilled water to which known quantities of plant food elements have been added, or in a soil substratum which had been fertilized with weighed quantities of the fertilizers to be tested. In some in-

stances, sterile sand has been used and in others poor soil.

In 1894 R. Heinrich[6] carried on some investigations to test the transpiration of the oat plant in water culture, the solution containing varying amounts of plant food elements. The solution was formed according to the following formula:

$$4\ H_2KPO_8 + CaCl_2 + 5\ Ca_2(NO_3) + 2\ Mg\ SO_4 + 2\ Fe\ \#$$

His results are shown in the following table:

Strength of Sol.%	Total dry matter	Amt. of H_2O for 1 g.dry substance
3	134	515
1	74	550
.5	44	684
.25	28	688
.1	18	629

With the exception of the .1 percent solution, it will be observed that as the concentration increased, the amount of water transpiredfor the production of one gram of dry substance decreased.

In the same article, the author points out that the amount of transpiration of the oat plant varies, not only with the concentration of the nutrient media, but with the humidity of the atmosphere as well. Thus in a constantly humid atmosphere the oat plant transpired 102 grams of water for each gram of dry substance while in a dry atmosphere, the water required was 618 grams.

In 1899 A. Pagnoul[21] of France conducted transpiration experiments to determine the effect of fertilizers on the rate of transpiration. He divided his pots into two series, one containing poor clay without fertilizers, and the other rich calcareous soil fertilized with nitrate of potassium and dried blood. The water content of the pots was kept constant and the same. From March 30 to June 21 fescue grass was grown. On May 2, 27, and June 21 the grass was cut, dried, and weighed with the following results:

Probably the chloride.

Water transpired for one gram dry substance

	Poor Soil	Good Soil
First period 33 days	1190	555
Second period 26 days	1053	581
Third period 27 days	1084	585

The analysis of the plant showed that for each gram of nitrogen stored 46 killograms of water were transpired from the plants in the poor soil while only one killogram# was required for the production of one gram of nitrogen when the plants were grown in the good soil.

Deherain[3] obtained similar results, but in a different way, and with different plants. For his experiment he put into each of five pots 60 killograms of exhausted soil. These pots were kept out of doors and irrigated as required with rain water. The amount that drained through was collected, measured, and analyzed. The difference between this amount and the amount applied was supposed to represent the amount that passed through the plants. He considered that the amount which evaporated from the soil could be neglected without affecting very seriously his results, so no check pots were kept. Raygras## was grown the first year and clover the second year of the experiment.

The difference seems to be too great.
Arrhenaterum elatius.

The following table gives a summary of his results:

1890 Treatment	Pot No.	Wat. added 4/7 to 9/7 c.c.	Drainage 4/7 to 9/7 c.c.	Wat. evap. c.c.	Dry mat. harv. Per pot g.	Per ha. kg.	Wat. req. for 1 g. dry sub. c.c.
					Raygras		
Manure	1	37770	9400	28370	45	2700	630
Poor soil	2	37770	11140	26630	39	2340	683
Art.fert.	3	37770	10650	27120	102	6120	266
Manure leach.	4	37770	9900	27870	64	3840	436
Manure leach.& art.fert.	5	37770	8580	29190	65	3900	449
1891					Clover		
Manure	1	37770	9068	28702	89	5340	322
Poor soil	2	37770	8140	29630	65	3900	456
Art.fert.	3	37770	9050	28720	72	4320	399
Art.fert.	4	37770	12410	25360	99	5940	256
Manure leach.& art.fert.	5	37770	11920	25850	95	5700	272

From the table just given we find first, that, with one exception, the plants grown in the pots to which fertilizers were added used considerably less water than the check pot. The exception occurs the first year in pot No.1. This probably is due to the fact that the manure did not become thoroughly incorporated with the soil for some time and thus its influence was not felt until the second year. Second, the various fertilizers exerted a very different influence on the amount of water used by the plants. Third, there was considerable difference in the amount of water used by the grass and the clover in the production of one gram of dry substance.

Deherain's# conclusion from his own experiment was to the effect that the plantsin the fertilized soil required less water for the production of one gram of dry substance than the plants growing in the unfertilized soil, the amounts being, for the fertilized soil, 250 to 300 grams and the unfertilized soil 450 to 600 grams for every gram of dry matter produced.

The results obtained by King (8) of Wisconsin substantiate, in general, the statement made concerning the amounts of water required by different crops.

The following table gives the results he obtained from a number of trials with various crops:

Crops	No. of trials	Lbs. water for 1 lb. dry sub.
Dent corn	4	309.84
Red clover	3	452.80
Barley	3	392.89
Oats	5	557.34
Peas	1	477.37
Potatoes	2	422.70

Three years later the same author published data, giving the results of his experiments for a number of years, both in the field and in the plant house. The following is a table of his results:

Crops	No. of trials	Water req.per T. dry sub. acre inches##
Corn in field	8	2.433
Corn in plant house	44	2.386
Oats in field	8	5.011

#Die Verdunstungs grosse pro g.Trockensubstanz sank also mit der Ertragshohe und dem Bodenreichtum. Wahrend die Pflanzen im armen Boden 450-600 gr. Wasser zur Erzengung von 1 g.Trockensubstanz verdunsten mussen, genugen im nahrstoffreichen Boden 250 zo 300 g."

An acre inch is water enough to cover one acre one inch deep and is equal to 3,630 cu.ft. and weighs 103.39 tons.

Crops	No. of trials	Water req. per T. dry sub. acre inches
Oats in plant house	12	4.535
Clover in field	24	5.345
Clover in plant house	22	5.005
Potatoes# in field	6	4.283
Potatoes in plant house		2.618

In 1850 J. B. Lawes (14) of the Rothamsted Station of England performed an experiment in which he tested the amount of water required by different plants taken from the two orders, Gramineae, on the one hand, andLeguminoseae, on the other. These plants were transplanted into pots containing both manured and unmanured soil and grown under extremely artificial conditions. The following table gives a summary of his results:

Soil treatment	Crops	G. water for 1 g. dry sub.
Unmanured	Wheat	248
	Barley	258
	Beans	209
	Peas	259
	Clover	220
Manured with MineralManures	Wheat	222
	Barley	256
	Beans	219
	Peas	211
	Clover	229

The results obtained by Lawes do not agree with those obtained by Deherain, King, and others which I shall give in another connection. In explanation, it should be said, that the wheat and barley, especially, did not yield readily to the transplanting and were sickly throughout the experiment. It is very probable, also, that the extremely artificial conditions under which the plants were placed had something to do with the results obtained.

Potatoes did not develop normally and thus the difference.

In 1895 M. Mäercker (17) tested the influence of crude potassium saltsupon the amount of water required by plants grown on the soil which contained these salts in varying proportion. His experiments were conducted in pots. The pots were divided into two series, according to the amount of water given them. To the one, 60 percent of the water holding capacity of the soil was added, to the other, 27 per cent. The plant used in this experiment was white mustard. The following table gives a summary of the results:

Salts	Amount added. lbs. per acre.	Comparative amount of water required	
		60%	27%
None	None	100	100
Kainite	890	90.5	77.1
Kainite	1780	88.4	38.2
Carnallite	1780	91.9	68.9
Sodium chloride	1780	61.2	55

From the above data it appears that the addition of the salts of both potassium and sodium decreases the transpiration of the plants growing under its influence, especially when the soil moisture is low. These results are in harmony with the conclusions of Sachs,(28) published in 1880. He says: "More than twenty years ago I further confirmed the remarkable fact, already in part noticed by Senebier, that the transpiration from leaves (of plants) may also be altered by the presence of material dissolved in the water which the roots take up."

F. H. King (7) of the Wisconsin Experiment Station, while testing the effect of applications of barnyard manure on the moisture of the soil, observed that, while the manured soil produced a much larger crop than the unmanured, it contained almost as much moisture at harvesting time. He concluded, therefore, "That the difference in yield was so great as to demand either that it takes less water to

produce a pound of dry matter on manured than on unmanured ground, or else the manured soil has the power of supplying water to the corn which the unmanuredsoil has not."

In 1896 M. R. Schröeder, Jr., (24) a Russian, published the results of his investigations on the development and transpiration of barley under the influence of different degrees of humidity and of fertility of soil. Since some of the details of the experiment resemble so closely my own, I give, in full, the French resume' together with the English translation:

"Development and Transpiration of Barley
Under the Influence of the
Difference in Humidity and Different Nutritive
Capacity of the Substratum."#

The author compares the effect which manifests itself under the influence of change in the humidity of the substratum with the corresponding effect of change in the concentration of the nutritive solution.

\# "Developpement et transpiration de l'orge
sous l' influence de differente humidite',
et de differente capacite' nutritive du substratum."

"Resume' de l'article de M.R.Schröeder. L'auteur compare l'effet qui se manifeste sous l'influence du changement dans l'humiditi du substratum avec l'effect correspondant au changement dans la concentration de la solution nutritive.

The experimentswere made upon barley which was raised in glass vessels filled with sterile sand.

The humidity of the sand contained in these vessels was a s follows: 1st series 80%; 2nd series 40%; and 3d series 20% of the capacity of the sand for water.

The nutritive mixture was prepared after the formula of Dr. Hellriegel (6.20 gr. $KH_2 PO_4$; 1.71 gr. KCl; 2.19 gr. $Mg SO_4 \; 7H_2O$; 29.90 gr. $Ca (NO_3)_2$).

The concentration of the nutritive mixture in the vessels was: 1st series .6%, .4%, .3%, .2%, .1%; 2nd series .6%, .4%, .3%, .2%; 3rd series 1.2%, .8%, .6%, .4%, .2%. These tests established the following results:

The development of the adventive stems was more pronounced as the rate of the salts was more elevated for the same degree of humidity, and for the same quantity of salts the duration of the vegetative

----

Les experiences furent faites sur de l'orge que l'on avait elevée dans des vases en verre, remplis de sable sterile.

L'humidite du sable, contenu dans ces vases, etait telle: I iere serie 80% II serie 40% et III 20% de la capacite du sable pour l'eau.

Le melange nutritif etait preparé d'apris le Dr. Hellreigel (6.20 gr. $KH_2 PO_4$; 1.71 gr. KCl; 2, 19 gr. $Mg SO_4 \; 7H_2O$; 29.90 gr. $Ca (NO_3)_2$).

La concetration du melange nutritif était dans ces vases: dans la I ière série 6 0/00, 4 0/00, 3 0/00, 2 0/00, 1 0/00; II serie 6 0/00, 4 0/00, 3 0/00, 2 0/00; III série 12 0/00, 8 0/00, 6 0/00, 4 0/00, 2 0/00.

Ces expériences permirent d'établir les consequences suivantes.

La developpement des tiges adventives etait d'autant plus pro-

period was prolonged according as the plant had more water at its disposal. The duration of the vegetative period was more prolonged as the quantity of salts contained in the soil was increased.

In regard to the dimensions of the plant it was always observed that the greatest length of the stems, of the blades, and of the heads corresponding to the maximum of humidity and to the concentration of salts in the soil. But the produce of the entire plant and of each of its parts we find each time by the harvest an increase in dry matter following the augmentation of the humidity and of the nutritive capacity of the soil.

As to the relative value of the harvest considered by all parts of the plant we find that in the condition corresponding to the highest degree of humidity and to the greatest nutritive capacity of the medium we gather twice the quantity of straw and grain that we do in the contrary conditions.

----

noncé que le taux des sels etait plus élevé pour un même degré d'humidite: et pour la même quantité des sels, la dureé de la période végitative était d'autant plus longue que la plante avait plus d'eau à sa disposition. La dureé de la période de vegetation etait d'autant plus longue que la quantite des sels, contenu dans le sol, etait plus éleveé.

Quant aux dimensions des plantes on remarquait toujurs que la plus grande longueur de la tige, du limbe et des épis correspondavent au maximus d'humidity et de concentration des sels, dans la sol.

Par rapport à la plante entiere et chacune de ses parties on constate chaque fois pour la récolte en matieres sèches, un surcroit, suivant l'augmentation de l'humidite et de la capacité nutritive du milieu.

Quant à la valeur relative de la recolte, rapporteé à chaque

The development of the root system increased with the diminution of the humidity and of the nutritive capacity of the medium in which it was developed. The development of the stems as well as the leaves increased according to the increase of the nutritive capacity of the medium.

The general quantity of water transpired by barley was increased, as was the humidity and the nutritive capacity of the substratum.

The quantity of water evaporated compared with a unit of dry matter varies insensibly after change in the concentration of the medium. It gained as the latter increased up to a certain limit (.4%) and then decreased. The rate of water evaporated corresponds directly with the quantity contained in the soil.

----

partie de la plante, on constate que dans la condition correspondant au plus haut degre' d' humidité et à la plus grande capacite nutritive du milien, on recoltait deux fois plus de paille et de grain que dans des conditions contraires.

Le developpement du systeme radiculaire augmente aver la diminution de l'humidite et de la capacité nutritive du milieu dans lequel il fait son évolution.

Le developpement des tiges airisi que des feuilles, saccroit suivant l'augmentation de la capacite nutritive du milieu.

La quantite générale de l'eau transpiree par l'orge etait d'autant plus elevée, que l'etaient l'humidite et la capacite nutritive du substratum.

La quantite d'eau evaporeé, compareé à l'unite en matiere seche, variait insensiblement suivant le changement de la concentration du milieu: elle séleve quand celle ci augmente jusquá une certain limite (4 0/00), et ensuite elle retombe. Le taux d'eau évaporeé est en rapport immédiate avee la quantite contenue dans le sol.

The average amount of water dispensed by the barley for the formation of one gram dry matter was 475 grams.

The average amount of water transpired in 24 hours by a leaf surface of 100 cm. was 72 grams, while from the same surface of water it was for the same period 16.7 grams.

In comparing these data with the preceding figures (475 gr. H_2O for 1 gr. dry matter) the author concludes that the barley forms upon an average .015 grams of dry matter in 24 hours for 100 cm. of leaf surface, so that 100 grams of leaf tissue (having a surface of 200 square cm.) furnishes an average of 300 mgs. of dry matter in 24 hours."

Translated by Dr. T. J. Burrill.

La moyenne de l'eau depensee par l'orge pour former un gramme de matiere seche etait-475 gr.

La moyenne de l'eau transpirée en 24 houres par une surface de 100# c.c. recouverte de feuilles etait-72 gr. tandis que pour une surface libre recouverte d'eau, elle êtait pendant la même période 16.7 gr. c.c.

En comparant ces dounees avec les chiffres precedents (475 gr. H O pour 1 gr.de matieres seche) l'auteur conclut que l'orge forme en moyenne par 24 heures 0.015 gr. de matieres seches sur 100 c.c.# de surface foliaire, de sorte que 100 gr.c.c.de tissu foliaire (avec une surface de 200 □ c.c.#) fournit en moyenne 30 mmgr.de matieres seches en 24 hours."

It is c.m. in the original Russian.

Influence of Soil Moisture
On the Transpiration of Plants.

There is a very close relationship between the amount of water taken in by the roots of a plant and the amount transpired through the leaves. Within certain limits the plants, by opening or closing the stomata of the leaves, can regulate the transpiration stream. If, however, water is withheld from a soil which is supporting plants there comes a time, sooner or later, when the water content of the soil becomes so low that the plants are unable to gather enough to supply their needs, and as a consequence the plants wilt. Sachs (11) found that the tobacco plant (Nicotiana tabacum) behaved very differently when grown on various typesof soil with a low moisture content. When grown in humus soil, wilting occurred when the water content was at 12.3 per cent; but in loam the wilting did not occur till the water was reduced to 8 per cent, nor in sand till the reduction was as low as 1.5 per cent. Liebenberg (11) showed, however, that the power the soils possess of withholding their water from the plants does not depend upon their absorbing power.

The power of the plant to gather water from a substratum of low humidity depends upon their adaptation. The wilting point, according to Livingston, (13) varies between 5.5 and 13.7 per cent. Those plants which do not wilt until the soil is reduced to 5.5 per cent# of its moisture content are especially suited, structurally, for xerophytic conditions, while those that wilt at 13.7 per cent of the moisture content of the soil are mesophytes.

Hales (2) observed that the transpiration of the sunflower was greatest in wet earth. Some few years (1879) later Reister (2) and Bohm (2) found that as the water content of the soil diminished the

----

Per cent of wet volume.

transpiration of the plants growing upon it diminished also.

Hartig (2) grew oat plants from the middle of April to the middle of August under such conditions that the evaporation from the soil was controlled. The following table gives a summary of his results:

Per cent of water	80-60:	60-40:	40-30:	30-20:	20-10
Total Transpiration g.	7394:	5556:	5715:	3191:	642
Amt.of water for 1 g. dry sub.	538:	457:	444:	414:	405

From the above table it is seen that the transpiration increased with the increase of the water content of the soil; and that the production of dry substance, in proportion to the water evaporated, increased, in every case, as the water content of the soil decreased.

From the data obtained from experiments with ligenous plants Sorauer (2) reached the same conclusions as Hartig but adds further that the per cent of nutrient material is higher in plants grown with a scanty supply of moisture.

Widtsoe(34) of the Utah Station, under a system of irrigation, in which known quantities of water could be applied, collected data that agrees with that collected by Hartig and Sorauer. He also gives the following table which shows the relation existing between the amount of water in the soil and that found in the growing plant. He grew wheat under field conditions and made frequent moisture determinations with the following results:

Date	Water in plant	Water in soil 0-12 in.
June 25th	77.23	10.06
June 26th	77.81	20.05
July 1st	74.39	15.22
July 3rd	74.87	13.32
July 9th	72.61	18.18
July 11th	71.63	17.46
July 12th	69.30	20.12
July 13th	69.08	18.54
July 19th	67.24	20.46
July 30th	56.22	16.02

From the above table it is seen that when the per cent of water in the soil varies between 10 and 20 per cent the per cent of water in the plant, for any given period of growth, is practically constant and independent of the per cent of water in the soil.

The table is interesting, also, in that we get from it a confirmation of the generally accepted belief that the per cent of water in the plant becomes smaller as the plant approaches maturity.

Influence of Soil Moisture on Yield.

It often occurs that desert soils which are very rich in plant food elements produce but little or no vegetation, owing to the limited amount of moisture they contain, while, on the other hand, soils very poor in plant food elements can be made far more productive, for a time at least, by a copious supply of water.

Livingston (12) has shown that the amount of water which passes through the plant during a period of active growth is a safe criterion in judging the amount of growth the plant is making. Whatever this factor may be for ordinary soils, it is greatly modified by the addition of fertilizers.

A certain amount of water is absolutely essential for plant growth. The whole of this amount, in the case of the higher plants, is taken in through the rootsfrom the substratum in which the plant is growing.

The amount retained by a soil for any length of time depends upon the physical texture and chemical composition of the soil. According to E. Gain (4) this amount is not constant but fluctuates, ordinarily, between 25 and 35 per cent in the surface soil in place, "although the coefficient determined in the laboratory gives about 50 per cent." These numbers are given in terms of weight.

Concerning the capacity of a soil for water, Gain, (4) on the authority of Wollny, gives the following: "(1) A compact soil loses more water by evaporation than a loose one, because the capillary spaces are smaller in diameter and more easily conduct to the surface the water in the deeper layers. On this account the surface of a compact soil remains moist longer than a loose one. (2) A compact soil has a greater capacity for water than a loose one, although it is less permeable. The capillary spaces are smaller, the number of water pores are increased, and the penetration of water into the subsoil is hindered. (3) A compact soil offers more water for the plant than a loose one."

It thus appears that the amount of water in a soil is controlled, to a very great extent, by soil treatment. The amount a soil will produce is very largely determined by the amount and form of the plant food present and the water content, water acting not only as a solvent of the essential elements, but as a vehicle for the food elements intended for the roots of the plants. That fertilizers are far more effective when an ample supply of water is present was pointed out by E. Gain, (4) and borne out by the investigations of others.

Hellriegel is quoted by Whitney (31) as agreeing in the main with the following table given by Wollny (4) which is intended to show the optimum water content for the production of crops. Representing by 100 the quantity of water necessary for a complete saturation of the soil he finds that the production of dry matter in barley varies with the different water content of the soil as follows:

Moisture in Soil.	Yield in dry material.	
Per cent	Grain g.	Straw
80	8.77	9.47
60	9.96	11.
40	10.51	9.64

Per cent	Grain g.	Straw
30	9.73	8.70
20	7.75	5.50
10	.72	1.80
5	.00	.12

This table shows that while the optimum moisture content for maximum yield of grain is 40 per cent, for straw it is 60 per cent. That the maximum yield of both grain and straw is not obtained with the same moisture content is nowhere better shown than in a system of farming where irrigation is depended upon to furnish the most of the water required by the plants.

A given moisture content may be either, the average for the season, or a constant humidity. If the above experiment were repeated under the two conditions, as regards moisture, just stated, it is very likely that the results would not agree. If the water content were to be the average, short periods of drouth could be followed by copious watering which would result, if conducted wisely, very beneficially to the plant. The other case admits of no such fluctuations in the water content.

Then, too, according to Mac Dougal, (19) there is in the plant's life what are known as critical periods. In the case of grains, one of these periods occurs just as the heads are filling. Too humid conditions at this time results in adecrease in the amount of grain produced, while the amount of straw produced would not be so affected.

Previous soil treatment may influence very greatly any data that may be collected on this question. For example, Lawes and Gilbert (15) found that the effect of fertilizers on yields in dry and normal seasons were as follows:

Fertilizer used.	Yield of hay per Hectar 1870 dry season. .76 cm. of water.	Average 14 yrs. 1.63 cm.	Deficit
	Kg.	Kg.	Kg.
No fertilizer.	725	2771	2046
Mineral fertilizer. No nitrates.	3625	6527	2902
Mineral fertilizer. Nitrate of soda.	7000	7250	250

This table shows that if pot culture or plot culture experiments were carried on with soils rich in nitrates the optimum yield may be at a lower per cent of humidity than Hellriegel found, or, on the other hand, if very low in fertility, higher than he found. There is in volume 13, page 631, of the Experiment Station Record an abstract of an article published in 1900 by Prianishnikov, in which the author gives the results of his experiments in which he tested the influence of soil moisture on the growth of plants. The following quotation is taken from this abstract:

"It is usually accepted, that with an increase of moisture in the soil, the yield of straw increases while the yield of grain diminishes. This is contradicted by the author's experiments with wheat during two years in which there was a steady rise in percentage of grain with an increase in the amount of water in the soil."

The author found, however, that the amount of nitrogen in the seed decreased as the humidity of the soil increased, which is in general agreement with the results obtained by Lawes and Gilbert, (14) Von Seelhorst, (26) Mayer, Widtsoe (34) and others.

Summary.

If a water-logged condition is to be avoided, the greater part of the water that finds its way to a soil must leave it.

Soluble salts increase the power of the soil to retain moisture while barnyard manure decreases it slightly, but causes a translocation and a concentration of moisture in the first three feet of the soil.

"The rate of loss of water from soils varies directly with the initial per cent of moisture in the soil."

Plants use less water for the production of a given amount of dry substance when growing in media in which there is an abundant supply of available plant food than when the contrary condition is present.

Different crops of the different orders or of the same order of plants use very different amounts of water for the production of a given amount of dry substance when grown under the same conditions.

Plants grown in a relatively humid substratum transpire more freely than plants grown on a relatively dry substratum and use a larger amount of water for the production of a given amount of dry substance, but are poorer in the amount of nitrogen they contain.

Within certain limits, the amount of water in the growing plant is independent of the amount in the soil.

The amount of water in the soil varies with the amount reaching it and with previous soil treatment the variation, ordinarily, being between 25 and 35 per cent by weight in the first foot.

The optimum moisture content of the soil for the maximum grain yield is not the same as for straw, and depends upon the chemical composition of the soil, as also does the minimum for the production of either.

Part II

EXPERIMENTATION

EXPERIMENTATION.

Introduction.

As has already been pointed out, in testing the effect of fertility on the transpiration of plants, one may employ either distilled water, sterile sand or other sterile media to which have been added known amounts of the fertilizers; or one may use exhausted soil, the history of which is known and the composition of which has been determined by chemical and physical analysis. The soil used in this experiment, while not what may be called an exhausted soil, was of low futility for the type.

The time of year in which the experiment was conducted made the use of the green house imperative in order that the proper light and heat relations might be secured. There is no reason to suppose, however, that the comparative results would be materially changed under field conditions where the moisture is under control. The experiments of King of Wisconsin[9] show that when plants are grown the same time of year in the green house and in the field the amount of water required for the production of one gram of dry substance differs but little.

History of the Soil.

The soil used in this experiment was a brown silt loam, a type that is very common in the corn belt region. It was obtained from between plots 770 and 771 from the South Farm of the University of Illinois. These two plots are separated by a strip 8 1/4 feet wide. Plot 771 has received treatment but plot 770 together with the strip has received no treatment, save cultivation. Previous to the year 1903, at which time the station began its work upon it, the land had

been under a system of tenant farming and cropped principally to corn and oats. The following table gives the yield of plot 770 from 1903 to 1907 inclusive:

Year	Yield	
	Corn bu.	Stover T.
1903	34.2	1.33
1904	35.6	1.50
1905	44.3	1.21
1906	53.2	?
1907	52.1	1.70
Average	43.8	1.43

It is assumed that the soil taken from the strip differed but little from that of plot 770, the history of which has just been given.

The soil was taken from the field the sixth day of November, 1907, in the following manner: Beginning at a place a few yards from the west side of the division, a strip of soil, averaging about one foot in width and about three inches deep, was taken and placed into a four-gallon jar. When the jar was full, the contents were emptied here and there into the box of a wagon which was driven alongside, care being taken to mix the soil at this handling. When sufficient soil had been emptied into the wagon box, it was taken to the green house and shoveled out into a pile by the door. From this pile it was shoveled into a half bushel can from which it was scattered along on a bench in the green house, thus insuring again a thorough mixing. At the time it was brought in, it contained just enough moisture to make it handle easily. It remained on the bench in the green house until the end of the first week in December, at which time it was placed into four-gallon, glazed, earthen jars which were used in the experiment. Just before the soil was put into the jars, however, it was passed through a sieve containing nine meshes to the inch. It was then placed into the jars and compacted by pressure from the hand.

No effort was made to put the same amount of soil in each pot. Every effort was made, however, to have the soil in all the jars perfectly uniform both chemically and physically. As the pots were filled they were transferred to another green house in which the experiment was conducted. The next day after filling, the soil in the jars was dampened down and allowedto settle until December 23rd. In the meantime just enough water was added to the jars to keep the soil damp. As was anticipated, the soil in the jars settled somewhat. Just before taking the final weights, the jars were again filled to a mark about one-half inch from the top with soil exactly the same as that already in the jars.

During the time intervening between December 23rd and 28th the soil was removed from each jar, the jar was carefully wiped out, the drain hole carefully covered over with glass wool and a small piece of wire gauze, weighed and the weights recorded. Before replacing the soil into the jars, it was thoroughly mixed and a small sample taken for the determination of the moisture content.

About one-half of the soil was now returned to the jar. With the other half the fertilizers were mixed then this, too, was returned to the jar. Thus to only about the first five inches of soil was any fertilizer added. The pot and soil were now weighed and the difference between this weight and the weight of the pot was taken as the weight of the soil plus the water it contained at the time of weighing.

The average moisture content of the soil at the time of sampling was 19.25 per cent, but varied from 15.38 per cent in jar No.209 to 24.73 per cent in jar 303 . The exact moisture content of each jar at this time may be ascertained from tables I, II, and III.

Hereafter, whenever weight of soil is referred to, except otherwise stated, reference is made to dry, or water free soil.

The average weight of soil to the jar was 14303 grams, but varied from 12858 grams in jar 306 to 15149 grams in jar 311. The exact number of grams of soil in each jar may be ascertained by referring to the tables just cited.

The soil was again allowed to settle in the jars and an attempt was made to keep the moisture content of all the jars at about 50 per cent of the water holding capacity of the soil as this was considered to be the most favorable for the decomposition of the organic fertilizers applied and the germination and growth of the seed subsequently.

Analysis of the Soil.

Physical: For the purpose of making a physical analysis of the soil, an average sample was set aside at the time the jars were filled. From this larger sample two five-gram samples were taken, placed into shaker bottles which contained several hundred cubic centimeters of distilled water and about twelve drops of ammonia each. The bottles were now placed in the shaker and agitated until all the soil particles were separated one from the other. The coarse, medium and fine sands were separated from the silt and clay, and from each other, by the sieve and modified decantation method that is now employed in the soil physics laboratory of the University of Illinois. The coarse and medium silts were separated from the fine silts and clay and from each other by the centrifugal and modified decantation method. The following table gives the results of the analysis as it was obtained in duplicate:

	I.	II.	Average
Hygroscopic moisture	2.61%	2.62%	2.61%
Loss on Ignition	6.09%	6.09%	6.09%
Clay and fine silt	17.28%	18.24%	17.76%
Medium silt	14.50%	12.50%	13.50%
Coarse silt	34.41%	33.16%	33.78%
Fine sand	22.44%	25.17%	23.80%
Medium sand	6.32%	6.32%	6.32%
Coarse sand	.36%	.35%	.35%
Total	101.40%	101.83%	101.61%

Chemical: In determining the moisture content of the soil in the various jars two twenty-gram samples were taken from the sample obtained at the time the jars were last filled, or,in other words, forty grams ofsoil were taken from each jar. The moisture determinations were made in duplicate in the usual way. The resultsof these determinations may be seen in tables I, II, and III.

After the moisture determinations were all made, the twenty-gram samples which had been used in these determinations were all put into a pan and thoroughly mixed, the idea being to get uniform, composite samples of the soil in all of the jars for the chemical analysis. The method employed in making this analysis was the same as that now in use at the Soil Fertility Laboratory in the University of Illinois. The figures in the following table, which gives the results of the chemical analysis, represent the total nitrogen, but only the amounts of phosphorus and potassium which were extracted by digesting the soil sample for ten hours at boiling temperature with Hydrochloric acid with a specific gravity of 1.115.

	I. Per cent	II. Per cent	Average Per cent	Lbs.per A.# 1st 7 inches
Nitrogen	.171	.173	.172	3450
Phosphorus	.056	.055	.055	1119
Potassium	.286	.286	.286	5738
Insoluble matter	82.95	82.95	82.95	
Dry matter	98.29	98.29	98.29	

It will be remembered that it was stated in the foregoing pages that partially exhausted soil was usedfor the experiment under discussion. A comparison of the figures just given with those obtained by analyzing a soil capable of producing 80 to 100 bushels of corn per acre, reveals the fact that the phosphorus and nitrogen are low and thus are the limiting elements in crop production. The crucial test, however, of the fertility of a soil is obtained when crops are grown upon it. The fertility of this soil, therefore, may best be judged by referring to the history. It will be seen that the average of the crops produced in five years was 43.8 bushels of corn, only about half that produced on the best treated plots on the Illinois Experiment Station farm. That the phosphorus and nitrogen are the limiting elements is also evidenced from ready response this soil shows when treated with fertilizers containing these elements. This fact is brought out clearly by referring to either the tables or the photographs in the appendix.

2,000,000 pounds per acre.

Fertilizers Used.

Steamed bone meal which yielded about 13 per cent of total phosphorus was used as a source of the phosphorus. For this experiment six grams of bone meal were applied to the pot which was equivalent

to 960 pounds per acre.

Fifteen grams per pot of dried blood, yielding 14 per cent of nitrogen, served as a source of the nitrogen. If applied at this rate in the field 2400 pounds per acre would be required.

The potassium and magnesium were applied in the form of the sulphates. Three grams per pot, which is equivalent to 480 pounds per acre, were added. The magnesium was added, not because it was considered that the soil was deficient in this element, but rather for a comparison with the potassium. By the acid-soluble method the amount of potassium obtained in the analysis of the soil was equivalent to 5738 pounds of potassium per acre. For a rough estimate it has been assumed that the equivalent of only about one per cent of the total potassium in the first 7 inches can, by practical methods of farming, be made available each year (4). On this basis 57 pounds would be made available and this would not be sufficient for a large crop, for a 100 bushel oat crop requires something like 68 pounds of this element (4). This being true, this soil is possibly slightly deficient in available potassium. In fact the Illinois Experiment Station has found (4) that the addition of potassium does not always increase the productivity of this soil, but, on the other hand, may sometimes act disadvantageously.

The method of analysis employed gave all the nitrogen, and practically all of the phosphorus the soil contained. According to Dr. Hopkins (4) of the Illinois Station, it may be roughly estimated that the equivalent of about two per cent of the nitrogen and one per cent of the total phosphorus contained in the first seven inches of the soil may be rendered available each year for the plant. Taking the total amount of nitrogen in the first seven inches of soil as 3450 pounds, and the total amount of phosphorus as 1119 pounds per acre,

according to the above calculation there would be about 70 pounds of nitrogen and 11 pounds of phosphorus available per acre per annum. Since it requires 97 pounds of nitrogen and 16 pounds of phosphorus to produce a 100 bushel crop of oats or 148 pounds of nitrogen and 23 pounds of phosphorus for 100 bushel crop of corn, it becomes evident that these two elements are the limiting factors in crop production on this soil. From what has been said, it is plainly seen that this soil is capable of producing only about one-half of a hundred bushel crop. Referring again to our history we see that the actual average yield for the last five years is 43.8 bushels of corn, which is just such a crop as we might expect from our calculations and the results of our analysis.

The manure that was added was well rotted, finely ground stable manure that had been subjected for some little time to leaching. 62.5 grams of dry matter were added to those pots receiving manure treatment. This amount is equivalent to 5 tons of dry matter per acre, or to 20 tons of average fresh manure.

The legume that was added was the one year old red clover,and the material added represented the entire plant (roots and branches). The amount added was the same as in the case of manure.

By referring to tablesI, II, and III the pots to which the various fertilizers were added may be ascertained.

General plan.

The 66 pots, the total number used in the experiment, were divided into three series with 22 pots in each series. The series differed from each other only in the amount of water the soil contained. To the 100 series, 20 per cent# to the 200 series, 40 per cent;

That is, 20 per cent of the water holding capacity of the

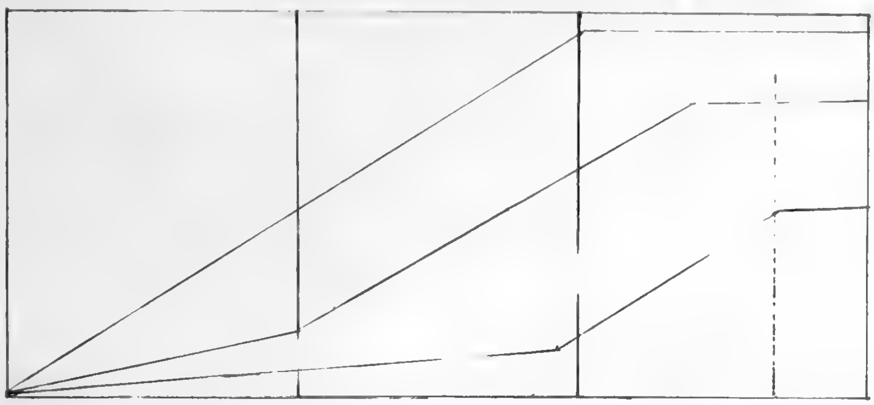
and to the 300 series 80 per cent of the water holding capacity of the soil was added. The pots were run in duplicates in all three series. In order to ascertain the amount of water that evaporated from the soil the first two pots in each series were kept as checks. To these six pots no fertilizers were added.

The fertilizers were mixed with only the first five inches of the soil, as has already been stated. About thirty days intervened between the time of mixing and the planting of theseeds. That the organic fertilizers had begun to decompose in the meantime and yield the fertilizing elements they contained for the use of the plants, is evidenced by the acceleration in the growth of the seedlings as soon as they became large enough to draw upon the soil for their nutriment. This lead in growth was especially noticeable in those pots which contained the dried blood. The nitrogen in the form of the legume (Red clover) did not show marked effect till about 40 to 50 days after planting. From this on to the time of heading, the abundant vegetative growth and the dark green color of the foliage gave ample assurance that plants were drawing upon the nitrogen in the decomposing legume for the amount required for their vigorous growth. After about 30 days from seeding, the general appearance of the plants growing in the pots which contained the dried blood seemed to indicate that the fertilizer was going to be harmful. The plants were making good vegetative growth, but the color was not that of healthy plants. This unhealthy color soon faded away, however, and the plants took on that deep green color so characteristic of plants growing where an abundant supply of nitrogen and moisture is available.

----

soil. The average of five trials with the soil in the pots as used for planting gave 44.4 per cent of the dry weight of the soil. 45 per cent was taken as total capacity of the soil for water. 20,40,and 80 per cents of this amount would therefore be 9,18,and 36 per cent,respectfully of the dry weight of the soil. These were the per cents used in finding the standard weights.

The effect due to the fertilizers was not equally apparent in the three series. If we divide the grand period of growth into three equal parts and consider the effects of nitrogen in the dried blood only, the following diagram will represent the difference:



From this diagram it is seen that in the 300 series, in which was 80 per cent of water, the influence of nitrogen appeared at once and reached its maximum at the beginning of the third period. In the 200 series, which contained 40 per cent of water, the effect of the nitrogen was not so manifest until near the end of the first period and reached its maximum somewhat later than in the 300 series; that is, near the middle of the last period. While the plants in this series showed the same deep green rank appearance, the influence of the nitrogen was never so markedly evident as in the 300 series.

The influence of the nitrogen was so slight for so long a time in the 100 series that it was thought to be without effect. Near the end of the second period, however, after the plants in the other two series had made the greater part of their vegetative growth, the plants in those pots containing nitrogen seemed suddenly to have taken on new life and made a rapid growth for a short time. The maximum was hardly reached when the first heads began to make their appearance. The legume in this series had but little or no effect, while in the next series the influence was marked enough to be readily noticeable.

The results of this experiment confirms the generally accepted idea that nitrogenous fertilizers cause the plant to take on a deep green color and make a rank growth. This rankness of growth was in proportion to the amount of water the soil contained, being most evident in the soil with the highest per cent of water.

About the beginning of the third period some of the plants in the green house, (which, however, were not in this experiment) became affected with plant lice. To check the spread of this pest, the green house was fumigated with hydrocyanic acid gas. This gas discolored parts of a few of the leaves of the plants in all the three series. It was noted, however, that the plants growing in the soil to which nitrogen had been applied escaped the action of the gas. Of all the plants affected those growing in the soil containing the application of potassium alone suffered the most. In those cases where the effect was most noticeable it was not serious enough to interfere in the least with the results of the experiment.

Seeding.

In this experiment the oat plant was used. The variety was what is generally known as the 60 day oats. Just before planting, the seed was treated with a weak solution of formaldehyde for the prevention of smut (Ustilago avenae). Pots from 302 to 306 inclusive were planted January 25 and the remaining, two days later. The planting was done in the following manner: About two inches of soil was removed from the pot and passed through a sieve containing four meshes to the inch. About one-half of this was again placed back into the pot and carefully leveled. Upon this were arranged thirty plump, medium to large seeds. About half of the remaining soil was now spread evenly over the seeds, as was also the other half afterit had

been passed through a sieve containing nine meshes to the inch. The inch of soil that now covered the seeds was snugly pressed on to them. The advantage gained by thus carefully planting was that the moisture which came up by capillarity was retained just beneath the surface, thus insuring quick and uniform germination. By thus retaining the moisture, it was found unnecessary to make further applications till the plants had attained considerable size, well out of danger of any injury that may arise by reason of the soil crusting upon the first application of water. By February 1, about ninety per cent of the seed had produced vigorous plantlets. Ten days later, these were thinned to eighteen of the strongest, best placed plants to the pot. This number was finally reduced to fifteen. No attempt was made to establish the desired water contents of the pots until the plants had become thoroughly established, as there was some apprehension that "damping off" may occur in the 80 per cent moisture series, while the plants in the 20 per cent moisture series may perish for want of water. The first weighing to ascertain the exact amount of water in the pots was made February 14. The pots of the 300 series was found to be deficient in water, while the amount in the 200 series was slightly in excess, and in the 100 series far in excess of the required amount. At this time the pots in the 300 series were made up to the required standard, that is, to 80 per cent. By March first, the excess of water had passed from all but two of the pots in the 200 series; but so slow was the evaporation from the pots of the 100 series, that it was not until April first that the majority of the pots in this series contain the required 20 per cent of moisture. Accurate data were kept of all the pots in all the series from March first. The totals obtained for March in the 100 series represent the amounts of water that was transpired by the plants when growing in a soil which was

constantly decreasing from 35 or 40 per cent to the required 20 per cent.

This lack of data the first month, that is, February, vitiated the final results but slightly, for it was ascertained by check pots that the amount of water transpired by the plants which were the most vigorous in the 300 series amounted, during the whole month, to no more than 600 c.c., which was less than one-half the amount transpired in a single day by the most vigorous plants in the same series in May.

After the pots were made up to standard weights, the approximate amount of water that was given off was returned daily. At the end of each week, the pots were weighed. In case there was a deficiency, which was nearly always the case, water was added to bring it to the standard; or in case there was an excess, which occasionally happened, the amount was ascertained and no more water was added until the excess had time to pass off.

An examination of the tables which give the daily amounts of water added brings out clearly the fact that the amounts added from day to day were very inconstant. This was due to the changes in the weather which were very frequent. When weather conditions were constant, the variations in the amount of water required for any one pot were very slight. During those days in which there was bright sunshine and drying winds, fully three times as much water was given off from the pots of the 300 series as when the contrary condition prevailed. The plants growing under the influence of 40 per cent of moisture were far less susceptible to these weather changes than were those under the influence of 80 per cent of moisture, while the plants under the influence of only 20 per cent of moisture were far less susceptible than either of the others. The plants growing under the influence of nitrogen were more influenced by weather changes than the others.

This was more especially true of the 300 series.

The water that was applied was the ordinary tap water. This was introduced from a graduate cylinder directly into the center of the pots by pouring it through a glass tube about 12 inches long and one inch in diameter which had been inserted into the center of the pots. This allowed the addition of small quantities of water without disturbing the earth mulch, in series 100, from the beginning to the end of the experiment, and in series 200 the greater part of the time. It was found to be impracticable to add all of the water through the tubes in the 300 series, so only a portion was thus added, the remaining being poured over the surface. In this experiment one c.c. of water was taken as the equivalent of one gram of water.

Results of the Experiment.

An examination of the photographs in the appendix gives very convincing proof that the plants responded markedly to both the water and fertilizer treatment. The plants growing under the influence of 80 per cent of water in the soil produced more abundant foliage and longer, better-filled heads than in the other two series. The vegetative growth and head production decreased as the per cent of water in the soil decreased. The proportion of head to straw, however, increased as the per cent of water in the soil decreased. It was noted also that the plants growing under the influence of only 20 per cent of water made slow growth and as a consequence used but little water. The following tables give the amounts of water required by the plants for each month.

Table I.

Total Transpiration

(not including water evaporated from the soil).

Series 100 (20% of saturation)

Pot No.	2	2′	3	3′	4	4′	5	5′	6	6′
soil treat.	None		P.		N.		K.		N.P.	
March	678	878	968	998	1384	962	916	794	1013	1097
April	604	438	1398	1348	678	538	894	878	1292	1313
May	1203	1170	726	1791	1860	895	1610	1591	2141	1865
Total	2485	2486	3092	4137	3922	2395	3420	3263	4446	4275
June	690	372	655	501	474	310	640	450	435	450
Total	3175	2858	3747	4638	4396	2705	4060	3713	4881	4725
Series 200 (40% of saturation)										
March	1562	1257	2042	4102	1732	2242	2452	2642	3982	3622
April	4610	3885	7580	9490	5018	5815	3920	7240	10710	9610
May	6453	6073	5945	10528	8408	9653	7533	9533	14673	13188
Total	12625	11215	15667	24120	15158	17710	13905	19415	29365	26410
June	2790	1710	2510	2760	3210	3230	2960	2760	4360	4135
Total	15415	12925	18177	26880	18368	20940	16865	22175	33725	30545
Series 300 (80% of saturation).										
March	4844	2442	5652	4462	4622	4252	3697	4457	4668	4826
April	9695	6955	12208	6680	15590	14735	4780	7335	16385	16700
May	8393	7643	14188	8983	26478	25048	5308	8288	25368	27653
Total	22932	17040	32048	20125	46690	44035	13785	20080	46421	49179
June	2770	1010	4320	2580	9330	8280	1360	2240	10630	11810
Total	25702	18050	36368	22705	56020	52315	15145	22320	67051	60989

Table I con.

Total Transpiration

Series 100

Pot No.	7	7′	8	8′	9	9′	10	10′	11	11′
Soil treat.	K.P.		K.N.P.		Mg.N.P.		Mnr.		Leg'm	
March	826	1889	884	1003	1345	1013	665	1015	940	741
April	888	1083	1088	882	1298	1512	498	842	1033	583
May	1420	2481	1691	1532	1817	1995	1417	1215	1902	850
Total	3134	5453	3663	3417	4460	4520	2580	3072	3875	2174
June	260	1075	500	686	514	575	270	430	670	310
Total	3394	6528	4163	4103	4974	5095	2850	3502	4545	2484

Series 200

	7	7′	8	8′	9	9′	10	10′	11	11′
March	4312	4162	3612	3152	2602	3052	2142	2112	2052	1020
April	9040	9100	9960	9605	6595	8605	5495	6300	5770	3095
May	12168	12288	13778	13473	10168	11978	8634	9363	9208	6233
Total	25510	25550	27250	26230	18365	23635	16271	17775	17020	10348
June	2460	1610	4110	3810	3060	3500	2430	3300	3870	3185
Total	27970	27160	31360	30040	22425	27135	18701	21075	20890	13533

Series 300

	7	7′	8	8′	9	9′	10	10′	11	11′
March	5424	5168	4707	4583	5184	5132	5691	6082	5381	6187
April	9270	8935	16875	15150	14320	15960	10045	8385	13593	12755
May	12468	11193	27568	24838	35363	27468	12578	9208	19438	17163
Total	27162	26296	49150	44571	54867	48550	28314	23675	38412	36095
June	4150	2970	13410	13410	12750	12130	4980	3500	·7250	7790
Total	31312	29266	62560	57981	67617	60690	33294	27175	45662	43885

The duplicate pots in all three series were very similar in appearance, yet from the tables we observe that they used, in most cases, quite different amounts of water. To compare them accurately, therefore, it is necessary to take a unit and ascertain how many of these units were produced and how much water was required for each unit. A gram of dry substance produced is generally chosen as the unit. For the computing of the results in this experiment I have chosen two units, namely, centimeters of heads produced and the grams of dry weight.

To obtain results in terms of centimeters of heads produced the experiment ran from Feb. 1st till May 27. At this time the heads were well developed and the transpiration current was beginning to slacken. To obtain results in terms of dry weight the crop was allowed to mature and dry weight of both straw and grain ascertained.

To ascertain the number of centimeters of heads produced each panicle was carefully measured. The lengths of the panicles in each pot were added together. By dividing this total into the total number of grams (c.c.) of water used during the experiment the number of grams of water required for each centimeter of heads produced is found. The following tables of results give this data, also the number of heads to each pot and the soil treatment.

Table 2.

Table of Results.

Series 100.

Pot No.	Soil Treat.	No. of heads Prod.	T. length of heads C.M.	Av. lgt. of heads C.M.	Av. hgt. of plants C.M.	T. water used G.	G. water req. for 1 C.M. length of heads	av.
102	None	15	160	10.6	50	2485	15	15
102'	None	15	155	10.3	58	2486	16	
103	P	15	186	12.4	68	3092	11	15
103'	P	15	210	14.1	66	4137	19	
104	N	14	170	11.5	54	3922	17	17
104'	N	14	139	10.	57	2395	17	
105	K	15	198	13.2	60	3420	17	17
105'	K	15	187	12.5	60	3263	17	
106	NP	16	237	14.8	68	4446	19	19
106'	NP	16	221	14.	68	4275	19	
107	KP	15	192	12.8	60	3134	16	19
107'	KP	16	249	15.1	65	5453	22	
108	KNP	15	228	15.1	65	3663	16	16
108'	KNP	17	212	12.5	65	3417	16	
109	MgNP	15	220	14.66	67	4460	20	20
109'	MgNP	15	218	14.5	68	4520	20	
110	Mnr	15	175	11.66	50	2580	15	15
110'	Mnr	15	191	12.66	58	3072	16	
111	Legm	17	209	12.3	64	3875	18	16
111'	Legm	15	165	11.	63	2144	14	

Table 3.

Table of Results.

Series 200.

Pot. No.	Soil Treat.	No. of heads Prod.	T. length of heads C.M.	Av. lgt. of heads C.M.	Av. hgt. of plants C.M.	T. water used G.	G. water req. for 1 C.M. length of heads	av.
202	None	18	278	15.4	100	12625	45	40
202'	None	20	314	15.7	95	11215	35	
203	P	20	317	15.8	110	15667	49	56
203'	P	22	383	17.4	125	24120	63	
204	N	26	467	21.2	100	15158	32	33
204'	N	30	495	16.5	100	17710	35	
205	K	23	324	14.	94	13905	43	49
205'	K	22	350	15.8	114	19415	55	
206	NP	37	628	16.9	124	23365	37	39
206'	NP	37	633	17.1	115	26410	41	
207	KP	20	379	18.9	120	25510	67	70
207'	KP	20	344	17.2	120	25550	74	
208	KNP	31	565	18.2	120	27250	48	
208'	KNP	28	521	18.6	120	26230	50	49
209	MgNP	22	419	19.	117	18365	44	
209'	MgNP	26	489	18.8	120	23635	48	46
210	Mnr	15	258	17.2	115	16271	63	
210'	Mnr	21	359	17.1	110	17775	51	57
211	Legm	25	422	16.8	111	17020	40	
211'	Legm	22	327	14.8	90	10348	31	35

Table 4.

Table of Results.

Series 300

Pot No.	Soil Treat.	No. of heads Prod.	T. length of heads C.M.	Av. lgt. of heads C.M.	Av. hgt. of plants C.M.	T. water used A.	G. water req. for 1 C.M. length of heads	av.
302	None	18	334	18.5	125	22932	68	66
302′	None	16	265	16.5	120	17040	64	
303	P	22	433	19.6	145	32048	74	75
303′	P	16	262	16.3	130	20125	76	
304	N	39	774	19.8	147	46690	60	60
304′	N	39	745	19.1	150	44035	59	
305	K	15	249	16.6	126	13785	55	63
305′	K	16	284	17.7	135	20080	70	
306	NP	44	862	19.6	150	46421	53	55
306′	NP	41	855	20.8	150	49179	57	
307	KP	16	302	18.7	145	27162	89	85
307′	KP	18	318	17.6	150	26296	82	
308	KNP	42	842	20.	152	49150	58	68
308′	KNP	29	572	19.7	165	44571	79	
309	MgNP	44	845	19.2	150	54867	64	64
309′	MgNP	42	752	17.9	157	48550	64	
310	Mnr	19	349	18.5	148	28314	81	81
310′	Mnr	16	287	17.9	140	23675	82	
311	Legm	26	522	20.	150	38412	73	74
311′	Legm	25	492	19.6	150	36095	75	

It will be observed from the foregoing tables that there is a pretty general agreement in the duplicates in the number of heads produced and also in the amount of water required for the production of a centimeter of head growth. There are some irregularities in this latter, however. In order to make the results more nearly comparable and more easily compared the table of averages (Table 5) is given. This table also gives the average amounts of water required for the production of one gram of dry straw and grain.

Table 5.

Table of averages showing the amounts of water required for a unit of growth and production under varying conditions of soil treatment.

Soil Treat.	None		P		N		K		NP		KP		KNP		MgNP		Mnr.		Legm.	
Pot No.	2		3		4		5		6		7		8		9		10		11	
unit	cm	g.	cm	g	cm	g	cm	g	cm	g	cm	g	cm	g	cm	g	cm	g	cm	
p. of pl. %	h.	dm.	h.	d.m.	h.	d.m.	h.	d.m.	h.	d.m.	h.	d.m.	h.	d.m.	h.	d.m.	h.	d.m.	h.	d.m.
20	15	214																		
40	40	358																		
80	66	341																		
20			15	276																
40			56	367																
80			75	377																
20					17	206														
40					33	305														
80					60	349														
20							17	209												
40							49	409												
80							63	346												
20									19	[illegible]										
40									39	349										
80									55	3[illegible]										
20											19	210								
40											70	[illegible]								
80											85	394								
20													16	[illegible]						
40													49	345						
80													68	374						
20															20	[illegible]				
40															46	[illegible]				
80															64	[illegible]				
20																	15	[illegible]		
40																	57	[illegible]		
80																	81	400		
20																			16	[illegible]
40																			35	3[illegible]9
80																			74	380

p. of Pl. = parts of the plant. h = heads. d.m. = dry matter.

As has been said, to obtain results in terms of dry matter produced the crop was allowed to mature. The amount of water the soil contained influenced quite markedly the time of maturity as also the time of heading. This difference was not so marked between series 100 and 200 as between series 200 and 300. The crop on series 100 was cut June 5, on series 200 June 9, and on series 300 June 1[illegible]. After the plants were thoroughly sun dry, the grain was threshed out and the weight of grain and straw ascertained.

The following tables give these results, also the soil treatment, pounds per acre, total number of grams of water used, and the amount of water required for the production of a gram of dry matter.

Table 6. Table of Results.

Series 100

Pot No.	Soil Treat.	Grain Pro. g.	Straw Pro. g.	T. dry sub. Pro. g.	Grain per A. lbs.	Grain per A. bu.	T. water used g.	G. water req. for one g. dry substance	Av. req.
102	None	5	8.7	13.7	800	25	3175	[illegible]	
102	None	5.1	9:5	14.6	816	25.3	2858	196	214
103	P	7.5	16.1	23.6	1300	40.6	3747	159	
103	P	8	16	24	1280	40	4638	[illegible]	176
104	N	5.5	11.4	16.9	880	27.5	4396	260	
104	N	4.5	9.5	14	720	22.5	2705	[illegible]	[illegible]
105	K	6.5	13	19.5	1040	32.5	4060	208	
105	K	6.5	11.1	17.6	1040	32.5	3713	[illegible]	209
106	NP	10.5	17.6	28.1	1680	52.5	4881	173	
106	NP	8.1	16.6	24.7	1296	40.5	4725	191	[illegible]
107	KP	6.3	13.5	19.8	1008	32	3394	171	
107	KP	8.2	17.9	26.1	1312	41	6528	250	210
108	KNP	8.7	16.6	25.3	1392	43.5	4163	165	
108	KNP	7.4	15.8	23.2	1184	37	4103	177	171
109	MgNP	9.5	16.8	26.3	1520	47.5	4974	189	
109	MgNP	10	18.2	28.2	1600	50	5095	180	184
110	Mnr	5.5	9.9	15.4	880	27.5	2850	185	
110	Mnr	7	10.8	17.8	1120	35	3502	197	191
111	Legm	7.5	15	22.5	1300	40.6	4545	202	
111	Legm	4.5	9	13.5	720	22.5	2484	184	193

Table 7. Table of Results.

Series 200

Pot No.	Soil Treat.	Grain Pro. g.	Straw Pro. g.	T.Dry sub.Pro. g.	Grain per A. lbs.	Grain per A. bu.	T.Water used g.	G.Water req. for one g.dry sub.	Average
202	None	17.2	23.8	40	2752	86	15415	385	
202	None	15	14	39	2400	75	12925	331	358
203	P	17.2	32.8	50	2752	86	18171	363	
203	P	27.7	44.4	72.1	4432	138.5	20880	372	367
204	N	25.8	35.2	61	4048	120.2	18368	301	
204	N	28.6	39	67.6	4576	143	20940	309	305
205	K	16	24.6	40.6	2560	80	16865	415	
205	K	22	32	54	3520	110	22175	403	409
206	NP	39.2	59.8	99	6272	196	33725	340	
206	NP	34.8	51.9	86.7	5568	174	30545	351	345
207	KP	25.3	41.3	66.6	4048	120.2	27970	420	
207	KP	23.5	40.3	63.8	3760	116.2	27160	424	422
208	KNP	35.5	54.1	89.6	5680	177.5	31360	350	
208	KNP	36.6	51.4	88	5856	183	30040	341	345
209	MgNP	28	41.5	69.5	4480	140	22425	308	
209	MgNP	32.7	52.4	85.1	5232	163.5	27155	318	313
210	Mnr	17	28.1	45.1	2720	85	18701	412	
210	Mnr	22.5	34	56.5	3600	102.9	21075	373	392
211	Legm	25.1	34.9	60	4016	125.5	20890	348	
211	Legm	19.4	24.2	43.6	3104	97	13533	310	329

Table 8.

Table of Results.

Series 300.

Pot No.	Soil Treat.	Grain pro. g.	Straw pro. g.	T. dry sub. pro. g.	Grain per A. lbs.	Grain per A. bu.	T. water used g.	G. water req. for one g. dry sub.	Average
302	None	23.8	51.2	75	3808	119	25702	[illegible]	
302	None	15	38	53	2400	75	18050	340	341
303	P	33	67	100	5280	165	36568	365	
303	P	16.5	41.5	58	2640	82.5	22705	391	377
304	N	63	95.5	156.5	10080	315	56020	364	
304	N	60.9	95.6	156.5	9744	304.5	52515	334	349
305	K	15	35.5	50.5	2400	75	15145	300	
305	K	18	46	64	2880	90	22320	372	336
306	NP	63.3	101.7	165	10128	316.8	67051	406	
306	NP	64.5	106	170.5	10320	322.5	60989	358	382
307	KP	24.7	55.3	80	3952	123.5	31312	391	
307	KP	24.7	52.8	77.5	3952	123.5	29266	377	384
308	KNP	61.8	110.8	172.6	9888	309	62560	362	
308	KNP	56	94	150	8960	311.2	57981	386	374
309	MgNP	59.5	97	156.5	9520	297.5	67617	432	
309	MgNP	63.8	101.4	165.2	10208	319	60690	367	399
310	Mnr	25.3	54.7	80	4048	[illegible]	33294	416	
310	Mnr	19	45.2	64.2	3040	95	27175	[illegible]	419
311	Legm	41.8	77.7	119.5	6688	209	45662	382	
311	Legm	41.8	74.2	116	6688	209	43855	378	380

From tables [illegible], 6, and 7 it [illegible] grain and straw [illegible] up to 80 per cent [illegible]. The [illegible] was almost the same in series 100 and 200 [illegible] ious pots within the [illegible] series 300 [illegible] to straw was [illegible]. [illegible] increase the yield in series 100 [illegible] series 200 and 300 [illegible] a marked increase in yield following the application [illegible] or in combination with Phosphorus. Phosphorus gave [illegible] in series 100 than Nitrogen, [illegible] series 200, [illegible] considerably less than Nitrogen in series 300. When used in combination with Nitrogen the largest yields [illegible] series 200 and 300 than with any other combination. In series 100 [illegible] the application of [illegible], [illegible] in this series the yield was greater when [illegible] applied in combination with magnesium.

Potassium when applied alone gave an increase in grain yield save in series 100, in which case the increase was but slight. When applied in combination with the phosphorus or with nitrogen and phosphorus combined, it proved to have a detrimental effect. The largest yields of grain in series 100 followed the application of magnesium in combination with nitrogen and phosphorus. This increase was slight, however, and in series 200 and 300 no beneficial effects of magnesium were found.

The manure had but little effect. A slight increase in yield of both grain and straw followed its application in all the series. The application of the legume gave an increase in yield in all the series over the manure. In series 300 this increase was very pronounced.

When considered from the standpoint of grams of water required for the production of a gram of dry matter, it does not appear from the data obtained that any of the treatments applied to the soil had any appreciable effect under the three conditions. When the moisture content of the soil was at 20 percent of saturation the plants growing under the influence of K.N.P. treatment used 45 grams of water less for a gram of dry matter, which was equivalent to about 20 percent less, for the production of a gram of dry matter, than the plants on the soil without treatment. The same is true, to a less extent, in series 200 with both the K.N.P. and Mg.N.P. treatment, but the smallest amount of water was used by the plant growing under the influence of nitrogen, the difference being in the latter case 56 grams or about 15 percent for a gram of dry matter in favor of the nitrogen treatment. There was a slight checking of transpiration in the 60 percent moisture series following the application of potassium. It amounted, however, to only 5 grams of water, or less than 2 percent, for the production of each gram of dry matter.

The Root System.

After the crop was harvested the roots were carefully washed out of pots 102, 108, 202, 208, 302, and 308, dried and weighed with the following results:

No. of Pot	Soil Treat.	Wt. of roots.	To. wt. dry mat. in tops.	Pro. of root to top.	Average
102	None	1.6	13.7	1:8.5	
108	K.N.P.	2	23.2	1:11.6	1:10.1
202	None	4.8	40	1:8.3	
208	K.N.P.	5.1	51.4	1:10	1:9.1
302	None	6.1	75	1:12.3	
308	K.N.P.	9.1	150	1:16.4	1:14.3

It will be seen from the above table that an increase of both top and roots followed the K.N.P. soil treatment, but the proportion

of top to roots is considerable less without the treatment.

The yield of both roots and tops increase as the percent of water in the soil increased and reached its maximum proportion with 80 percent of water in the soil.

Conclusions.

From the results of the foregoing experiment the following conclusions may be drawn.

The yield was increased by increasing the water content of the soil up to 80 percent of its water holding capacity.

With the water content of the soil at 20 per cent of its water holding capacity, nitrogen in the form of dried blood, did not increase the yield of heads. With a water content at 40 or 80 per cent, nitrogen in the form of dried blood, whether alone or in combination with phosphorus or potassium, gave an increase in head yield as well as in straw yield. In every two cases, nitrogen gave better returns in combination with the other elements, especially phosphorus. When the water content of the soil was sufficient for good growth, i.e., at 40 percent, nitrogen decreased transpiration. With an abundance of water this was not true.

The influence of phosphorus in the form of bone meal was marked during the second period of growth. It had but little effect in increasing the number of heads; but a marked effect on the length of head and the filling of the panicle. This is especially true in the 20 per cent of moisture content of the soil. It had no retarding effect on transpiration save in series 100, in which case there was a saving of about 13 per cent.

Potassium alone in the form of the sulphate had no appreciable effect either in the number of heads or the length of heads in series 100 and 200, but was harmful in series 300. In all three series the plants "fired" early under the influence of potassium. It had a retarding influence on evaporation in a soil containing 80 per cent of water. In series 100 it retarded evaporation slightly and increased the average yield 2.9 gr.

Potassium and phosphorus when applied together did not increase very markedly the number of heads produced, but the length of the

heads in each series was increased. This is more especially true in series 100. The maximum amount of water for the production of one centimeter of heads was reached in each series under the influence of this soil treatment. With this treatment the plants "fired" but this trouble came on somewhat later than when potassium was applied alone. ¶ Potassium, nitrogen and phosphorus when applied together gave the maximum yield. The plants growing under the influence of the three elements in series 100 and 200 used but slightly more water for the production of one centimeter of heads than was used by the plants growing in the soil without treatment. In the 200 series, however, the amount of water required was considerably in excess of that required by the plants in the soil alone. "Firing" of the plants did not occur under this soil treatment. ¶ On the whole the magnesium proved to be quite as effectual as the potassium when applied with nitrogen and phosphorus. In each series the plants growing under this treatment resemble very closely the plants growing under the influence of potassium nitrogen and phosphorus.

It had no retarding effect on transpiration nor was its application accompanied by early "firing."

The application of manure was accompanied, after a time, by an increase in vegetative growth.

The legume treatment gave better results than the manure. The plants in these pots receiving this treatment resembled the plants in those pots which had received the dried blood.

The number of grams of water required for one centimeter of heads produced increased as the water content of the soil increased. This increase is not proportional in the various soil treatments.

Soils low in fertility have their productive power increased by a copious supply of water.

An increase in soil humidity decreased the temperature of the soil and delayed the maturity of the crop. When the water content of the soil is sufficient for good growth the proportion of grain to straw varied but little with an increase of soil humidity, but by decreasing the water content to 20 percent of saturation the proportion of straw to grain increased. Fertilizers give larger returns when applied to the soils that were abundantly supplied with water.

The results following a specific soil treatment may be greatly modified by the humidity of the soil.

Plants growing on the soils low in humidity used considerably less water per unit of dry matter when an ample amount of soluble plant food is available than when the contrary condition prevailed.

Fertilizers increased the production of both roots and top but decreased the proportion of top to root.

An increase of water in the soil from 20 to 40 percent saturation effected but little the proportion between top and root but a further addition of water up to 80 percent saturation decreased this proportion.

Literature cited.

1. Beal, W. H.
   Farmers' Bul. U.S.Dep. of Agr., No.114
2. Burgerstein, Alfred
   Die Transpiration Der Pflanzen, 1904, 135-139.
3. Deherain, P. P. von
   Biederman's Centralblatt, 1893, XXII, 644.
4. Gain, E.
   Exp. Sta. Rec., vol. 8, 3.
5. Hopkins, C. G.
   Ill. Exp. Sta., Bul. 123.
6. Heinrich, R.
   Zweiter Ber. landw. Vers. Stat., 1894, 170-174.
7. King, F. H.
   Wisconsin Sta. Report, 1893, 167-200.
8. " " " 1894, 240-248.
9. " " " 1897, 229.
10. " " " 1890, 111-120.
11. Kohl, F. G.
    Die Transpiration der Pflanzen, 1886, 82-86.
12. Livingston, B. E.
    Botanical Gazette, 1905, XL, 178-195.
13. " " 1903, XXXVIII, 67-71.
14. Lawes, J. B.
    Jour. Hort. Society, London, 1886, V, 38, also
    Rothamsted Memoirs, 1886, I.
15. Lawes and Gilbert
    Ann. Agron., 1875, I, 251

16. Maxwell, W.

Jour. Amer. Chem. Soc., 1898, XX, 469-483.

17. Mäercker, M.

Jahrb. Agr. Chem. Vers. Stat. Halle, 1895, 15-16.

18. Mäercker, M.

Chem. Centbl., 1894, LXV, 595

19. Mac Dougal, D. T.

Plant Physiology, 1901, 6

20. Pfeffer, W.

Physiology of Plants, 1880, I, 234-286

21. Pagnoul, A. von

Bul. Sta. Agron. Pas de Calais, 1898, 10-15

22. Pagnoul, A. von.

Biederman's Centbl., 1900, XXIX, 96

23. Prianishnikov, D.

Exp. Sta. Rec., XIII, 631.

24. Schroeder,M. R., Jr.

Annual Agricultural Institute, Moscow, 1896, II, 231-232

25. Seelhorst, C. von

Journal Landw. 1901, IXL, 231-250

26. Seelhorst, C. von

Jour. Landw., 1900, VIIIL, 165-177.

27. Seelhorst, C. von.

Exp. Sta. Rec., XIII, 6

28. Sachs, J. von.

The Physiology of Plants, 1882, 252, also Landw. Vers. Stat., 1858, I, 203

29. Tucker, M. and Seelhorst, C. von.

Journal Landw., 1898, 46, 53-63

30. Thorne, C. E.

Ohio Exp. Sta. Bul. 167

31. Whitney, M.

Mary Sta. Rep., 1891, 249-296

32. Wollny, E.

Vrtljschr. Bayer. Landw. Rathes, 1899, IV, 437-479, Exp.Sta. Rec., XI, 717

33. Willard, J. T.

Kans. Exp. Sta. Bul. 89

34. Widtsoe, John A.

Utah Exp. Sta. Bul. No. 80, 101

APPENDIX

PLATES AND TABLES

Explanation of Plates.

Plates I, II, and III are the photographs of one half of the pots in series 100, 200, and 300 respectively. The top row of numbers on the pots represent the series and pot numbers. The middle row represents the water content of the soil. The letters at the bottom represent the soil treatment. For example, 108 means pot eight in 100 series.

20

K.N.P.

20 means that the soil contains water to make it 20 per cent of saturation, K means potassium, N means nitrogen, and P means phosphorus. Plates IV to XIII inclusive represent the corresponding pots in each series. Plate XIV represents corresponding pots in the three series as they appeared just before heading. Plate XV represents corresponding pots in the three series as they appeared after 60 days from planting.

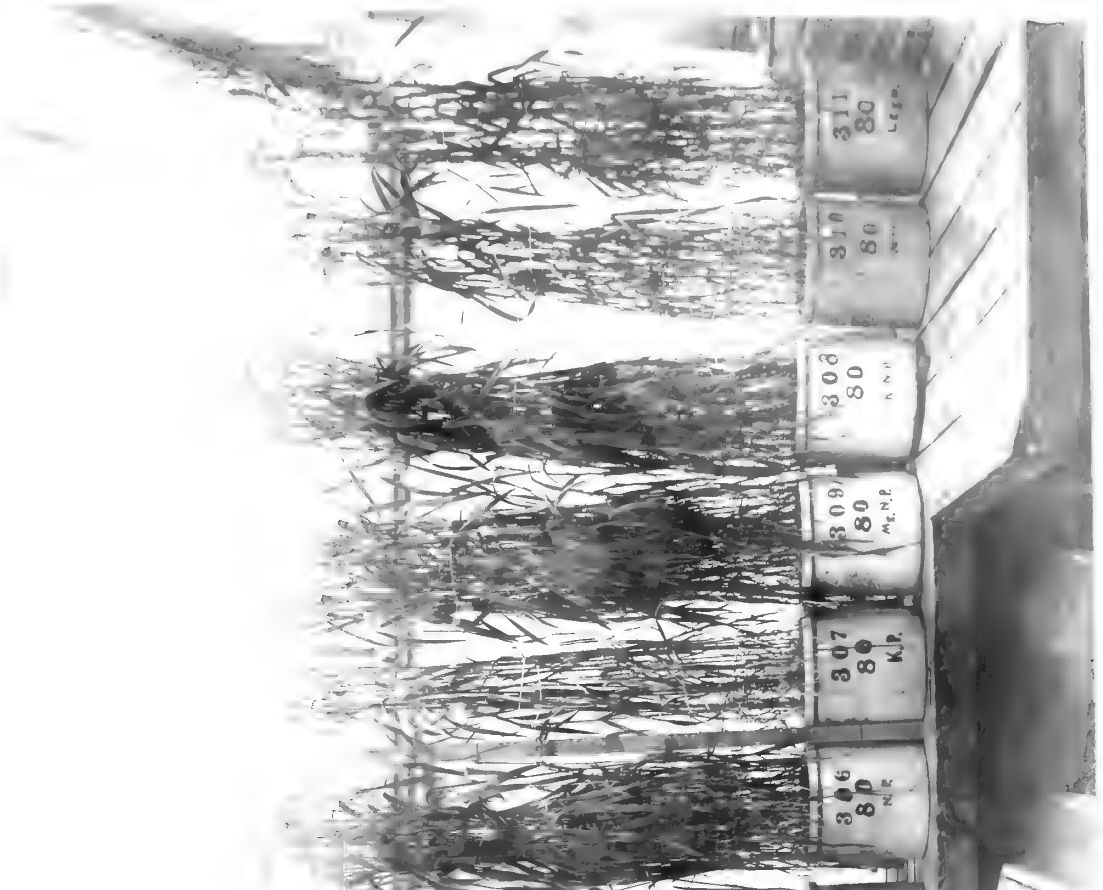
PLATE I.


101 20 Check
102 20
103 20 P.
104 20 N.
105 20 K.
106 20 N.P.
107 20 K.P.
108 20 K.N.P.
109 20
110 20

PLATE II.

201
40
Check
202
40
Soil
203
40
P.
204
40
N.
205
40
K.
206
40
NP.
207
40
KP.
208
40
KNP.
209
40
MgNP
210
40
211
40

PLATE III.



301 80 Check
302 80 Soil
303 80 P.
304 80 N.
305 80 K.
306 80 N.P.
307 80 K.P.
309 80 Mg.N.P.
308 80
310 80
311 80

PLATE IV.

PLATE V.

PLATE VI.

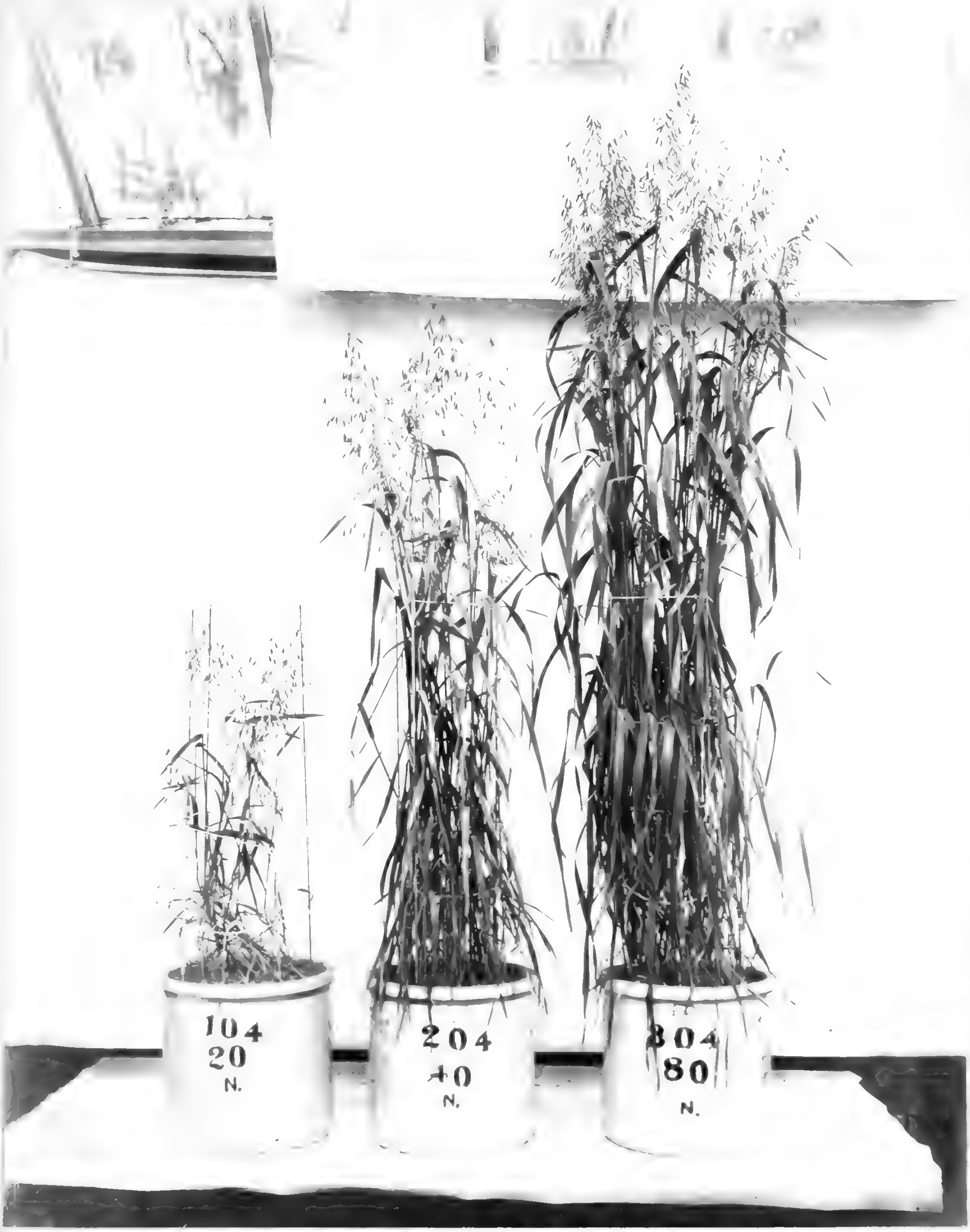


PLATE VII.

PLATE VIII.

PLATE IX.

PLATE X.

PLATE XI.

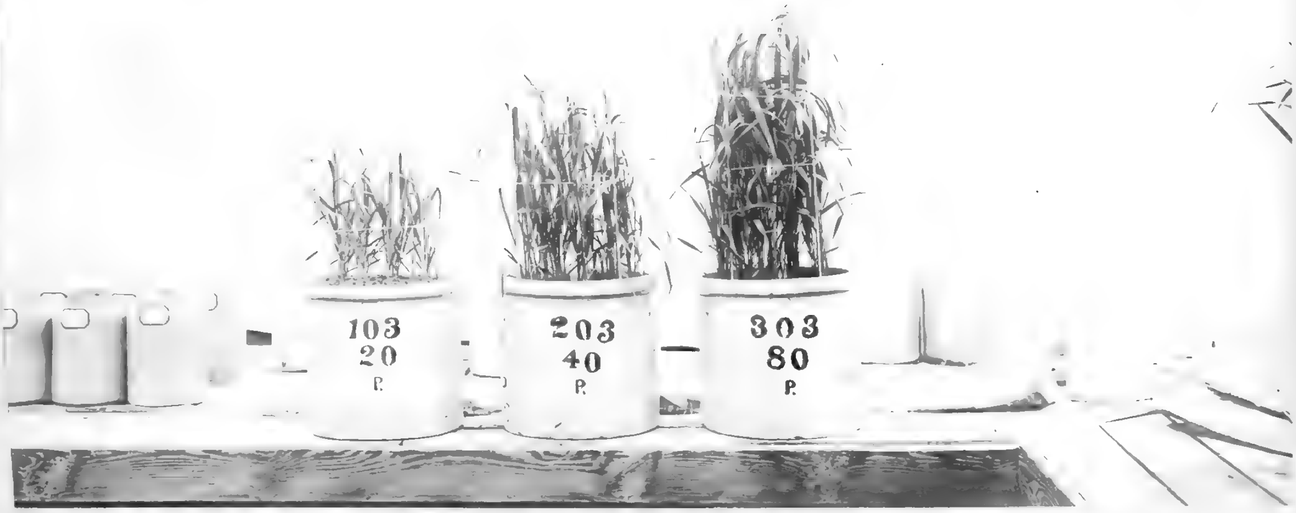
PLATE XII.

PLATE XIII.

PLATE XIV.

109
20
Mg.N.P.
209
40
Mg.N.P.
309
80
Mg.N.P.
108
20
K.N.P.
208
40
K.N.P.
308
80
K.N.P.
106
20
N.P.
206
40
N.P.
306
80
N.P.

PLATE XV.



Explanation of Tables.

The numbers in the first columns in tables I, II, and III represent the pot numbers. The numbers in the second column represent the weight of the empty jars at the time of filling them with soil; in the third the weight of the soil plus the water it contained at the time the fertilizers were added; in the fourth, the per cents of water in the soil of the various pots at the time the soil was weighed; in the fifth, calculated weights of the water free soil in the various pots. Each number in the sixth column in each table represents the sum of the weights of the pot, the dry soil, the amount of water to make it up to the required moisture contents, the glass tube in the center of the pot, and the supports for the plants. The letters in the last column represent the soil treatment. P = phosphorus; N = nitrogen; K = potassium; Mg = magnesium; Mnr. = manure, and Leg. = legume (Red clover). The "checks" were pots in which no plants were growing and were kept to ascertain the amount of evaporation from the soil.

In the tables "Daily amounts of water added", the top row of numbers is the pot numbers. The other numbers, excluding totals, represent the number of cubic-centimeters of water which were added daily. In all these tables the first two pots were check pots.

Table I. Table of Weights. Series 100.

No. of Pot	Wt. of Pot g.	Wt. of Soil g.	Per cent Water	Wt. of Dry Soil g.	Standard Wt. of Pot g.	Fertilizer added
101	7255	17825	18.80	14474	23094	Check
101′	8190	17070	16.30	14288	23826	Check
102	9270	16985	20.10	13571	24469	None
102′	7435	16150	18.19	13213	22244	None
103	8830	17515	18.96	14195	24799	P.
103′	8970	16360	16.10	13726	24428	P.
104	6890	18695	18.80	15181	23844	N.
104′	7315	17820	16.07	14957	24025	N.
105	7315	17755	16.45	14935	24201	K.
105′	7985	17595	18.16	14400	24088	K.
106	7635	16115	16.98	13379	22715	N.P.
106′	7565	16615	15.30	14073	23311	N.P.
107	8320	17235	17.52	14216	24222	K.P.
107′	7880	17030	16.59	14205	23770	K.P.
108	8275	17305	18.56	14094	24044	K.N.P.
108′	7705	17295	16.76	14398	23805	K.N.P.
109	7365	17950	18.89	14560	23731	Mg.N.P.
109′	7800	17870	16.84	14861	24495	Mg.N.P.
110	7430	17190	16.66	14327	23453	Mnr.
110′	7300	18080	16.19	15153	24223	Mnr.
111	7290	18080	17.18	14974	24018	Lege.
111′	9195	16425	18.09	13455	24267	Lege.

Table II. Table of Weights. Series 200.

No. of Pot	Wt. of Pot g.	Wt. of Soil g.	Per cent Water	Wt. of Dry soil g.	Standard Wt. of Pot g.	Fertilizer added
201	8860	16405	17.51	13633	25021	Check
201'	8800	15550	16.82	12935	24138	Check
202	8370	20535	24.34	15531	27163	None
202'	7925	19200	23.32	14723	25758	None
203	8140	20165	24.49	15227	26567	P.
203'	7795	17965	20.05	14364	25204	P.
204	9175	17175	21.07	13557	25632	N.
204'	8430	17205	19.27	13890	25280	N.
205	7925	18055	18.65	14688	25716	K.
205'	8105	18280	19.20	14771	25991	K.
206	8300	17985	19.23	14527	25901	N.P.
206'	8140	17595	17.75	14472	25764	N.P.
207	7570	17930	16.71	14934	25652	K.P.
207'	7705	17465	17.05	14488	25260	K.P.
208	8320	17640	18.09	14459	25841	K.N.P.
208'	7685	16490	18.20	13489	24092	K.N.P.
209	8495	17315	19.93	13865	25315	Mg.N.P.
209'	7760	16370	15.38	13853	24566	Mg.N.P.
210	9300	16205	17.16	13425	25601	Mnr.
210'	7380	18790	20.05	15023	25227	Mnr.
211	6600	17715	18.18	14495	24164	Lege.
211'	7570	18155	21.15	15104	25852	Lege.

Table III. Table of Weights. Series 300.

No. of Pot	Wt. of Pot g.	Wt. of Soil g.	Per cent Water	Wt. of Dry Soil g.	Standard Wt. of Pot g.	Fertilizer added
301	8930	16785	19.84	13455	27303	Check
301′	8890	17015	19.13	13761	27679	Check
302	7860	17615	19.71	14143	27510	None
302′	6385	20135	23.58	15378	26068	None
303	7900	18400	21.47	14450	27967	P.
303′	9020	19680	24.73	14814	28752	P.
304	7570	19910	22.23	15485	29044	N.
304′	8995	19975	23.68	15246	29336	N.
305	8860	19740	28.88	15027	28780	K.
305′	7445	19700	22.60	15248	28124	K.
306	9150	15400	16.51	12858	27051	N.P.
306′	8510	18030	20.28	14374	28273	N.P.
307	8905	15655	16.23	13115	27156	K.P.
307′	9145	18330	23.12	14093	28728	K.P.
308	7360	19670	22.14	15315	28604	K.N.P.
308′	8275	16910	19.62	14593	27962	K.N.P.
309	7435	16625	17.03	13794	26609	Mg.N.P.
309′	8340	16175	17.28	13380	26941	Mg.N.P.
310	6845	17745	18.76	14416	26865	Mnr.
310′	7650	18040	21.10	14234	28013	Mnr.
311	8070	20250	22.23	15749	29903	Lege.
311′	9070	18665	22.13	15535	29252	Lege.

Table IV. Water holding capacity of Soil.

First test.

No. of Pot	Wt. of Soil	Water absorbed	Per cent
301	13455 g.	5780 g.	42.9

Second test.

301′	13761 gr.	6319 gr.	45.9

Third test.

201	13633 gr.	6127 gr.	44.2

Fourth test.

301	13455	5785	43.

Fifth test.

301′	13761	6322	46.
		Average	44.4

Table V. Daily amounts of water added.

Series 200. C.C. March.

Date	201	201′	202	202′	203	203′	204	204′	205	205′	206	206′
1	60	60	20	15	50	60	60	60	60	60	60	60
3	60	60	20	10	50	300	130	140	130	130	130	130
8	66	80	250	140	100	400	190	260		400	540	480
9	15	20	50	30	40	80	40	50	80	100	100	100
10	15	20	50	50	60	60	40	50	80	80	80	80
11	20	20	50	50	60	60	40	40	80	80	80	80
12	20	20	50	50	60	60	40	40	80	80	80	80
13	20	20	50	50	60	60	40	40	80	80	80	80
14			200	180	380	450	220	250	200	190	390	240
15	20	20	80	80	130	130	70	70	100	100	135	135
16	20	20	80	80	130	130	70	70	100	100	135	135
17	20	20	80	80	130	130	70	70	100	100	135	135
18	20	20	80	80	130	130	70	70	100	100	135	135
19	20	20	80	80	130	130	70	70	100	100	135	135
20	20	20	80	80	130	130	70	70	100	100	135	135
21	#50	#50			60	220		170	#350		220	150
22			80	80	130	130	70	70	70	100	135	135
23			80	80	130	130	70	70		100	135	135
24			80	80	130	130	70	70		100	135	135
25	20	20	80	80	130	130	70	70	100	100	135	135
26	20	20	80	80	130	130	70	70	100	100	135	135
27	20	20	80	80	130	130	70	70	100	100	135	135
28			200	100	420	750	290	500		410	580	500
29	20	20	90	90	150	150	100	100	100	100	150	150
30	20	20	100	100	210	210	115	115	110	110	200	200
31	20	20	100	100	210	210	115	115	110	110	200	200
Total	516	540	2090	1785	3470	4630	2260	2770	2980	3170	4510	4150
Total Transp.	##528		1562	1257	2042	4102	1732	2242	2452	2642	3982	3622

Excess.

Obtained by subtracting average evaporation (528) from the check pots from the totals.

Table V con. Daily amounts of water added.

Series 200. c.c. March.

Date	207	207'	208	208'	209	209'	210	210'	211	211'
1	60	1000#	60	60	60	60	60	60	60	818
3	130		130	130	130	100	130	130	50	
8	500		410	310	130	150	220	210	110	
9	100		80	60	40	50	40	40	40	
10	80		80	60	50	50	40	40	40	
11	80		70	70	50	50	40	40	40	
12	80	80	70	70	50	50	40	40	40	
13	80	188	70	70	50	50	40	40	40	
14	350	135	370	250	250	660	340	250	250	420
15	135	135	110	110	85		90	90	90	
16	135	135	110	110	85		90	90	90	
17	135	135	110	110	85		90	90	90	
18	135	135	110	110	85		90	90	90	
19	135	135	110	110	85	85	90	90	90	40
20	135	372	110	110	85	85	90	90	90	90
21	312	160	250	200	240	390		30		#225
22	160	160	130	130	110	110	90	90	90	
23	160	160	130	130	110	110	90	90	90	
24	160	160	130	130	110	110	90	90	90	
25	160	160	130	130	110	110	90	90	90	90
26	160	160	130	130	110	110	90	90	90	90
27	160	160	130	130	110	110	90	90	90	90
28	700	620	500	450	420	500	200	340	204	
29	200	200	150	150	130	130	100	100	90	90
30	230	230	180	180	180	180	120	120	120	120
31	230	230	180	180	180	180	120	120	120	120
Total	4840	4690	4040	3680	3130	3580	2670	2640	2580	1548
Tot. Trans.##	4312	4162	3512	3152	2602	3052	2142	2112	2052	1020

Excess.

Obtained by subtracting the average evaporation (528) from the check pots from the totals.

Table VI. Daily amounts of water added.

Series 300. C.C. March.

Date	301	301′	302	302′	303	303′	304	304′	305	305′	306	306′
1	100	100	100	100	100	100	100	100	100	100	100	100
3	150	160	155	155	155	155	155	155	155	155	155	155
8	350	364	918		890	610	890	950	570	770	790	860
9	75	75	180	180	180	160	180	210	120	170	170	170
10	75	75	180	180	180	160	180	180	180	170	170	170
11	75	75	180	180	170	170	180	180	175	175	170	170
12	75	75	180	180	170	170	180	180	175	175	170	170
13	75	75	180	180	170	170	180	180	175	175	170	170
14	130	132	80	#120	200	200	230	60	130	140	156	158
15	85	85	170	50	180	180	180	180	170	170	170	170
16	85	85	170	170	180	180	180	180	170	170	170	170
17	85	85	170	170	180	180	180	180	170	170	170	170
18	85	85	170	170	180	180	180	180	170	170	170	170
19	85	85	170	170	180	180	180	180	170	170	170	170
20	80	80	170	170	180	180	180	180	170	170	170	170
21	#60	#60	404	#100	540	370	290	140	250	350	310	366
22	60	60	200	200	220	220	190	190	185	185	200	200
23	60	60	200	200	220	220	190	190	185	185	200	200
24	60	60	200	200	220	220	190	190	185	185	200	200
25	60	60	200	200	220	220	190	190	185	185	200	200
26	60	60	200	200	220	220	190	190	185	185	200	200
27	60	60	200	200	220	220	190	190	185	185	200	200
28	290	340	1620	830	1950	1250	1390	1250	1150	1500	1540	1570
29	70	50	250	250	250	250	250	250	250	250	250	250
30	70	70	350	350	400	400	350	350	350	350	400	400
31	70	70	350	350	400	400	350	350	350	350	400	400
Tot.	2475	2531	7347	4945	8155	6965	7125	6755	6200	6960	7171	7329
Tot. Trans.##	2503		4844	2442	5652	4462	4622	4252	3697	4457	4668	4826

Excess.
Obtained by subtracting the average evaporation (2503 c.c.) from the check pots from the totals.

Table VI con. Daily amounts of water added.

Series 300. C.C. March.

Date	307	307′	308	308′	309	309′	310	310′	311	311′
1	100	100	100	100	100	100	100	100	100	100
3	155	155	155	155	155	155	155	155	155	155
8	860	900	100	436	950	850	1130	1380	1000	1180
9	170	190	175	170	190	190	220	270	200	230
10	170	190	175	170	190	190	220	270	200	230
11	180	180	175	175	190	190	250	250	315	215
12	180	180	175	175	190	190	250	250	315	215
13	180	180	175	175	190	190	250	250	315	215
14	202	206	250	190	82	120		250	154	250
15	180	180	190	190	190	190	250	250	200	200
16	180	180	190	190	190	190	250	250	200	200
17	180	180	190	190	190	190	250	250	200	200
18	180	180	190	190	190	190	250	250	200	200
19	180	180	190	190	190	190	250	250	200	200
20	180	180	190	190	190	190	250	250	200	200
21	500	500	500	250	300	300	116	400	380	560
22	230	230	220	220	220	220	250	250	240	240
23	230	230	220	220	220	220	250	250	240	240
24	230	230	220	220	220	220	250	250	240	240
25	230	230	220	220	220	220	250	250	240	240
26	230	230	220	220	220	220	250	250	240	240
27	230	230	220	220	220	220	250	250	240	240
28	1680	1380	1680	1540	1600	1610	1300	1000	1320	1610
29	250	250	250	250	250	250	250	250	250	250
30	420	420	420	420	420	420	380	380	420	420
31	420	420	420	420	420	420	380	380	420	420
Tot.	7927	7671	7210	7086	7687	7635	8196	8585	7884	8690
Tot. Trans.	5424	5168	4707	4583	5184	5132	5691	6082	5381	6187

Table VII. Daily amounts of water added.

Series 100. C.C. April.

Date	101	101′	102	102′	103	103′	104	104′	105	105′	106	106′
1					35	35	45		45		45	25
2					35	35	45		45		45	45
3	#194	#40	#100	#125	35	40	#286	#230	#30	#75		
4					40	40						
5			35	35	40	40			40	40	40	40
6			35	35	40	40			40	40	40	45
7			35	35	40	40			40	40	40	45
8			35	35	40	40	30	30	40	40	40	40
9			35	35	40	40	30	30	40	40	40	40
10	144	24	100	125			150	150		90		
11					40	40			40		40	40
12					40	40			40		40	40
13			25	25	60	60			60	40	60	60
14			40	40	60	60	50	50	50	40	50	50
15			25	25	40	40	50	50	40	40	40	40
16			25	25	40	40	50	50	40	40	40	40
17	#60	30	26		125	#100		100	56	50	#110	85
18		10	25	25	55	55	50		50	50	70	70
19		10	25	25	55	55	50		50	50	70	70
20		10	25	25	55	55	50	50	50	50	70	70
21		10	25	25	55	55	50	50	50	50	70	70
22		10	25	25	55	55	50	50	50	50	70	70
23		10	25	25	55	55	50	50	50	50	70	70
24			120	40	150	120		50	75	60	84	60
25	10	10	40	30	65	65	50	50		55	75	70
26	10	10	40	30	65	65	50	50	25	55	75	70
27	10	10	40	30	65	65	50	50	25	55	75	70
28	10	10	40	30	65	65	50	50	50	65	75	70
29	10	10	40	30	65	65	50	50	50	55	75	70
30	10	10	40	30	65	65	50	50	50	55	75	70
Tot.	254	190	826	660	1620	1570	900	760	1116	1100	1514	1535
Tot. Trans.##	222		604	438	1398	1348	678	538	894	878	1292	1313

Excess.

Obtained by subtracting the average evaporation from the check pots (222 c.c.) from the totals.

Table VII. con. Daily amounts of water added.

Series 100. C.C. April.

Date	107	107′	108	108′	109	109′	110	110′	111	111′	Temperature F House	Soil
1	45	45	45		15	40			40			56
2	45	45	45		40	40			40		51.5	
3	#40	130		#100		35	#130			#200	57.5	57.5
4	45	45	45		40	40		40	40		57.5	
5	45	45	45	45	35	35					57	
6	45	45	45	40	40	40	40	40	40		68	65
7	45	45	45	40	50	50	40	40	40		60	60
8	45	45	45	45	50	50	40	40	40	40	49	53
9	45	45	#45	#45	50	50	40	40	#40	40	60	58.5
10	#150	310	50	30			#130	#100	20	#200	63	65
11		80		45	50	50			20		60	55
12			45		50	50			40		65	64.5
13			70	70	85	85	40	60	60		74.5	70
14	40		60	60	70	70	40	50	50	40	68	72
15	40		45	45	50	50	40	50	40	40	57	58
16	40		45	45	50	50	40	50	60	40	57.5	55.5
17				50		95	#100		90	175	57.5	62.5
18	40		45	45	65	65		50	50	40		64
19	40		45	45	65	65		50	50	40		
20	40		45	45	65	65	50	50	50	40	77	68
21	40		45	45	65	65	50	50	50	40		
22	40	40	45	45	65	65	50	50	50	40	80	74
23	40	40	45	45	65	65	50	50	50	40		
24	90	45	90	34	70	94	#100	54	115	40	72.5	73
25	50	50	55	45	65	70		50		#100	67	
26	50	50	55	45	65	70		50			62	65
27	50	50	55	45	65	70	50	50	50	40	51	51.5
28	50	50	55	45	65	70	50	50	50	40	52	50
29	50	50	55	45	65	70	50	50	50	40	55	57
30	50	50	55	45	65	70	50	50	50	40	59	54
Tot.	1110	1305	1310	1104	1520	1734	720	1064	1255	805	61.5	60.7
Tot. Trans.	888	1083	1088	882	1298	1512	498	842	1033	583		

Table VIII. Daily amounts of water added.

Series 200. C.C. April.

Date	201	201′	202	202′	203	203′	204	204′	205	205′	206	206′
1	10	10	35	35	75	75	40	40	40	40	110	60
2	10	10	40	40	75	75	40	40	40	40	115	65
3			265	100	205	575	200	450		565	725	595
4	20	20	100	100	210	210	115	115	110	150	325	325
5	20	20	100	100	210	210	115	115	110	150	325	325
6	20	20	100	100	210	210	115	115	110	150	325	325
7	20	20	100	100	210	210	115	115	110	150	325	325
8	20	20	100	100	210	350	115	115	110	150	325	325
9	20	20	100	100	210	350	115	115	110	150	325	325
10	#50	#50	200	100	475	300	168	450	#75	335	#60	#250
11			120	110	250	350	125	165	160	175	325	100
12			120	110	250	350	125	165	160	175	325	325
13	15	15	200	175	375	500	200	300	275	325	500	500
14	20	20	425	400	550	650	425	300	500	300	650	650
15	20	20	120	110	250	350	125	165	160	175	325	325
16	20	20	120	110	250	350	125	165	160	175	325	325
17	#145	#76	150	100	400		250	350	300	580	345	100
18			195	170	350	365	200	225	150	270	400	340
19			195	170	350	365	200	225	160	270	400	340
20	20	20	195	170	350	365	200	225	160	270	400	340
21	20	20	195	170	350	365	200	225	160	270	400	340
22	20	20	195	170	350	365	200	225	160	270	400	340
23	20	20	195	170	350	365	200	225	160	270	400	340
24	#70		430	310	300	570	490	320	100	620	750	560
25		20	200	190	50	400	240	250	160	320	450	380
26		20	200	190	350	400	240	250	160	320	450	380
27	10	20	100	95	175	200	120	125	80	160	225	190
28	20	20	100	95	175	200	120	125	80	160	225	190
29	20	20	200	190	350	400	240	250	160	320	450	380
30	20	20	200	190	350	400	240	250	160	320	450	380
Tot.	360	410	4995	4270	7965	9875	5403	6200	4305	7625	11095	9995
Tot. Trans.##	385		4610	3885	7580	9490	5018	5815	3920	7240	10710	9610

Excess.
Obtained by subtracting the average evaporation from the check pots (385 c.c.) from the totals.

Table VIII. con. Daily amounts of water added.

Series 200. C.C. April.

Date	207	207′	208	208′	209	209′	210	210′	211	211′	Temperature F House#	Soil
1	90	90	50	50	50	50	45	45	45	45		58
2	90	90	50	50	50	50	45	45	45	45		60
3	560	560	655	500	325	500	240	300	190	130		69
4	325	325	250	250	200	200	120	120	120			64.5
5	325	325	250	250	200	200	120	120	120	120		60
6	325	325	250	250	200	200	120	120	120	120		69
7	325	325	250	250	200	200	120	120	120	120		65
8	325	325	250	250	200	200	120	120	120	120		55
9	325	525	250	250	200	200	120	120	120	120		65
10	#225	#225	275	250		500	150	265	130	300		62
11	100	100	260	260	200	200	130	145	125			60
12	325	325	260	260	200	215	130	145	145			70
13	500	500	380	380	350	360	210	220	225	200		75
14	650	650	580	580	540	540	340	450	450	300		68
15	325	325	260	260	200	215	130	145	145	100		59
16	325	325	275	275	200	215	130	145	145	100		
17	80	90	500	325	105	475	275	455	340	200		58
18	330	330	360	360	260	300	200	240	240	200		63
19	330	330	360	360	260	300	200	240	240	100		
20	330	330	360	360	260	300	200	240	240	100		68
21	330	330	360	360	260	300	200	240	240	100		72
22	330	330	360	360	260	300	200	240	240	100		
23	330	330	360	360	260	300	200	240	240	100		
24	600	500	600	600	500	820	740	660	510	275		71
25	370	360	420	420	300	370	275	300	300	125		66
26	370	360	420	420	300	370	275	300	300	125		64
27	185	180	210	210	150	185	140	150	150	75		57
28	185	180	210	210	150	185	140	150	150	40		58
29	370	360	420	420	300	370	275	300	300	125		58
30	370	360	420	420	300	370	275	300	300	125		51
Tot.	9425	9485	10345	9990	6980	8990	5880	6685	6155	3480	61.5	64
Tot. Trans.	9040	9100	9960	9605	6595	8605	5495	6300	5770	3095		

See Table VII con.

Table IX. Daily amounts of water added.

Series 300. C.C. April.

Date	301	301′	302	302′	303	303′	304	304′	305	305′	306	306′
1	30	30	125	125	150	150	125	125	125	125	150	150
2	40	30	125	125	150	150	125	125	125	125	150	150
3	150	130	555	300	550	100	690	575	100	245	710	660
4	70	70	350	350	400	400	350	350	350	350	400	400
5	70	70	350	350	400	400	350	350	350	350	400	400
6	70	70	350	350	350	250	350	350	350	350	400	400
7	70	70	350	350	400	350	350	350	350	350	400	400
8	70	70	150	150	200	150	150	150	150	150	200	200
9	70	70	350	350	400	350	350	350	350	350	400	400
10	50	50	230	#350	308	#150	600	500	#485	#250	665	640
11	70	70	350		400	250	350	350		100	420	420
12	70	70	350	300	400	350	400	400	300	300	420	450
13	70	70	500	500	1200	500	1200	1260	300	300	1400	1400
14	70	70	600	615	1200	1000	1140	1200	350	350	1300	1300
15	70	70	350	300	400	350	400	400	300	300	225	450
16	70	70	350	300	400	350	400	400	300	300	225	450
17	300	250	700			#300	560	300	#250	910	800	480
18	90	90	450	300	500	100	630	630	100	360	700	700
19	90	90	450	300	500	400	630	630	300	360	700	700
20	90	90	450	300	500	400	630	630	300	360	700	700
21	90	90	450	930	500	400	630	630	300	360	700	700
22	90	90	450	300	500	400	630	630	300	360	700	700
23	90	90	450	300	500	400	630	630	300	360	700	700
24	290	250	1060	6001	600	700	2500	2000	520	900	2100	2330
25	120	120	550	420	660	440	900	900	350	450	900	900
26	120	120	550	480	660	440	900	900	350	450	900	900
27	60	60	180	190	220	150	300	300	120	150	300	300
28	60	60	180	190	220	150	300	300	120	150	300	300
29	120	120	550	480	660	440	900	900	350	450	900	900
30	120	120	550	480	660	440	900	900	350	450	900	900
Tot.	2840	2720	12475	9735	14988	9460	18370	17515	7560	10115	19165	19480
Tot. Trans.##	2780		9695	6955	12208	6680	15590	14735	4780	7335	16385	16700

Excess.

Obtainedby subtracting the average evaporation from the check pots (2780 c.c.) from the totals.

Table IX Con. . Daily amounts of water added.

Series 300. C.C. April.

Date	307	307′	308	308′	309	309′	310	310′	311	311′	Temp. Soil#
1	155	155	155	155	155	155	125	125	155	155	56
2	155	155	155	155	155	155	125	125	155	155	56
3	265	340	725	705	565	500	500	380	500	595	64
4	420	420	420	420	420	420	380	380	420	420	61
5	420	420	420	420	420	420	380	380	420	420	58
6	335	335	420	420	420	420	380	380	420	420	65
7	375	375	420	420	420	420	380	380	420	420	60
8	150	150	200	200	200	200	150	150	200	200	54
9	375	375	420	420	420	420	380	380	420	420	61
10	#75	#50	500	125	290	425	75		168	125	60
11	375	375	420	420	420	420	380	380	420	420	58.5
12	375	375	420	420	420	420	380	380	420	420	66
13	500	500	1250	1250	125	1250	1200	1200	1250	1250	72
14	700	700	1300	1300	1300	1300	800	800	1300	1300	67.5
15	375	375	420	420	420	420	380	380	420	420	59
16	375	375	420	420	420	420	380	380	420	420	58.5
17	420	190	640	140	320	620	90	#250	45	#350	57
18	450	440	700	650	650	700	500	250	600	200	63
19	450	440	700	650	650	700	500	475	600	575	
20	450	440	700	650	650	700	500	475	600	575	67
21	450	440	700	650	650	700	500	475	600	575	69
22	450	440	700	650	650	700	500	475	600	575	70
23	450	440	700	650	650	700	500	475	600	575	
24	1060	1030	2550	2210	2300	2050	800	100	1780	1380	70
25	540	520	900	860	860	880	540	480	780	690	65
26	540	520	900	860	860	880	540	480	780	690	64
27	180	175	300	285	285	295	180	160	260	230	57
28	180	175	300	285	285	295	180	160	260	230	58
29	540	520	900	860	860	880	540	480	780	690	57.5
30	540	520	900	860	860	880	540	480	780	690	55
Tot.	12050	11715	19655	17930	17100	18745	12825	11165	16373	15235	61.7
Tot. Trans.	9270	8935	16875	15150	14320	15960	10045	8385	13593	12755	

See Table VII con. for house temperature.

Table X.

Daily amounts of water added.

Series 100 c.c. May.

Date	101	101′	102	102′	103	103′	104	104′	105	105′	106	106′
1	#46	#46	42	74			#25	#150	94	#50		
2			40	40	65	65	50		50	55	75	70
3			40	40	65	65	50		50	55	75	70
4			20	20	37	37	25		25	23	37	35
5			20	20	37	37	25		25	23	37	35
6	10	10	40	40	65	65†	50	50	50	55	75	70
7	10	10	40	40	65†	65	50	50	50	55†	75†	70†
8				#50	#30		#75	#125†	†	#25		
9	10	10	40		65	65			50	55	75	70
10	10	10	40	40†	65	65	75†		50	55	75	70
11	10	10	40†	40	65	65	75	50	50	56	75	70
12	10	10	60	75	102	102	112	75	75	88	112	105
13	10	10	40	50	65	65	75	50	50	55	75	70
14	10	10	40	50	65	65	75	50	50	55	75	70
15			170	80	84	194	70		204	116	210	66
16	10	10	40	40	65	65	75	50	50	55	75	70
17	10	10	40	40	65	65	75	50	50	55	75	70
18	10	10	80	100	130	130	150	100	100	110	150	140
19	10	10	40	40	65	65	75	50	50	55	75	70
20	10	10	60	60	98	98	107	75	75	78	108	105
21	10	10	60	60	98	98	107	75	75	78	108	105
22	#36	#36	70	80	130	170	75		158	124	164	95
23	10	10	55	65	70	75	60	60	66	80	85	90
24	10	10	83	83	105	105	90	90	87	120	125	135
25	10	10	83	83	105	105	90	90	87	120	125	135
26	10	10	55	55	70	75	60	60	65	80	85	90
27	10	10	55	55	70	75	60	60	65	80	85	90
Tot.	190	190	1393	1360	1916	1981	2050	1085	1800	1781	2331	2055
Tot. Trans ††	190		1203	1170	1726	1791	1860	895	1610	1591	2141	1865

Excess.
† Date the first head appeared.
†† The total transpiration was obtained by subtratting the number of c.c. of water which evaporated from that check (190 c.c.) from the other totals.

Table X con.

Daily amounts of water added.

Series 100 c.c. May.

Date	107	107'	108	108'	109	109'	110	110'	111	111'	Temperature House	Soil
1	50	128	72				#100		112	#75	64	60
2	50	60	50	45	65	70		50	50		58	56.5
3	50	60	50	46	65	70	50	50	50	40	59.5	56.5
4	25	30	25	23	23	35	25	25	25	20	64.5	61
5	25	30	25	23	23	35	25	25	25	20	64.5	61
6	50	60	50	45	65	70	50	50	50	40	60	60
7	50†	60	50†	45	65†	70†	50	50	50	40	58	68
8	#50	154					#125	50	72†	#100	55.5	62
9		50	55	45	65	70		50	50		74	68.5
10	50	50†	55	45†	65	70		50†	50	40†	82	83.5
11	50	50	55	45	65	70	50†	50	50	40	72	77.5
12	75	75	82	68	97	105	75	75	75	60	84	85
13	50	50	55	45	65	70	50	50	50	40	76	74
14	50	50	55	45	65	70	50	50	50	40	84	84.5
15	160	354	196	136	200	200	72	50	250		83	93
16	50	50	55	45	65	70	50	50	50	40	86.5	85.5
17	50	50	55	45	65	70	50	50	50	40	80	79.5
18	100	100	110	90	130	140	100	100	100	80	67.5	74.5
19	50	50	55	45	65	70	50	50	50	40	76.5	70
20	75	75	78	63	97	105	75	75	75	60	74	
21	75	75	78	63	97	105	75	75	75	60	85	90
22	55	360	155	245	80	140	#50	70	173		71	70
23	70	100	70	80	80	80	60	60	75	60	80	78
24	105	150	105	120	120	120	90	90	105	90	88	92
25	105	150	105	120	120	120	90	90	105	90	79	91
26	70	100	70	80	80	80	60	60	75	60	79	89
27	70	100	70	80	80	80	60	60	75	60	80	91
Tot.	1610	2671	1881	1722	2001	2185	1607	1505	2092	1060	80.5	73.6
Tot. Trans.	1420	2481	1691	1532	1817	1995	1417	1215	1902	850		

See notes table X.

Table XI.

Daily amounts of water added.
Series 200 c.c. May

Date	201	201′	202	202′	203	203′	204	204′	205	205′	206	206′
1	#125	#40	250	100	#550	200	300	525	350	175	700	500†
2			200	190	350	400	240	525	260	200	450	380
3			200	190	350	400	250	250	260	200	450†	380
4			100	95	175	200	120	125	130	100	225	190
5		10	100	95	175	200	120†	125†	130†	100	225	190
6		10	100	95	175†	200†	120	125	130	100†	225	190
7		10	100	95†	175	200	120	125	130	100	125	190
8	#70	#20	225	115	#833	150	320	590	150	200	650	500
9			200†	190		400	240	250	200	320	450	380
10			20	190		400	240	250	200	320	450	380
11	20	20	200	190		400	240	250	200	320	450	380
12	20	20	300	270	252	600	360	375	300	480	675	570
13	20	20	200	190	175	400	240	250	200	320	450	380
14	20	20	200	190		400	240	250	200	320	450	380
15		35	660	340	#150	760	720	900	725	600	900	940
16	20	20	200	390		400	240	250	200	320	550	380
17	20	20	200	190	300	400	240	250	200	320	450	380
18	20	20	400	380	600	800	480	500	400	640	900	760
19	20	20	200	190	300	400	240	250	200	320	450	380
20	20	20	300	285	450	600	360	375	300	480	675	570
21	20	20	300	285	450	600	360	375	300	480	675	570
22	100	#40	200	400	#175	400	600	720	650	800	880	620
23	20	20	300	300	400	500	400	400	350	450	600	600
24	20	20	450	450	600	750	600	600	525	675	900	900
25	20	20	450	450	600	750	600	600	525	675	900	900
26	20	20	300	300	400	500	400	400	350	450	600	600
27	20	20	300	300	400	500	400	400	350	450	600	600
Tot.	400	365	6835	6455	6327	11910	8790	10035	7915	9915	15055	13570
Tot. Trans.	382		6453	6073	5945	10528	8408	9653	7533	9533	14673	13188

\# Excess.
† Date the first head appeared.

Table XI con.

Daily amounts of water added.

Series 200 c.c. May

Dt.	207	207'	208	208'	209	209'	210	210'	211	211'	Temp. Soil F.
1	450	500	500	500†	500†	575	#75	225	200	200	60
2	370	360	420	420	300	370	375	300	300	125	58
3	370	360†	420†	420	300	370	375	300	300†	125†	57
4	185†	180	210	210	150	185†	187	150	150	75	60
5	185	180	210	210	150	185	187	150	150	75	58
6	95	180	210	210	150	185	187†	150	150	75	60
7	185	180	210	210	150	187	187	150	150	75	65
8	425	450	500	335	340	560		150†	200	135	62.5
9	370	360	420	420	300	370	275	300	300	150	64.5
10	370	360	420	420	300	370	275	300	300	150	77
11	370	360	420	420	300	370	275	300	300	150	71
12	555	540	630	630	550	555	312	450	450	225	82
13	370	360	420	420	300	370	375	300	150	150	74.5
14	370	360	420	420	300	370	375	300	190	150	82.5
15	960	900	910	940	720	900	550	800	780	660	91
16	370	360	420	420	300	470	275	300	300	150	81
17	370	360	420	420	300	370	275	300	300	225	77
18	740	720	840	840	600	740	550	600	600	450	74
19	370	360	420	420	300	370	375	300	300	150	71.5
20	555	540	630	630	450	525	562	450	450	225	82
21	555	540	630	630	450	525	562	450	450	225	86
22	360	560	580	410	640	740	400	620	720	770	70
23	600	600	650	650	450	450	380	400	400	350	74.5
24	900	900	925	925	625	625	570	600	600	525	86
25	900	900	925	925	625	625	570	600	600	525	89
26	600	600	650	650	450	450	380	400	400	350	86
27	600	600	650	650	450	450	380	400	400	350	86
To	12550	12670	14160	13855	10550	12360	9016	9745	9590	6615	73.5
T.	12168	12288	13778	13473	10168	11978	8634	9363	9208	6233	

Trans.

Excess.
† Date the first head appeared.

Table XII.

Daily amountsof water added.

Series 300 c.c. May

Dt.	301	301′	302	302′	303	303′	304	304′	305	305′	306	306′
1	#40	#250	#475	#400	#300	#150	410	#175	#300	#200	800	575
2			550	480	660	440	900	900	350	450	900	900
3	120		550	480	660	440	900	900	350	450	900	900
4	60		275	240	320	220	450	450	175	225	450	450
5	60		275	240	320	220	450	450	175	225	450	450
6	60	60					450	450			450	450
7	60	60	275	240	320	200	450	450	175	225	450	450
8	#50	#100		#650	350	150	910	320	#150		1120	1250
9			350		660	440	900	900	350	450	900	900
10	120	120	350	480	660	440	900†	900	350†	450	900	900
11	120	120	350†	480†	660†	440†	900	900†	350	450†	900†	900†
12	120	120	525	720	990	660	1350	1400		675	1350	1350
13	120	120	350	480	660	440	1350	1350	350	450	1350	1350
14	120	120	350	480	660	440	1350	1350	350	450	1350	1350
15	210	40	350	500	500	355	1860	1660		105	2170	2360
16	120	120	700	700	540	290	900	900	350	450	900	900
17	120	120	350	350	660	440	900	900	350	450	900	900
18	120	120	700	600	1320	880	1800	1800	700	900	1800	2000
19	120	120	350	350	660	440	900	900	350	450	900	900
20	120	120	525	525	660	660	1350	1350	525	675	1350	1350
21	120	120	350	350	660	440	1350	1350	350	450	1350	1350
22	175	40	860	240	660	320	1330	1060	#50		1200	1310
23	120	120	400	350	660	500	1200	1200	350	450	1200	1200
24	120	120	600	525	990	750	1600	1600	525	675	1600	1600
25	120	120	600	525	990	750	1600	1600	525	675	1600	1600
26	120	120	400	350	660	500	1200	1200	350	450	1200	1200
27	120	120	400	350	660	500	1200	1200	350	450	1200	1200
T.	2665	2120	10785	10035	16570	11375	28860	27440	7700	10680	27750	30045
To. Trans.	2392		8393	7643	14188	8983	26478	25048	5308	8288	25368	27653

Excess.

† Date the first head appeared.

Table XII con.

Daily amounts of water added.

Series 300 c.c. May

Dt.	307	307′	308	308′	309	309′	310	310′	311	311′	Temp. Soil F
1	#550	215	500	150	575	1000		#150		300	58
2	540	520	900	850	860	880	540	480	780	690	54
3	540	520	900	850	860	880	540	480	780	690	56
4	270	260	450	425	430	440	270	240	390	545	59
5	270	260	450	425	430	440	270	240	390	345	57.5
6			450	425	430	440†			390	345	60.5
7	650	260	450	425	430	440	270	240	390	345	64
8	600	360	1200	550	1210	1200	350	150		300	61.5
9		520	900	850	860	880	540	480	780	690	65
10		520	900	850	860	880	540	480	780	690†	76
11	†	520†	900	850	860	880	540	480†	780	690	70
12	1000	780	1300	1275	1290†	1320	770†	720	1150†	1035	85
13	540	520	1350†	1275†	1290	1320	540	480	780	690	73.5
14	540	520	1350	1850	1290	1320	540	480	780	690	81
15	1580	340	2600	850	2310	2330	940	370	1600	1430	87.5
16	540	520	900	850	860	880	540	480	780	690	80
17	540	520	900	1700	1360	880	540	480	780	690	75
18	1080	1040	1800	850	1720	1760	1080	960	1560	1380	72
19	540	520	900	1275	860	880	540	480	780	690	73
20	820	780	1350	1275	1290	1320	810	480	1170	1035	70
21	540	540	1350	1275	1290	1320	540	480	1170	1035	89
22	1750	430	1300	1400	1380	1370	670	#180	1020	540	68
23	520	520	1200	1200	1200	1200	600	480	800	700	71
24	780	780	1600	1600	1600	1600	900	720	1200	1050	81
25	780	780	1600	1600	1600	1600	900	720	1200	1050	84
26	520	520	1200	1200	1200	1200	600	480	800	700	84
27	520	520	1200	1200	1200	1200	600	480	800	700	80
T.	14860	13585	29950	27230	37745	29860	14970	11500	21830	19555	72.1
T. Trans.	12468	11193	27568	24838	35363	27468	12578	9208	19438	17163	

Table XIII. D[illegible] A[illegible] A[illegible].

. . M[illegible]-J[illegible]

S[illegible] [illegible]00

Date	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]-09	20	20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	00	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]0			[illegible]	[illegible]	[illegible]	[illegible]00	[illegible]	[illegible]	[illegible]	[illegible]00	[illegible]	[illegible]
T[illegible].	[illegible]00	[illegible]00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
T[illegible].	[illegible]00		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
T[illegible].												

S[illegible] [illegible]00

Date	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]-[illegible]9	80	[illegible]	[illegible]00	[illegible]00	[illegible]00	[illegible]00	[illegible]00	[illegible]00	[illegible]	[illegible]	[illegible]00	1[illegible]00
[illegible]			[illegible]	#[illegible]00	#500		[illegible]00	[illegible]	[illegible]00		[illegible]00	[illegible]
[illegible]-[illegible]-5	100	[illegible]	[illegible]00	[illegible]00	[illegible]00	[illegible]000	[illegible]00	[illegible]00	[illegible]00	[illegible]00	[illegible]00	[illegible]00
[illegible]			[illegible]000	[illegible]00	[illegible]00	[illegible]	[illegible]00	[illegible]000	[illegible]00	[illegible]00	[illegible]	[illegible]
T[illegible].	[illegible]	[illegible]00	[illegible]	[illegible]00	[illegible]00	[illegible]	[illegible]00	[illegible]	[illegible]	[illegible]	[illegible]	
T[illegible].	1[illegible]0		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
T[illegible].												

S[illegible] [illegible]00

Date	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	400	[illegible]	[illegible]	[illegible]00	[illegible]00	[illegible]00	[illegible]	[illegible]	[illegible]00	[illegible]00
[illegible]	[illegible]	[illegible]	[illegible]00	[illegible]	[illegible]	[illegible]00	[illegible]00	[illegible]00	[illegible]00	[illegible]	[illegible]00	1200
[illegible]0	[illegible]0	[illegible]	[illegible]00	[illegible]	[illegible]00	[illegible]00	[illegible]00	[illegible]00	[illegible]	[illegible]	[illegible]00	1200
[illegible]	[illegible]0	[illegible]0	[illegible]00	[illegible]	[illegible]00	[illegible]00	[illegible]00	[illegible]00	[illegible]	[illegible]	[illegible]00	1200
[illegible]	[illegible]0	[illegible]0	[illegible]00	[illegible]	[illegible]		[illegible]00		[illegible]	[illegible]		[illegible]
2	[illegible]0	[illegible]0										
3	[illegible]0	[illegible]0	[illegible]00	[illegible]	[illegible]00	[illegible]	[illegible]00	[illegible]00	[illegible]	[illegible]	[illegible]00	[illegible]00
4	[illegible]0	[illegible]0	[illegible]00	[illegible]	[illegible]00	[illegible]	[illegible]00	[illegible]00	[illegible]	[illegible]	[illegible]00	[illegible]00
[illegible]	[illegible]0	[illegible]0	[illegible]	[illegible]	[illegible]00	[illegible]00	[illegible]00	[illegible]00	[illegible]	[illegible]	[illegible]	[illegible]00
[illegible]	[illegible]0	[illegible]0										
[illegible]	[illegible]0	120	[illegible]00	[illegible]	[illegible]00	[illegible]00	[illegible]00	[illegible]00	[illegible]	[illegible]	[illegible]00	[illegible]00
9	[illegible]0	[illegible]	400	[illegible]	[illegible]00	[illegible]	[illegible]00	[illegible]00	[illegible]	[illegible]	[illegible]00	2400
[illegible]	[illegible]0	[illegible]0	[illegible]00	[illegible]	[illegible]00	[illegible]00	[illegible]	[illegible]00	[illegible]	[illegible]	[illegible]00	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]00	[illegible]00	[illegible]	[illegible]	[illegible]00	[illegible]	[illegible]	[illegible]00	[illegible]00	14[illegible]0
T[illegible].	[illegible]000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]00	[illegible]	[illegible]	[illegible]	[illegible]00	14[illegible]0
T[illegible].	[illegible]0[illegible]0		[illegible]	[illegible]	[illegible]	[illegible]	9[illegible]0	[illegible]	[illegible]	[illegible]	0[illegible]0	11810
T[illegible].												

\# Excess.

Table XIII con. Daily Amounts of Water Added.

c.c. May-June

Series 100

Date	7	7	8	8	9	9	10	10	11	11
28-29	140	200	140	160	160	160	120	120	150	120
31	70	100	70	80	80	80	60	60	75	60
1		250	140	186	52	140	#50	110	200	
3-4	70	100	70	80	80	80	60	60	70	60
5	70	100	70	80	80	80	60	60	75	60
10	40	425	110	200	162	135	70	120	200	110
Tot.	360	1175	600	786	614	675	870	530	770	410
Tot. Trans.	260	1075	500	686	514	575	770	430	670	310

Series 200

Date	7	7	8	8	9	9	10	10	11	11
28-29	1800	1800	1950	1950	1350	1350	1140	1200	1200	1050
1	#800	#900		#200	160	440	120	640	800	500
3-4-5	400	400	1200	1200	900	900	760	800	800	525
9	450	#400	1200	900	850	1000	600	750	1260	1300
Tot.	2650	1800	4300	4000	3250	3690	2620	3490	4060	3375
Tot. Trans.	2460	1610	4110	3810	3060	3500	2430	3300	3870	3185

Series 300

Date	7	7	8	8	9	9	10	10	11	11
28	520	520	1200	1200	1200	1200	600	480	800	700
29	520	520	1200	1200	1200	1200	600	480	800	700
30	520	520	1200	1200	1200	1200	600	480	800	700
31	520	520	1200	1200	1200	1200	600	480	800	700
1	940	460	680	580	220		1200	950	1620	2460
2										
3	260	260	600	600	600	600	300	240	400	350
4	520	260	600	600	600	600	300	240	400	350
5	260	520	2400	2400	2400	2400	600	480	800	700
6										
7	520	520	1200	1200	1200	1200	600	480	800	700
9	520	520	2400	2400	2400	2400	600	480	800	700
11	520	520	1200	1200	1200	1200	600	480	800	700
15	1600	1900	2600	2700	2400	2000	1450	1300	1500	2100
Tot.	7220	6040	16480	16480	15820	15200	8050	6570	10320	10860
Tot. Trans.	4150	2970	13410	13410	12750	12130	4980	3500	7250	7790

Excess.