# RECOMMENDATIONS

TO

# STÖCKHARDT'S CHEMISTRY.

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*Extract from a Letter of* S. L. DANA, M. D., LL. D.

"This book is preëminently clear, concise, practical in all its allusions to art, simple in its arrangements, and illustrated by experiments requiring no array of costly apparatus. It is a work worthy of its author, and will bear the character we have given to it, even when subjected to the severest scrutiny."

*From* A. A. HAYES, M. D., *Assayer to the State of Massachusetts.*

"After reading this work in the translation by Dr. Peirce, I have formed the opinion that, as an easy introduction of the student to the principles of chemistry, it is unrivalled by any book in our language. Rarely is it possible to find an elementary work which, without being voluminous, discusses so many subjects clearly."

*From* CHARLES T. JACKSON, M. D.

"Stöckhardt's Chemistry will prove a useful elementary book in teaching the principles of chemistry. It has the advantage over most of the English works on chemistry, of introducing among pupils of our schools and colleges the Continental system of notation, and the metrical system of weights and measures. The old Daltonian atomic numbers, advocated by Prout and others, is only used in England, and will soon be abandoned there. It is therefore highly desirable that the Berzelian system, generally employed on the continent of Europe, should be introduced here. Stöckhardt's book will serve this valuable purpose. It also conveys much useful elementary knowledge of the science of chemistry, perhaps as much as could be condensed within so narrow limits."

*Extract from* PROFESSOR HORSFORD'S *Introduction.*

"The qualifications of this work as a text-book for schools are such as to leave little, if any thing, to be desired. The classification is exceedingly convenient. The elucidation of principles and the explanation of chemical phenomena are admirably clear and concise. The book is also well adapted to the wants of teachers who desire to give occasional experimental lectures at a moderate expense, and of those who design to commence the study of chemistry, either with or without the aid of an instructor."

*From* John A. Porter, *Professor of Chemistry applied to Art, in Yale College.*

"I concur entirely in the views of the work expressed by Professor Horsford in the Introduction, and shall recommend it to those pursuing the study of chemistry under my direction."

*From* David A. Wells, *Practical Chemist.*

"I consider Stöckhardt's 'Principles of Chemistry,' as an elementary book, superior to any work of the kind hitherto published."

"I have carefully studied Stöckhardt's Chemistry, and have used it in the instruction of my classes. As a text-book it is worthy of all praise; far better than any I have examined since the progress of science rendered the Conversations on Chemistry obsolete. The original is the work of a man at once skilful as a teacher, and profound in his knowledge of the history and principles of his science, and familiar with facts and the details of manipulation. The translation is faultless. It has entirely the air of an original; and in simplicity, clearness, and conciseness may be regarded as a model.

"GEORGE B. EMERSON."

"This Chemistry in particular is fitted for those who desire to study chemistry without the aid of a master, or to get up for themselves good illustrative chemical experiments. Many of the modes of explanation are singularly happy, particularly those which are employed to elucidate the mysteries of organic chemistry, and the doctrine of compound atomic groups." — *From the London Literary Gazette.*

"An excellent work, preëminently adapted to practical purposes. Not only does it familiarly expound the latest accepted views and discoveries, but it is essentially one to make a chemist of the student." — *From the Leader.*

"This deservedly popular Chemistry is written in so easy and agreeable a manner, that it must soon be in the hands of every beginner of chemistry, and we recommend all such to procure a copy of it at once, and to read it carefully and perform the experiments described in it; when they have done this, they will have a very good knowledge of the science." — *From the London Chemist.*

# CHEMICAL FIELD LECTURES

FOR

# AGRICULTURISTS.

BY

DR. JULIUS ADOLPHUS STÖCKHARDT,
PROFESSOR IN THE ROYAL ACADEMY OF AGRICULTURE AT THARAND.

TRANSLATED FROM THE GERMAN.

EDITED, WITH NOTES,

BY

JAMES E. TESCHEMACHER.

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# EDITOR'S PREFACE.

The very favorable reception by the public of a translation of Dr. Stöckhardt's Principles of Chemistry, which has rapidly passed through ten editions, has been considered a sufficient inducement to offer a translation of his recent work, entitled "Chemical Field Lectures."

This, as might be expected, is characterized by the same clearness and simplicity which run through his other work, with the additional recommendation, that, as he states, he has especially exerted himself, and it is believed successfully, to make the subject perfectly intelligible and truly useful to the "non-chemical" agriculturist.

Some of the leading principles of agriculture, which have for the last few years been prominent subjects of discussion, are here amply treated of, and, as I think, placed exactly in their right view and position.

Amongst these, one of the chief points is the use and value for vegetation of nitrogen, in its practical form, ammonia. On this subject the following additional remarks may perhaps be acceptable.

The principle being admitted of the indispensable use of ammonia to all kinds of crops, the question is then, How does it act on vegetation?

When it is desired to increase the number of petals in a flower, in other words, to transform a single into a double flower, the experimenter chooses a single flower which shows a few additional petals within its outer circumference; the appearance of these indicates an inclination of Nature to deviate in this direction. This is then planted in a very richly manured soil, where of course there is great abundance of ammonia; with this treatment, each year, the number of additional petals increases, until, after a series of strong ammoniacal manurings, the whole interior area of the circumference of the flower is filled with petals. But let it be observed, that, in proportion as the number of petals increases, the number of seeds decreases, so that in a full double flower the seeds are generally obliterated. By reverse treatment, the seed-bearing power may be restored.

This has been the course pursued by nature and art, and this the result, with the well-known dahlia, within my own knowledge, as I well remember its original introduction as a single flower from Mexico, and have followed its successive transformations to the present period; and this is the process with the camellia, and all other double flowers. The botanist very well understands that the additional petals forming a double flower arise from the transformation of the filaments of the stamens into petals, and that petals are merely advanced forms of leaves. Ammonia, then, performs the action of increasing the surface of the foliar appendages, or the leaves of plants; that it also increases the health of these parts may be seen by the bright, deep green and luxuriant growth of plants manured by nitrate of soda, or Chili saltpetre, and by those in pots watered with a solution of guano. In trees this action extends to shoots and branches.

As the absorption of a considerable portion of the nourishment of plants, and the rejection of nearly all the useless parts thrown off by them, are actions of the leaves, it is evident that a luxuriant and healthy state of these organs must essentially conduce to the vigorous action of all the other functions, and chiefly to that one so important to the agriculturist, the bearing of seed. But besides the nitrogenous portions of the seed, one other ingredient here is absolutely necessary, namely, phosphoric acid, or the phosphates (salts of phosphoric acid); without these, all the ammoniacal manure in the world would fail to give crops of grain; both of these in abundance, on properly tilled soil, will give the heaviest possible harvests. Nor is this all; for the luxuriance and vigor induced by ammonia will enable the plants to absorb and use up more than the usual quantity of the phosphates, and the grain will naturally be richer in these ingredients. Now as all flesh, blood, and bone require a considerable quantity of phosphates for their formation,—for they are shown by analysis to contain a large proportion,—it follows as a consequence, that the richer in these the food of cattle is, the better they must thrive, the quicker they will be ready for market, and the more they must improve in their general condition. There is, however, one consideration often overlooked. A surface of land has only room for a certain quantity of vegetation, and all attempts to make it bear more must fail. If a manure be given which will make the Indian corn plant grow to double the usual size, and bear double the usual quantity of heads, it must have more room to grow, and must not be planted so close as in the usual manner. In manuring with abundance of guano, if only the same distance be allowed from hill to hill, the circulation of the air and the ingress of the rays of the sun are so much impeded, that the plants are drawn up, and smut or mildew supervenes.

The great principle of the absorption and powerful retention, for the use of vegetation, by clay, of the valuable alkaline salts of potash, soda, and ammonia, which was first publicly promulgated by the editor, in January, 1851, in Boston, the discussions on which by Professor Way have created considerable interest in Engand, may here be incidentally alluded to, as it will certainly not escape the sagacity of Dr. Stöckhardt.

The practice of manuring with clay is not new to many intelligent farmers; it strengthens, as they term it, light lands, rendering their manuring more permanent. The discovery by the chemist of its mode of action, and the considerations arising therefrom, must, however, considerably extend the sphere of its utility, as well as spread the knowledge of its powers amongst those at present in ignorance on the subject, and also afford instruction as to the most economical use of so powerful an absorbent of manure; for instance, it may be added with great advantage as an ingredient to the compost-heap, if spread in very thin layers, so as not to impede the circulation of decomposing heat through the mass.

The views of Dr. Stöckhardt on nearly all the chief points of the preparation, action, and values of manures, their consolidation and perfect protection, agree so exactly with those which have been offered to the public by the editor in various addresses delivered by him within the last few years, that he cannot but congratulate himself on the support of his opinions by a scientific writer of such acknowledged talents, particularly as no communication has ever passed between them. Even the discussion of those points on which a difference of opinion exists, such as the value of fresh manure spread on the land, &c., must tend to elicit truth.

The same may be said of his exposition of the value of guano, experiments on which were exhibited here publicly by the editor in 1842, and on the value of which manure he published a pamphlet in 1845, not a word of which requires alteration, even after the lapse of seven years' experiment.

These observations are made in no spirit of boasting; they are merely intended to support the idea, which runs through the whole of Dr. Stöckhardt's excellent work, of the benefit to be derived from science by being properly applied to agriculture, and of the years of rich harvests which have been lost from the want of faith in this idea.

The information contained in this work respecting the value of the cultivation of rape, of its products, and the influence of its residuum as a food for cattle and a manure, is particularly recommended to the attention of the agriculturists of this country. The seeds might easily be imported from France or Holland, and experiments be made under the direction of our State Agricultural Society, which would no doubt offer a premium for the encouragement, at all events, of the experiment.

It is hoped that this work will add weight to the already numerous proofs of the facts in the preceding paragraphs, and that the public will not fail to encourage and support every attempt to bring agriculture and science into closer union and connection.

J. E. T.

# AUTHOR'S PREFACE.

Incited not only by the strongest persuasion, that chemistry has the power to be of the most essential service to agriculture, but also by the writings of Liebig, I have for the last eight years strenuously endeavored to obtain for this science the favor of the practical agriculturist. And to this end I have laid before the Agricultural Society at Chemnitz the leading principles thereof, in a series of lectures or propositions.

The result of these Lectures has been so far satisfactory, that it has clearly proved to me to be less difficult than is generally supposed to obtain the confidence and interest of the agriculturist in this science, if the chemist will but take the proper means. This he can accomplish only by abandoning dogmatical learning, precepts, and as far as possible scientific names, — by studying to explain his views in a simple and intelligible manner, — and by placing the practical knowledge and experience of farmers in the foreground, permitting science only to shed its light thereon, and by its help elucidate and explain the grounds and principles on which they are founded.

Simple experiments must not be omitted, for they make the connection between various points more visibly comprehensible, and enliven the monotony of long oral discourses.

Encouraged by my experience on this subject, when, four years ago, I abandoned the study of technical for that of agricultural chemistry, I resumed these efforts, and have delivered above one hundred lectures before about sixty agricultural societies in Saxony.

My devotion to this subject has been in general gladly received; chemistry has everywhere been consulted, and has inspired confidence. More recently, I have succeeded in planting the banner of agricultural chemistry beyond the confines of Saxony, and I have every reason to hope that there also it has acquired many friends.

That by such fragments of chemistry as are exhibited on these occasions, incomplete from their very nature, the farmer should become a chemist, is not possible, nor indeed desirable. Let him first see and hear what chemistry is, how it works, and what it can offer to the agriculturist. If chemistry can stand these tests, it has gained every thing; for if the agriculturist only perceives that it may be useful to his calling, means will soon be found, not only to gather harvests from it for future generations, but even to permit the present to share in its benefits.

Then would Germany follow the example of England, by encouraging and supporting chemical investigations on agricultural subjects, by erecting chemical laboratories to meet the present demands of this profession, and by establishing chemical councils and lecturers for agricultural associations, etc., etc. May Germany soon follow England in these wise steps for the support and prosperity of her agriculture!

The subjects I have treated of in these Lectures are here offered to the public, at the repeated request of many of my hearers. I cannot help feeling strongly, however, how difficult it is to communicate in print the interest excited by word of mouth, and how much more incomplete this endeavor must be in a science which requires experiments for its elucidation, the full description of which would lead too far from my real object. But this cannot be helped. To be plain and intelligible to the non-chemical agriculturist is my chief aim.

The chemist by profession will perhaps find many repetitions, which I have made in order to be clear, — many expressions unscientific or trivial, which to me seem popular and simple.

All these and many other objections will not disturb me, if only the agriculturist does not complain that the Lectures are too theoretical, too learned, or unintelligible. If the book is but useful, and gains amongst agriculturists some few more friends to chemistry, its publication will require no apology; if a better one appears, let this be forgotten.

J. A. STÖCKHARDT.

THARAND, 15 July, 1851.

# CONTENTS.

| | | PAGE |
|---|---|---|
| I. | Chemistry indispensable to the Farmer | 1 |
| II. | Nourishment of Plants | 20 |
| III. | On increasing the Growth of Plants by Manuring | 46 |
| IV. | Excrements and Urine | 75 |
| V. | Drainings | 102 |
| VI. | Stall-Manure and Straw | 120 |
| VII. | Importance and Value of Artificial Manures | 149 |
| VIII. | Guano | 171 |
| IX. | Bones | 198 |
| X. | Oil-Cake | 227 |
| XI. | Malt-Grains, or Refuse from Breweries | 240 |

# CHEMICAL FIELD LECTURES.

## I. CHEMISTRY INDISPENSABLE TO THE FARMER.

Through all periods of history two principal desires have been always entertained, and are probably still cherished by mankind; a craving after the constant enjoyment of unfading youth and health, and the possession of wealth sufficient for their necessities. Obscure tradition had intimated that a wondrous stone, which possessed the power to fulfil both these aspirations, was hidden somewhere in Nature's dark recesses, or might be fashioned from her products. By its assistance it would be an easy task, so ran the fable, to convert lead into gold, and to prepare a life-elixir which should abolish sickness, and, in all probability, even death itself. A thousand years were spent in searching for these treasures, but without unveiling them. At length, however, a discovery was made; not indeed this *philosopher's stone*, but in its stead a new science, Chemistry.

Although barely eighty years have elapsed since this discovery, the new science has already gained a practical importance in the affairs of daily life, and an influence upon the material welfare of man, consequently also upon the state of civilization, which must in truth excite astonishment. To a certain extent, chemistry really possesses the virtues ascribed to the philosopher's stone; for by chemical knowledge many a manufacturer has converted, albeit in a manner less direct, masses of comparatively worthless metal into precious gold; and by chemical therapeutics many a sufferer has again recovered health. The complete annihilation of disease, indeed, it has not yet been able to accomplish.

To the rapid and wide-spread diffusion of chemical science, the numerous and diversified uses to which it can be profitably applied in every-day life have especially contributed. Chemistry instructs the apothecary how to prepare his remedies; teaches the physician how to banish sickness by its instrumentality; and not only reveals to the miner the metal hidden in the quarry, but aids him in its fusion and refinement. Chemistry, in conjunction with physics, has been, above all else, the lever by which, within the last ten years, so many arts and sciences have been raised to their present extraordinary perfection; by its means those innumerable comforts and conveniences of life, of which our immediate ancestors were destitute, but which we now so cheaply enjoy, have been afforded us. The results which would be brought about by natural forces, whose existence was unknown until revealed by chemistry, especially in the circle of the operative arts, were so self-evident, that here a door was opened for it almost at once. And although sound practical knowledge regarded its occasionally rather unsubstantial and high-flown theories at first with some distrust, a closer acquaintance with it has now changed those misgivings into entire confidence, and led to a thorough union and reconciliation of both.

In the most recent times chemistry has strenuously applied itself to the investigation of the essential or constituent elements of the *organized bodies* of plants and animals, and to an examination of the circumstances which befall them during life, and likewise after death. Of what do these bodies consist? Whence do they acquire their component parts, their means of sustenance? What changes must the latter undergo in the living organisms of animals and plants, in order to produce their nourishment and growth? How can *we* accelerate this growth? Such, in the main, are the inquiries which chemical research tasks itself to answer.

From these and similar investigations, may we then, in sober truth, expect to derive real advantage in the field of practical agriculture? Chemists and many agriculturists, especially such of the latter as are acquainted with chemical science, are fully convinced that this may be anticipated; from other quarters, on the contrary, doubts, at one time feebler, at another stronger, are perpetually heard, of their utility to husbandry. To arrive at a right decision upon any subject, it must first be accurately understood; for otherwise the essential preliminary to a correct judgment is altogether wanting. Many of those who entertain such doubts have still, perhaps, no clear idea of the proper nature, design, and powers of chemistry, and for this reason it will best comport with the end we have in view, to premise a few observations upon the character and objects of this science, as also upon the ways and means by which it seeks to attain its end.

Every body knows that a piece of *iron*, when hammered at a red heat, is converted into black scales, and also, that by exposure to the damp atmosphere, or burial in moist earth, it changes into rust; that the expressed *juice of the grape* is gradually transformed to wine, and this, again, to vinegar; that *wood* in an oven, or *oil* in a lamp, disappears by combustion; and that *animal* and *vegetable substances* in time become putrid, disorganized, and finally, in like manner, disappear.

Iron scales and rust are *altered iron:* iron itself is hard, malleable, of a grayish-white color, and glistening; when heated to redness it becomes, with an increase of its specific gravity, black, dull, and brittle; when kept in a moist atmosphere, it is converted into a brownish-yellow powder. Wine is *altered juice*, called *must*, in which the sweet taste of the grape-juice can no longer be perceived; as wine it has acquired a spirituous flavor, and possesses heating and intoxicating properties, which had no existence in the must. Vinegar is *altered wine:* it has an acid smell and taste, in lieu of the spirituous qualities of wine, and, when taken as a beverage, acts no longer as an intoxicant, but as a refrigerant and sedative. We must look in the atmosphere for the *wood* or *oil* which have vanished by combustion, for by this process both these substances are *converted* into vapor or gas; if in this transformation heat and light are simultaneously developed, it is accompanied by the phenomenon of fire. Of like character are the alterations which animal and vegetable substances undergo when kept for a long-continued space of time; they are gradually converted, as they putrefy or decay, into gases of various kinds, some of which possess a very disagreeable odor.

*Such processes, by which not merely the external form, but the whole essential nature, of bodies become completely changed, are called chemical processes,* or *chemical action;* by their agency, often with the phenomena of heat and fire, bodies are so radically altered in weight, form, solidity, color, taste, smell, action, etc., that *new* bodies with entirely *new* properties are formed from them. Wherever we glance upon our earth, we behold proof of chemical action: on the land, in the air, in the depths of the sea, in the inanimate stone, no less than in the living tribes of the animal and vegetable kingdoms. The hardest stone becomes gradually friable, changes its color, crumbles into smaller and smaller fragments, and at length forms earth. A potato when planted in the ground grows soft, loses its previous mealy taste, becomes sweet, then rotten, and at last entirely disappears. Yet this apparent annihilation is but a chemical metamorphosis; from the offensive products of putrescence the creative energy of nature produces a fresh plant, endowed with new life, and all the diversified substances peculiar thereto, viz. sugar, starch, oil, etc.

The tuber of the potato-plant forms one of our most important articles of food. The starch contained in it is insoluble in water, but when received into the stomach rapidly undergoes a change, by virtue of which it can be dissolved or digested, and then introduced as a liquid into the blood. In the lungs the blood comes into contact with the inhaled atmospheric air, is thereby changed in color and also in its constitution, whilst the heat developed during this alteration is the source of that warmth which we feel in our whole body. Hence it is evident that in our own organism, as in that of plants, chemical action is perpetually going on; the plant, the animal, and in no less degree man himself, are composed of material upon which chemical forces are ever acting. And it is through chemical processes, not only that their nourishment is prepared, but aided in its digestion and conversion into animal or vegetable substance. Finally, when life has ended, chemical processes again assert their mastery, and, as if the grave-diggers of nature, accomplish the fulfilment of the old truism, "What is of the earth shall again return to earth."

If we, moreover, but look around within the narrow circle of our every-day life, we shall be reminded almost at every glance, by our necessities and occupations, of the beneficial fruits of chemistry. The clothing which we wear has been finished by its instrumentality; by which we mean not to assert that the tailor, who made our coat, was himself a chemist, but that the cloth was bleached, dyed, and dressed by chemical processes. The soap with which we cleanse our skin is a chemical preparation; the fire from which we gather warmth, and the light wherewith we illuminate our evenings, are both produced by chemical action.

Chemistry, then, proposes to ascertain the way and manner in which chemical changes take place, the *cause* of their occurrence, and the laws *in conformity with which* they happen. To effect these objects, it must previously learn of what those bodies, whose changes it desires to investigate, are composed; it therefore resolves, decomposes, or analyzes them, and thereby arrives at the knowledge of their constituent elements. For this reason it was formerly called the Art of Analysis (*Scheidekunst*, separating art). The simple bodies or substances thus discovered, which could be decomposed no further by any known method of analysis, received the name of *chemical elements*, or *elementary substances.*

The process by which the elements of a compound body are brought into combination is directly opposite to that by which it is separated into its ultimate constituents. It was very natural that the chemist should attempt to reproduce the body which he had decomposed, by putting these parts or elements again together; that he should labor to imitate by artificial means the chemical changes taking place in nature; and that he should essay, even if he failed to gain his end, to produce new bodies and fresh chemical changes, in addition to those already in existence and in active operation. From this circumstance chemistry derived its second appellation, the Art of Combination (*Mischungskunst*, mixing art). The numerous discoveries and inventions with which these experiments were crowned are too universally known to need corroboration by the citation of examples.

As long as chemistry did not inquire, in its methods of analysis and combination, into the respective weight and measure of bodies, it remained little more than a mere *docimacy*, or art of assaying; it did not become a science until the habit was acquired of instituting chemical researches with the BALANCE, constantly in hand. This instrument is to the chemist what the compass is to the mariner. The ocean had indeed been navigated before the discovery of the compass, but to continue steering with certainty to a preappointed mark, and to recover the proper course, however often it might be lost, was not possible to the sailor, until the magnetic needle was put into his hand. And so, in chemistry, no predetermined plan or systematic course of investigation could be confidently pursued, until the introduction and employment of the balance. By means of the balance, which furnishes a trustworthy guide, and in no less degree a certain test for chemical experiments, the confident assurance, forming the foundation of scientific chemistry, that all chemical combinations and decompositions take place only in accordance with the fixed and unalterable measure and weight of the ultimate elements of bodies, was, amongst other discoveries, first arrived at. This certainty may now be regarded as a *natural law*.

Many such laws of nature have been already ascertained in the continued prosecution of chemical discovery; they enable us to reply with entire confidence to those questions which have been proposed respecting the mode and the cause of chemical action. Unlike human laws, they cannot be arbitrarily evaded or changed. Their discovery has placed us in a condition to propound, rationally to discuss, and to estimate beforehand scientific chemical *generalizations*, by which alone we can attain to a clear and luminous apprehension of those chemical processes that happen in conformity therewith. It may be objected, that all our knowledge is fragmentary. This, indeed, no chemist will refuse to acknowledge; but notwithstanding such a confession, no undue presumption can be imputed to him for cherishing the belief that this knowledge, fragmentary as it may be, is yet sufficient to justify his pronouncing chemistry a most interesting, practical, and profitable science, and an indispensable friend to every individual of his *species*.

From this sketch of the nature of chemistry, let us present a few examples, furnished by *operative chemistry*, of the directions in which a beneficial application of this science to agriculture may be anticipated. The surprising activity of operative art possesses, thus far, the greatest similarity to that of agriculture; they are both referable to the action of natural forces, and, we may add, of the same powers of nature. If the first has become great and mighty from the fact, that, led on by science, it has arrived at a more intimate acquaintance with these natural powers, and, after having attained mastery over them, has made them its servants, the expectation would seem equally feasible, that a more precise knowledge of the same forces would be of equal advantage to the interests of practical husbandry.

It has long been known that wine or diluted brandy will turn into vinegar, if allowed to stand for a few months at the ordinary temperature, or for a few weeks in warm chambers with free access of air. Chemical research demonstrated the exact constituent elements of the alcohol and of the vinegar formed therefrom, and pointed out that it must be possible to convert the former far more rapidly into the latter, by bringing a large surface of the liquid into contact with greatly increased quantities of air. This intimation was sufficient for the manufacturer, and no long time elapsed before he ascertained the specific conditions under which this rapid conversion might be actually effected. Hence the chemical process, which formerly lasted for weeks, nay, months, is now completed in as many hours, by the improved method of acetification, and that, moreover, with far greater certainty and perfection. May it not, then, be considered probable, that the practical agriculturist, even if he should not attain more rapid, might yet achieve more complete and sure results, if accurately acquainted with the essential ingredients of the soil, as also with those of the plants he might wish to cultivate thereon, and that, by this means, he might perhaps raise advantageously one and the same kind of crop successively upon the same field?

In the mineral kingdom there is found, although extremely rare, a stone of so beautiful a blue color, that the painter weighs its worth in gold, in order, when triturated, to employ it in his art. A German chemist analyzed it, and succeeded perfectly, moreover, in reproducing it, with all its peculiar properties, from the constituent elements he found it to contain. The magnificent artificial ultra-marine, now met with in commerce, has thereby become so cheap, that it is bought at scarcely the hundredth part of its original price. Does not this fact appear to warrant the conclusion, that we shall be able to prepare *manures* by artificial means, and at a reasonable cost, when continued investigations shall have established beyond all doubt what are the separate component parts of those manures necessary to the nourishment of each individual plant? Since the English have succeeded in tracing phosphorite, a stone which consists of the same component parts as bone-earth, throughout a mountain range in Spain for upwards of four miles, the possibility seems scarcely to admit of doubt, that, by more exact chemical scrutiny, various kinds of stone or earth, or other substances possessing the fertilizing power of manures, or capable of acquiring it by admixture with other elements, may be brought to light around us, and perhaps even in our own immediate neighborhood.*

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* There are two localities in the United States where this natural phosphate of lime is abundantly found. Specimens from both have been analyzed by Dr. Charles T. Jackson, with a view to their use in agriculture.

The crystallized phosphorite, from Hurdstown, New Jersey, contains, according to his analysis,

| | | |
|---|---|---|
| Phosphate of lime, | 92 | per cent. |
| Fluate of lime, | 7 | " |

The eupyrchroite of Emmons, from Crown Point, Essex County, New York, contains, according to the same chemist,

| | | |
|---|---|---|
| Lime, | 47.22 | per cent. |
| Phosphoric acid, | 45.70 | " |

These require to be ground very fine, and mixed with sulphuric acid, in order to render them quickly available to crops. The application of these substances being new, the experience of the chemist is required to point out the most advantageous method of use; yet as they contain ingredients absolutely necessary for grain, no doubt can exist as to their value. — J. E. T.

Let us recall to remembrance the lengthy prescriptions and enormous quantity of medicine formerly enjoined by the physician, when compared with the practice of the present day; how short and simple, in like manner, have the formulas and recipes become, by which the printer prepares his ink, the dyer his dye, the joiner his varnish! What is the reason of this change? Is it not that a better insight into chemistry has demonstrated the exact value and mode of action of each specific ingredient, in these recipes, and made it possible to separate the inefficacious from the truly efficacious element? whereas, so long as the principle, that, if one answered no good purpose, another might, remained in vogue, doubts were necessarily felt as to the expediency of attempting any alteration, from the apprehension that in so doing the best ingredient of the compound might peradventure be removed. — Has *agriculture* in this respect attained to clear and distinct principles? In no wise. Let us but read, not indeed books upon agricultural chemistry, but the writings of practical agriculturists themselves; are they agreed upon the *modus operandi* and the manner of applying the simplest manures, lime, gypsum, humus, ammonia, rock-salt, etc.? By no means. Yet how can trustworthy precepts be laid down for the method of employing these substances as manures, if no clear notions are entertained respecting their influence upon the soil and upon plants?

Thirty or forty years ago phosphoric match-boxes were introduced, but again went out of fashion, on account of their failing to stand the test of long-continued use. Now it would surely have been rash to infer positively from this circumstance that phosphorus was unsuitable to the purpose of instantaneous ignition, for the Lucifer or friction matches, now so universally employed, show that it is excellently adapted to this end. The reason why the first experiments miscarried consisted entirely in the *erroneous form* in which it was attempted to be used. A like state of things has frequently prevailed, in the different results obtained by the application and trial of this or that substance as a manure; favorable results were secured when by accident alone it was made use of in the *right form* and at the *right time*, unfavorable ones, on the contrary, when this was not the case. Here then, also, a wide and immeasurable field may be opened up to chemico-agricultural investigations.

Comparisons of a similar kind might be instituted in still greater number, but we may be satisfied with these few, which, it is hoped, will be sufficient to show that the vocation and inherent capabilities of chemistry are, at all events, not inconsistent with the idea of its profitable influence upon practical husbandry.

That practical knowledge has, nevertheless, in numerous instances opposed, and to some extent continues to oppose, the concession to chemical science of so much land and time as are necessary to establish and demonstrate by actual proof this salutary influence, can excite no astonishment; without dispute and opposition, new ideas, which demand an alteration in the existing order of things, have never yet been brought to realization. In addition to this circumstance, the course which their advocates have taken, with the view of introducing them into the affairs of daily life, has not always been the most judicious and correct. It was rash in Theory to bring forward its opinions, speculations, and conjectures as indubitable truths, without submitting them to the previous ordeal of practical experiment, and from isolated facts to deduce forthwith general conclusions; it was unreasonable in Theory to demand of practical knowledge that it should yield unconditional credence to the promises it made, and renounce at once its long-cherished standards in order to march with drum and fife into the new encampment; it was irrational in Theory to undervalue, and indeed to despise, the lessons of practical experience, instead of turning them to profitable use, and to believe in the possibility of science becoming practical without an accurate knowledge of the striking results long since obtained by practice, and without attaching itself closely to the latter by the only means in which this could possibly be effected.

As one extreme invariably produces another, practical knowledge has fallen, in its turn, into the same error. It was rash in Practice, without experiments, or from a few isolated and defective ones, to pronounce a sentence of utter condemnation upon scientific deductions; it was unreasonable in Practice to demand of a science still so young the sure and circumspect advance of mature age, and to claim from it specific facts in lieu of principles, hints, and suggestions,—recipes, precepts, experimental lessons already cut and dried, instead of simple counsel and advice; it was irrational to claim, generally speaking, more from science than from its very nature it is able to supply.

It is precisely at this point that difficulties present themselves in the path of chemical investigation, which render the knowledge of the true relations of things and the production of proof by counter-experiment extremely difficult. The chemist has not now to deal with purely chemical processes, but must laboriously inquire of nature what modifications or changes these processes undergo in consequence of the vital force inherent in plants and animals; he cannot here exert a sovereign sway over fixed, invariable quantities and uniformly continuous conditions, in order to subject to actual proof the accuracy of his conclusions, but is as dependent upon soil, climate, wind, and weather, as the husbandman himself; and, finally, he cannot here, as in the majority of his operations, institute decisive experiments as quickly and as often as he pleases, but must wait for years before he can elicit his results.

Under these circumstances, is it fair to judge chemistry by the results it has already furnished, in the brief period during which *earnest* efforts have been made to apply it to agriculture? or would it not be more just to wait, before expressing an unfavorable decision, until the many germs which during the last five years it has put forth, in consequence more particularly of the impulse it has received from the labors of Liebig and Boussingault, show themselves in their issues to be universally unfruitful? Chemistry awaits the arrival of this epoch without solicitude or apprehension; if many buds and blossoms should fall away and perish from its earliest shoots, others will undoubtedly at a later period set for fruit, and yield a bountiful and serviceable harvest.

Chemistry, again, is able to prove eminently serviceable to the agriculturist when he carries on, in addition to mere tillage and cattle-breeding, various *operative and collateral trades;* viz. distilling, brewing, the preparation of starch or starch-sugar, and the manufacture of sugar from beet-root. Here it is not found a difficult task to gain the confidence of the farmer, because the advantages to which it led were so palpable, as to admit of direct translation into current coin. And reasons of this kind have still the greatest power in producing conviction; they gain acceptance at the outset. Since chemistry here possesses that confidence which it also desires to gain on the land and in the stable of the husbandman, it would be superfluous to add thereto assurances, proofs, or illustrations.

The reason why chemistry succeeded here in at once producing positive vouchers of its utility, lies simply in the fact, that in researches of this kind it has to do, not with living bodies in a perpetual state of change, like plants and animals, but with inanimate substances, which are more readily susceptible of chemical examination than the former. As long as a plant or an animal lives, the chemical processes are under the guardianship of a higher and a mysterious power, which is called the *vital energy*, and are constrained by this to furnish the materials for the construction of the animal or vegetable organism. The vital energy is, so to speak, the architect which plans the outline of the building, whilst the chemical processes must see to the provision of the requisite materials, and work them up in conformity with his design. In inanimate bodies, on the contrary, this guardianship no longer exists, and the chemical processes have free and unimpeded course for their development. The chemist can, it is true, evoke and imitate the action of chemical forces, but not that of the vital energy; he will, therefore, in cases where chemical power enjoys free sovereignty, attain more easily and rapidly to positive results, than in others, where the vital energy, over which he can exercise no sway, comes directly into opposition with him.

Finally, chemistry possesses an additional or detective function, whereby it proves extremely useful to every man, and therefore to the farmer, since *it discloses frauds and impostures*, to which, as is notorious, all are at present more exposed than formerly. Pure merchandise! genuine merchandise! solid merchandise! real merchandise! what manufacturer or merchant does not now-a-days deem himself justified in stamping one of these commendatory appellations upon his articles of trade! And yet his real linen contains, it may be, cotton; his choicest soap, water, gluten, or clay; his genuine syrup, starch-sugar; his guano or bone-powder, sand, earth, lime, and stone. Against such adulterations and losses, chemistry constitutes the most certain and secure defence, since it possesses the power of bringing to light admixtures and adulterations, however cunningly contrived, which our eyes and other means of proof are unable to discover. Many such chemical tests have been already so simplified, that any one, with little trouble or expense, may use them for himself.

If after this statement of the different directions in which chemistry is capable of exercising a salutary influence upon agricultural practice, more special proofs should be required of its ability to realize the promises it makes, these could be readily supplied. Let us inquire only of English agriculturists; let us merely bring together the facts relating to this subject which have been communicated by English agricultural journals within the last five years, or simply calculate the sums which have been expended in that country by agriculturists themselves, with the view of extending and deriving larger returns from chemistry; and we shall not only arrive at a knowledge of the *extraordinary and mighty efforts made in England, and the extremely slight attention paid in Germany to chemico-agricultural objects*, but also at the conviction, that there a harvest has been already reaped, whilst cautious Germany is still debating the question, whether the seeds sown by chemistry possess a germinating power or not! And this knowledge will be fraught with blessings, if it leads us to the conclusion that chemistry will soon become in Germany, what from its essential character and destiny it ought to be and must be, — *a true and indispensable aid to the farmer.*

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## II. NOURISHMENT OF PLANTS.

An inscrutable Wisdom has imparted to every grain of seed the power of germinating in the moist earth, and of growing up into a plant, which puts forth leaves, flowers, and seed, and then perishes and disappears. Germination, growth, flowering, seed-bearing, and decay are the chief stages of development through which plants have to pass. When they have advanced so far as to produce seed, that is, new bodies capable of life, they have fulfilled their appointed task, and their course then tends downward to decay. Whether they may attain this goal in one brief summer, or not until after centuries of life, this, their general history, remains essentially unaltered.

The divine spirit of LIFE, which effects these changes and calls forth the phenomena of existence in the vegetable world, is in its essence entirely unknown to us. We give it, indeed, the name of *vital power*, but gain thereby no clearer appreciation or knowledge of its nature. Its operations are conducted in a manner so replete with mystery, as to render it apparently improbable that the speculations and inquiries of the human intellect will ever be converted into full and distinct knowledge upon this point. We feel, it is true, the rushing of the vital current in the joy which pervades our being when in spring it bursts the buds and covers the earth with showers of blossoms, as also in the melancholy which attacks us when in autumn the withering of the leaves announces its withdrawal; but whence it comes, whither it goes, and by what magic it evokes the wonders of the vegetable world, we are altogether uninformed. That which it produces, and that from which it brings this forth, are alone cognizable by our senses.

Two paths stand open to the inquirer, by means of which he may penetrate, up to a certain point, into the mysterious laboratory of vegetable life:—1st. That of *observation*, which, by the aid of the microscope especially, has led to a very accurate knowledge of the structure of plants, and of those changes in the *form* of their separate parts which happen during growth; 2d. That of *chemical experiment*, by which the constituent elements of plants, their means of sustenance, and some *transformations* of their *substance* occurring during growth, have been ascertained.

From the results arrived at by these researches, a special science, called *Vegetable Physiology*, or the knowledge of the vital phenomena, conditions, and laws of plants, has been attained, and of this science *Agricultural Chemistry* constitutes a principal division.

Among the problems connected with practical agriculture which this science has to solve, that more especially relating to the *nourishment of plants* is of preëminent importance. For it is manifest that if the farmer knew precisely what nutrients would best promote the growth and cultivation of his plants, in what form, quantity, and at what period they must be administered, in order to reap the greatest benefit therefrom, — if he were, moreover, acquainted with the sources from which he could procure them at the cheapest price, — he would be able to make the most extensive, diversified, and profitable applications of this information in his calling. Unfortunately, however, science is not so far matured as to be able to furnish certain intelligence upon all these points, but is still compelled in many cases to have recourse to mere conjectures. Nevertheless these may prove serviceable, if communicated to the husbandman merely as *conjectures*, not as indisputable facts, and in such a form as to be available for the purposes of practical experiment.

That plants, like animals, must obtain nourishment in order to live and grow, is indubitable. To ascertain, however, the kind of nourishment which they do procure is an inquiry far more difficult than that which makes us acquainted with the food of animals; inasmuch as by our senses we are unable to perceive what vegetables take as food, or how they take it; nor can we in this way discover any thing beyond the fact that they absorb water, and again exhale it. Thus much, indeed, is generally known, that soil, moisture, air, warmth, and light are necessary to the growth of plants; but this amounts to very little, for very dissimilar elements are contained in the soil, the water, and the air. The essential point is to ascertain which of these separate elements must be regarded as nourishment to the plant, and which do not subserve this end. In earlier times men lived in the belief that the knowledge of these individual constituents was in no respect important, because vegetables possessed the power of converting one body into another; for example, lime into silica, or silica into lime, just as one or the other might be needed. This belief has been shown, however, to be erroneous. It is now known with entire certainty, that plants have not this power; it is further known, that they can grow vigorously and reach complete development only when all the constituent elements requisite to their organic structure are freely at their service. For this reason, then, an exact knowledge of the chemical elements of plants, of the soil, of water, and of the air, must be deemed absolutely indispensable, — the starting-point, indeed, from which all subsequent inquiry must proceed.

The first question, then, which requires to be answered in this connection, is of the following tenor: —

### 1. Of what do Plants consist?

When the chemist wishes to investigate the composition of any body, he reduces it, in the first instance, into its coarser components, and then again resolves these into their finer elements. The former are called the *proximate*, and the latter the *ultimate* constituents of bodies. If these last admit no further separation into still simpler elements, they receive the name of *elementary substances*, or *chemical elements.*

In this way numberless plants have been already examined, and have been found to contain proximate constituents of very different character. In many cases these can be readily distinguished from each other by their appearance, taste, and other external characteristic marks. Grapes, carrots, and many other fruits and roots, have a sweet taste; they contain *sugar*. The branches and leaves of the grape-vine have a sour taste; they contain an *acid salt.* Those of the wormwood have a bitter taste; they contain a peculiar *bitter principle.* The latter possess also a powerful odor, which proceeds from a *volatile oil.* In the seed of our various kinds of grain, and in the tubers of the potato-plant, we find a substance resembling meal, *starch;* in the seed of the rape and flax plants, a lubricous fluid, *fat oil.* From the cherry and plum trees there exudes a viscous matter, soluble in water; from fir and pine trees a similar product, but insoluble in water; we call the former *gum*, the latter *resin.* That which gives mechanical support to plants, forming as it were their bones and blood-vessels, receives the name of *vegetable fibre*, or, when it has become tough, insoluble, or indigestible, the name of *woody fibre.* In the sap of plants we meet with a substance, which coagulates by boiling, like the white of an egg or the albumen of the blood; in pease and other leguminous fruits, a substance which is extremely like cheese; in the seed of rye, wheat, oats, and other kinds of grain, a substance whose composition is identical with that of the flesh of animals; the first is called *vegetable albumen*, the second *vegetable caseine*, and the third *gluten.* Finally, on the combustion of the plant, we find a residue consisting of an earthy or saline powder, which neither burns up nor volatilizes by heat; this contains its *mineral constituents.*

By separating the various proximate constituents of vegetables still further, we come to their more remote elements and elementary substances, their *ultimate constituents.* If man is seized with amazement and admiration, when with intelligence and sensibility he contemplates the infinite diversity and variety he encounters in the wondrous beauties of the vegetable world, how must he be filled with amazement and admiration on contemplating the simplicity of the means employed by Divine Omnipotence in producing this multifarious variety. As the main pillars, in a strict sense, upon which plants, nay, still more, all living creatures upon the earth, build up the structure of their bodies, four elements alone deserve special notice. They are called *oxygen*, *hydrogen*, *carbon*, and *nitrogen*. Taken collectively, they receive the more general appellation of *organic constituents*, because they must be viewed as the principal elements of all organic substances. They are also denominated *combustible* elementary substances, because upon heating in the air they entirely burn away and disappear; that is, they are converted into gaseous combinations. They may, again, be called *putrescible* elementary substances, because they are capable of corruption, putrescence, or putrefaction, by which process they are equally converted, although more slowly than by combustion, into gaseous combinations. Finally, they sometimes take the name of *atmospheric* elementary substances, because they are contained in atmospheric air.

1. *Oxygen*, when uncombined, is an invisible kind of air or gas, without taste or odor. We find it in our atmospheric air, of which it constitutes one fifth. Every one knows that men and animals cannot live without air, and that vegetable and animal sub-

stances cannot putrefy without air. The property we here ascribe to the air, of supporting life, combustion, and putrefaction, is in reality due to the oxygen it contains. This alône imparts to the air the power of maintaining the chemical processes we have named. Where oxygen unites chemically with hydrogen, it passes into a fluid form and becomes water; when, again, it unites with metals and other mineral substances, it becomes solid, and in this state forms a principal element of all our stones and earths.

2. *Hydrogen*, in like manner, when uncombined, is a kind of air or gas, without color, taste, or odor, and so light as to be used for filling air-balloons. We find it in a solid or fluid form most extensively diffused in nature, in water, snow, and ice, since, as already mentioned, it forms the second essential element of water.

3. *Carbon*, when uncombined, presents itself as a solid body, of a black or gray color, as is seen in charcoal, soot, plumbago, coke, and other substances, of which it is the principal constituent. It may also assume, however, the form of a colorless, lustrous, and transparent stone; for the most precious of our stones, the diamond, has been demonstrated by chemical examination to be pure carbon. In precisely the same way it changes its color and form, when it unites with oxygen, hydrogen, or nitrogen; for wood, sugar, and starch are not black, and yet half of each of these substances consists of carbon.

This is readily shown by subjecting them to heat, which drives off in the form of vapor their oxygen and hydrogen, and leaves a charred or carbonaceous mass behind. Upon continuing the application of heat with free access of air, not only the color, but the solid form, is altered; for then the carbon combines with the oxygen of the atmosphere to form a kind of air or gas, which has received the name of carbonic acid gas, and is colorless like the ordinary air. The same thing happens in the putrescence and decay of animal and vegetable matter.

4. *Nitrogen* or *azote* constitutes the bulk, that is to say, four fifths of our ordinary atmosphere, and when uncombined, as is evident from the fact just mentioned, is of an aerial nature, and invisible. Except in the air, it is but scantily diffused in nature. In the mineral kingdom it is entirely wanting, and in soils we meet with it only in such as contain decaying or putrid vegetable and animal matter. In the organic kingdom, we find it in far larger quantity in the bodies of animals than in those of plants. Of the vegetable organs, the seeds are particularly rich in nitrogen. It unites with oxygen to form an acid, which has received the name of nitric acid, and forms with basic or alkaline bodies (for example, potash, soda, lime, &c.) the so-called nitrates or nitric acid salts, which are more especially produced in decaying vegetable or animal substances. When united with hydrogen it generates a kind of air or gas, which is called ammoniacal gas, and possesses

an extremely pungent odor. This latter gas is always evolved in the putrescence of animal and vegetable matter.

The proximate constituents of plants may be grouped, according to the elementary substances of which they are composed, into two principal divisions. The first includes those vegetable substances which are composed of but *three* elements, — carbon, hydrogen, and oxygen; the second comprises those which consist of *four* elements, — carbon, hydrogen, oxygen, and nitrogen. This classification possesses not merely a theoretical, but in an eminent degree also a practical interest, since very important conclusions are deducible therefrom in relation to the food of plants and the refuse matter engendered from them. The distinction upon which it rests will be seen at once to depend upon the presence or the absence of nitrogen. Hence the first group may be said to comprise *non-azotized* vegetable substances, or such as are destitute of nitrogen; and the second, *azotized* vegetable substances, or those which contain nitrogen. The latter contain, besides nitrogen, small quantities of phosphorus and sulphur.

The proximate constituents of plants already known may accordingly be thus arranged: —

| *Non-azotized Substances.* | *Azotized Substances.* |
| --- | --- |
| Vegetable fibre, | Albumen, |
| Starch, | Caseine, |
| Vegetable Mucus, | Gluten, |

| *Non-azotized Substances.* | *Azotized Substances.* |
| --- | --- |
| Gum and Dextrine, | Chlorophyll, |
| Sugar, | Vegetable Bases, etc. |
| Fat and Oil, | |
| Resin, | |
| Vegetable Acids, etc. | |

In all plants, however, certain *inorganic constituents*, in small quantity, partly dissolved in the sap, and partly deposited in the cells, are also found. These are called the *mineral* constituents of vegetables, because they are derived from the mineral substances contained in the ground or soil. They may also be denominated *incombustible*, because they are not burnt up or volatilized by heat; or *ashy*, because upon the combustion of the plant they remain behind as ashes. They are distinguished from the organic constituents by being incapable of putrescence or decay.

It was formerly supposed that these constituents were unimportant to plants, and that their existence in them was due to the accidental circumstance of their dissolution in the water contained in the soil, and subsequent introduction into the organism of the plant. That this assumption is nevertheless entirely erroneous must be inferred at once from the consideration, that we can powerfully promote and hasten the growth of vegetables by a superficial covering of gypsum, lime, ashes, salt, or other mineral ingredients, and any thing which furthers and accelerates their growth cannot be unimportant to plants. It is now positively known that vegetables always require certain mineral substances, in addition to the organic, for their nourishment and complete development, and that they are obstructed in their growth when they do not obtain a sufficient supply of them. Accordingly, we must regard the ashy constituents in like manner as *necessary* elements of plants.

How greatly these inorganic constituents differ, not only in different plants, but even in the different parts of one and the same plant, and also how greatly they vary at different seasons of the year in quantity and quality, may be learned from the following table, in which these elements are compared as they exist in certain vegetable ashes.

In a dried state,

| | Yielded | Of which were soluble in water: |
|---|---|---|
| 100 lbs. of Grains of Wheat, . . | 2 to 3 lbs. of ashes, | $\frac{1}{2}$ |
| " " Wheat-straw, . . | 4 " 5 " " | $\frac{1}{9}$ |
| " " Potato-tubers, . . | 8 " 9 " " | $\frac{4}{5}$ |
| " " Potato-tops, . . | 12 " 15 " " | $\frac{1}{20}$ |
| " " Oak-wood, . . . | 2 " 4 " " | $\frac{1}{3}$ |
| " " Oak-bark, . . | 5 " 6 " " | $\frac{1}{12}$ |
| " " Oak-leaves in the spring, | 5 " " | $\frac{1}{2}$ |
| " " " in the autumn, | $5\frac{1}{2}$ " " | $\frac{1}{6}$ |
| " " Walnut-wood in the spring, | 10 " " | $\frac{1}{2}$ |
| " " " in the autumn, | 3 " " | $\frac{1}{5}$ |
| " " Walnut-bark in the spring, | 9 " " | $\frac{1}{2}$ |
| " " " in the autumn, | $6\frac{1}{2}$ " " | $\frac{1}{12}$ |
| " " Walnut-leaves in the spring, | $7\frac{3}{4}$ " " | $\frac{1}{2}$ |
| " " " in the autumn, | 7 " " | $\frac{1}{4}$ |

If we inquire what is the constitution of the mineral constituents of plants, chemical analysis replies, that they consist mainly of *potash*, *soda*, *magnesia*, *oxide of iron*, *silica*, *phosphoric acid*, *sulphuric acid*, *muriatic acid* (*chlorine*), and *carbonic acid*. Of these substances the chemist places the first five amongst the *bases* or oxides, the last five amongst the *acids*, and understands by the former those bodies which, if soluble, have an alkaline taste, as, for example, wood-ashes or burnt lime, and by the latter, those which in a state of solution have a sour or acid taste. Potash and soda are also called *alkalies*; lime and magnesia, *alkaline earths*. If a base or alkali unites chemically with an acid, the peculiar properties of both disappear, and the combination, which presents itself as a wholly different body with entirely new properties, is no longer alkaline or acid to the taste, but saline. In this condition it is called a *salt*. Hence we obtain from the caustic potash and the corrosive aquafortis (nitric acid) a mild salt, the well-known saltpetre; and from the caustic soda and the corrosive oil of vitriol (sulphuric acid), an innocuous salt, the well-known Glauber salts. *Wherever bases and acids come into connection with each other, they combine to form salts.* This fact is exemplified in the mineral constituents of plants, and hence we meet with them in vegetable ashes, not in a free and uncombined state, but in a state of combination; therefore, as salts.

Of these combinations there are principally, —

1. *Soluble* in water: the *alkaline* salts (salts of potash and soda).

2. *Soluble* in diluted muriatic acid: the *earthy* salts (salts of lime and of magnesia, together with salts of oxide of iron).

3. *Insoluble* in water and acids: the *silicates*.

Whether one or the other class of these salts predominates in a plant, may be ascertained, although only in an approximate way, by treating its ashes first with water, and then with diluted muriatic acid. 50 ounces of the ashes of potatoes contained 40 ounces of alkaline salts; on the other hand, the same quantity of the ashes of the tops, only 2 or 2½ ounces; 50 ounces of ashes made from the young leaves of trees contained 25 ounces of alkaline salts, but when made from the old dry leaves, only 7½ to 10 ounces.

## 2. Whence do Plants obtain their Constituent Elements?

This inquiry follows directly from the first, and leads us to consider the *food of plants*; for we must regard every substance which supplies the plant with one or more of the elements necessary to the building up its body as a means of nutriment thereto. Plants can absorb their nutriment only through the pores — so fine as to be altogether invisible to the naked eye — of their root-fibres and leaves. Hence it follows, that every thing which can usefully contribute to their nourishment must be either *liquid* or *aeriform*, since solid bodies cannot possibly penetrate into their structure. From the results which have been obtained by modern investigation into all the sources connected with the supply of these nutrients, the following answer must be given to the above inquiry.

1. Plants receive their *oxygen* and *hydrogen* from *water*, without which, indeed, it is, generally speaking, wholly impossible that they can live and thrive. In addition to this fact, water is indispensable to vegetation, because it supplies a medium for dissolving all those nutritive ingredients which cannot of themselves become fluid or aeriform, and because, moreover, it occasions by its fluid constitution the formation of the solid vegetable parts; for it is from the juice made liquid by the water, that all the solid constituents of plants are produced or elaborated.

2. Plants absorb *carbon* in the form of *carbonic acid*, which enters as an unfailing constituent into our atmospheric air and spring-water, and is formed in every soil that contains humus. Carbonic acid is a kind of air which is unceasingly generated in extraordinary quantities by the three chemical processes most universally diffused in nature; we mean, the respiration of men and animals, the combustion of wood, coal, etc., and the putrefaction or decay of animal and vegetable matter. It is, moreover, evolved in fermentation, and causes the effervescence and foaming of the fermenting mass, as likewise the sparkle of beverages not thoroughly and completely fermented; viz. bottled ale, Champagne,

etc. Lastly, it streams forth from crevices in many regions of the earth where volcanic energies are active, or, as we may conjecture, were active in a former age.

All the carbonic acid generated by these different processes is taken up into the air. If it should continue there, the air must of necessity become gradually deteriorated and unsuitable for respiration ; more especially as in all the processes of breathing, combustion, and decay, free oxygen or vital air is removed from it. But this is not the case. The oxygen does not decrease, the carbonic acid does not increase. The vegetable world discharges the function, not only of a supporter, but also of a protector of animal life. It does not merely provide the whole animal kingdom with nourishment, but also restores again to the air the oxygen abstracted by the former. For plants by their roots and leaves absorb carbonic acid as their most important article of nourishment, and by their green or herbaceous parts again exhale its oxygen during the light of day. On the other hand, they firmly retain the carbon of the carbonic acid, and appropriate it to the construction of their leaves, blossoms, seed, and the proximate constituents which these contain.

Carbonic acid is generated in the soil wherever plants are produced. The falling leaves, the roots remaining in the ground, and the worms and insects which feed thereon, all become, as soon as life has left them, the subjects of corruption and decay. By this means the carbon they contain is converted into carbonic acid. We call the substance into which such organic matters are changed during decomposition, *vegetable mould* or *humus*, when, as speedily happens, it has assumed a dark color. Humus, when air and moisture can act upon it, is, by gradual but unceasing alteration in its constitution, still further decomposed, and therefore continually furnishes fresh supplies of carbonic acid to the roots of plants as nutriment. At the same time, also, the azotized and mineral substances which it contains become soluble, often by the aid of this carbonic acid, and capable of being received as food by plants, and are thus in like manner appropriated to their nourishment. The farmer is, therefore, quite correct in attributing to humus an especially beneficial influence upon the growth of plants, and is consequently laboring with all his energies to render his land rich in humus. By its means principally, he makes the soil at once looser, warmer, and better suited to the absorption and distribution of moisture, as well as richer in the power of attracting the nutritive materials existing in the air, as will be more precisely shown in the chapter upon Soil. The farmer, however, must not suppose that this enrichment of the land in humus can be achieved only by directly introducing into the ground in large quantities such substances (for example, straw-manure) as have especially the power to produce humus. This end can also be indirectly attained, and frequently with far greater pecuniary advantage, by a judicious succession of crops, and likewise especially by the application of very powerful manures (guano, bone-dust, etc.), although these, abstractedly considered, can furnish little humus. When by these a more vigorous growth of plants is effected, the roots and leaves become larger, and the soil acquires, therefore, by the fall of the latter and the decay of the former, more material for the formation of humus than by less vigorous forcing and a poorer vegetable growth; perhaps more than it would have acquired by manuring with straw-manure.

3. Plants receive *nitrogen* chiefly through the *ammonia* which is generated during the putrefaction and decay of vegetable, and, more particularly, of animal substances. Plants are always surrounded by air, and the air consists mainly of nitrogen. Hence it might be concluded that they could never lack the means of obtaining this element when it is necessary to the structure of their tissue, inasmuch as they have the opportunity of absorbing it in any quantity from the atmosphere. And yet they are without it in many, perhaps the greater number of fields; and it is for this reason that these do not produce so many or such vigorous plants as they in general might; a fact which will be more precisely shown in the following chapter. From the circumstance, therefore, that plants do not take up the nitrogen of the air as nourishment, we must infer their *inability* to do so, and come to the conclusion,

that pure nitrogen is to them no digestible and befitting food. And thus it is in fact. The chemist undertakes to explain this indigestibility of nitrogen, from its natural constitution. One of the distinctive chemical properties of this gas is its disinclination to combine with other bodies; if this is to be accomplished, it must be brought about by compulsory measures, which the chemist has frequently to apply in a very circuitous method. This unwillingness to give up its natural freedom is apparently so strong, that the plant does not possess sufficient power to overcome it.

Except in the atmosphere, we find azotized combinations only in the organisms of plants and animals; and this is the nitrogen which benefits plants, when, after the death of the organic matter, it has undergone an alteration by putrefaction and decay. These processes perform the same important service to the nourishment of plants, that boiling, roasting, and baking render to the nourishment used by man. The nitrogen is thereby carried over from those proximate constituents of animal and vegetable matter which are composed of four elements (page 26) into a simpler combination. Withdrawing itself from two of these elements (carbon and oxygen), it remains in combination with the third (hydrogen), and now furnishes the most important and valuable nutrient of plants, we mean *ammonia*. In a pure form this substance possesses a very pungent odor and exceeding volatility; for it is a kind of air or gas. Hence, if the process of putrefaction does not take place in the ground, it escapes into the atmosphere. By combination with acids (for instance, muriatic acid), or with humus, which comports itself in the same manner as an acid, ammonia may be deprived of its volatility. Such combinations are called *ammoniacal salts.*

Whoever wishes to become more accurately acquainted with this gas, so eminently important to vegetable growth (which may be represented to the farmer as "*putrid* nitrogen"), needs only to buy a small quantity of hartshorn, such as may be obtained from the apothecary, to heat it in a plated spoon over the flame of a lamp, and to hold over it an empty tumbler. The liquid part of hartshorn is water, containing a large quantity of ammonia in solution; upon being heated, the latter escapes, and mounts into the tumbler. To the external eye the glass seems empty, but the odor which is perceived reveals at once that it contains a pungent gas. This odor is entirely identical with that which is noticed, and is often very offensive, in stables, sheep-pens, or water-closets. Here it originates from putrefying animal excrements, and exhales into the air.

But there is also a second combination of nitrogen which must be regarded as a means of nourishment to plants. This is produced when substances containing nitrogen putrefy in connection with bases (lime, potash, etc.). By the agency of the latter, the nitrogen, instead of uniting with hydrogen, combines with oxygen; and in this way *nitric acid salts* (nitrates) are formed, from which plants have the power of abstracting nitrogen. In this manner nitrate of lime is often generated from the plaster of the walls of stables and the action of nitrogen of urinous secretions, upon heaps of rubbish, and in other places.

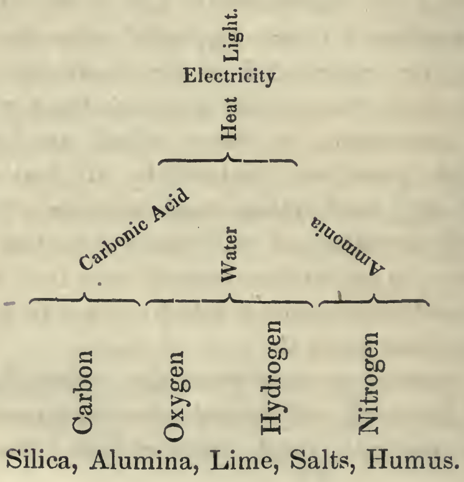
We find nitrogen — for the most part, indeed, in small quantities — in soils and in water. Here it is met with at one time in the humus, at another in the form of ammoniacal or nitric acid salts; but it is invariably derived from animal and vegetable substances which have putrefied or decayed in the earth. The more, therefore, such decaying matter is introduced into the ground, the richer will it become in nitrogen; and the water absorbed by plants will contain this element in a degree proportioned to the length of time during which it has percolated through such kinds of soil as are rich in nitrogen, or to the quantity of these which have been conveyed into it during the process of percolation. Dew, rain-water (especially that first descending from the clouds), and snow always contain ammonia, because by their means the ammonia, which has become volatile during the processes of putrefaction and decay, is again condensed and brought down upon the earth. In the fertilizing effects of transient showers, the greater quantity of ammonia which they contain undoubtedly contributes an essential share.

Finally, it is more than probable that the organic matter decomposing in the soil is in a condition to enable it to convert a part of the nitrogen absorbed from the air directly into ammonia; a circumstance which of course renders the presence and retention of humus in arable land of great importance.

4. The *inorganic* or *mineral substances* requisite to the growth of plants are conducted into their structure through the *soil* and the *water*. The original mass of our various soils consists of crumbled rocks, and these for the most part, except perhaps fossil silica or pure bog-earth, contain all the mineral substances which plants require for their support, although some of them in very inconsiderable quantity. In the solid rock these ingredients are insoluble in water; but nature provides for this, inasmuch as from year to year some portion of its mass is loosened and decomposed. This is accomplished by the process of *weathering*, which plays the same part in the preparation of the inorganic nutrients of plants, that putrefaction and decay perform in the elaboration of those which are organic. Chemical forces here, assisted by air and water, warmth and cold, plants and animals, effect at length the formation of pulverulent soils from solid rocks and the generation of *soluble* salts from insoluble mineral combinations, which salts may in that state be taken up by the roots of plants.

But weathering takes place also below the surface of the earth, and indeed wherever air and water can penetrate into the mass of rock. The substances thus rendered soluble are taken up by the rain-water, and constitute the salts contained in our common spring and river water. Accordingly, in many places plants receive from water inorganic matter also.

Finally, the air likewise contains inorganic substances, which have been conveyed into it by evaporation, especially from the ocean, and also by the force of the winds, and which are diffused by this instrumentality over the whole earth. These are returned again to the earth in rain, dew, snow, etc., and consequently we can no longer be surprised that we often find mineral substances (for instance, common salt, etc.) in plants, which we do not discover in the rocks from which the soil serving as a habitation for these vegetables has been derived.



Thus far, then, on the constituents of plants, and the means of nourishment by which they are provided. The table here exhibited may be regarded as a retrospective view of the essential elements and nutritive materials of plants, and may perhaps render still clearer what has been communicated in relation to these topics.

How Nature proceeds in order to develop from the three nutrients, carbonic acid, water, and ammonia, with the aid of a few mineral substances, the innumerable proximate constituents of vegetables, is a subject upon which we still know nothing. That which is called into existence by the creative power inherent in living plants, we cannot imitate by art, although we know with certainty that it avails itself of chemical forces for the performance of its works. On the other hand, we can imitate several of those transformations of one vegetable substance into another, (for instance, the conversion of starch into gum, of gum into sugar, of sugar into oxalic acid,) which are produced by the vital activity of plants during the period of their growth. In this respect, indeed, art can accomplish more than Nature; for it can effect combinations such as alcohol, ether, pyroligneous acid, chloroform, gun-cotton, and a thousand other compounds, which we never find ready made in living plants.

No doubt, however, now prevails in relation to the fact, that the elementary substances contained in the nutritive materials above mentioned are sufficient to generate all the constituent elements of plants. The greater proportion of plants consist of non-azotized substances (each composed of three elements); all these may be produced from carbonic acid and water, when the elements of the water combine with the carbon of the carbonic acid. If this occurs, the oxygen of the latter must necessarily be liberated, as the following summary shows: —

| | | |
|---|---|---|
| CARBONIC ACID is formed of | Oxygen | . . . . . is set free by exhalation. |
| | Carbon | Hence may be and are formed: Vegetable fibre, starch, gum, sugar, fat, oil, resin, etc. |
| WATER is formed of | Oxygen | |
| | Hydrogen | |

It is, however, also possible that not the carbonic acid, but the water, in plants may be decomposed, so that the elements of the carbonic acid may combine with the hydrogen of the water; and accordingly, that the oxygen which plants exhale during day-light may be derived from the water. The chemical process would then, indeed, be different, but the result would still be precisely the same as that just stated.

If to the two nutrients above mentioned, the third, ammonia, is superadded, all the primitive materials are present which are required for the formation of azotized (each composed of four elements) vegetable substances, as is evident from the following table: —

| | | |
|---|---|---|
| CARBONIC ACID is formed of | Oxygen | . . . . . is set free by exhalation. |
| | Carbon | Hence may be formed: Vegetable albumen, vegetable caseine, gluten, chlorophyll, vegetable bases, etc. |
| WATER is formed of | Oxygen | |
| | Hydrogen | |
| AMMONIA is formed of | Nitrogen | |

Nature, by means of rain and dew, decay and putrefaction, and by physical, chemical, and volcanic forces, provides that the three universal means of nourishment, water, carbonic acid, and ammonia, shall not be wanting to plants; and man also, without exactly intending it, contributes his share, by the processes of respiration and combustion. The air contains an inexhaustible provision of these substances, since the processes by which they are generated on the earth never suffer intermission. The air alone would accordingly suffice for the nourishment of plants, if they could but find in the soil the necessary inorganic salts in solution.

But as a building advances more rapidly when several parts are worked upon at the same time, so the growth of a plant proceeds more quickly and luxuriantly when it can absorb nourishment from several different sources, — not only by its leaves, but at the same time also by its roots; that is to say, when the soil contains in sufficient quantity *all* those materials which are essential to its nourishment. Art must assist wherever this is not the case; and this assistance is rendered by *manuring*, a subject which will be discussed in the following chapter.

## III. ON INCREASING THE GROWTH OF PLANTS BY MANURING.

If we give abundant and invigorating food to an animal, it becomes vigorous and fat; on scanty and slightly nutritive food it continues poor and lean. It is precisely the same with plants. If they find *all* the substances which they require for their nourishment and full development in abundant quantity and in suitable form in the soil and in the air, they will grow up more vigorously, and put forth more branches, leaves, flowers, and fruits, than when they meet with these substances, or even but one of them, in insufficient quantity. By rich and plentiful food the farmer fattens his cattle; by rich and plentiful food he can also fatten his plants. In this respect plants are placed in the same circumstances as animals during stall-feeding: they are confined to one fixed spot, and cannot quit it in order to seek in another place what may perhaps be wanting to them in their own locality. If, therefore, they are to grow luxuriantly, the farmer must take care that their food lies near enough for them to reach it by their roots.

In fattening animals, the farmer is careful to supply them, in addition to good food, with warm sheds and suitable littering; he also provides for their cleanliness and proper attendance, because he knows that this care promotes and increases their health and comfort, and that food acts better upon a healthy beast than upon one that is unsound. The same thing applies with equal force in fattening plants. If they are required to grow in greater quantity and luxuriance upon a field than nature alone admits, not only must more nutritive material be placed at their service, but at the same time a more grateful and appropriate domicile than the raw soil alone must also be made ready for them. The soil, in particular, must be sufficiently deep, loose, warm, and moist, in order that the roots may duly spread, and the nutrient matter be properly dissolved.

When, therefore, the farmer wishes to increase the natural fertility of his fields, two courses are to be adopted,—*tillage of the soil*, and *manuring*. These are the means which from time immemorial the practical agriculturist has put in active use, and by which he has often increased the produce of his ground in a tenfold, twentyfold, or still greater ratio.

By the *tillage of the soil*, concerning which we shall speak hereafter, the farmer principally improves its external or *physical* constitution. *Ploughing* and *harrowing* lessen the firm coherence of its mass, and at the same time render it more accessible to air and water. By this circumstance both the weathering of its mineral and the decay of its organic constituents are promoted. *Deep* and *subsoil ploughing*, *furrowing*, etc., effect the same beneficial changes in its deeper portions, as well as an intermingling of the different kinds of soil. The latter circumstance not only places a more efficacious substratum of earth at the disposal of plants, but likewise insures a more equable distribution of its moisture. By *carrying off its superabundant water*, or *draining*, the soil is not merely rendered more dry, friable, and warm, but also more energetic and sound; — more energetic, because air now penetrates, instead of water, into its interstices, producing a more active weathering and decay; — sounder, because the access of air prevents the further generation of acids, which are notoriously disadvantageous to plants grown upon the land. By *coating with marl* or *lime*, the free acids already present in the soil are most rapidly neutralized, and the activity of the ground in decomposing and dissolving its organic and inorganic components is materially promoted. At the same time an excessive binding of the soil is corrected; an improvement which might also be attained, were it not in the majority of cases too expensive, by *burning* earths of this description. A judicious *interchange* or *rotation of crops* may also essentially improve the physical constitution of a soil, inasmuch as leafy plants (for instance, peas, clover, etc.) shade the ground, and keep it moist during a whole summer, whilst deeply-rooting plants (for instance, rape, etc.) make it loose and mellow. Finally, *irrigation* may in like manner contribute to the improvement of the character of the soil.

By *manuring*, nourishment for plants is conveyed directly into the soil. According to the preceding chapter, we have to consider as nourishment all those bodies which are able to furnish plants with one or more of the chemical elements necessary to their growth. Here it is, however, to be expressly pointed out, that a plant can only grow vigorously, thrive, and attain fully to maturity, when these chemical elements are supplied *all together*. As the life of man ceases when any one of the conditions requisite to its continued existence — for example, air (oxygen) or water — is withdrawn, — as the works of a clock stand still when only a single little wheel is taken from them, — so also the complete development of a plant is checked, although but one of its necessary elements is wanting. Hence it follows that we can only regard such manures as in a strict sense perfect or complete, which contain *all* these constituents. Hence, moreover, a multitude of often entirely contradictory results, in agricultural trials of one and the same manure, are explained in a very simple manner. Lime, gypsum, bone-dust, etc. act excellently on many kinds of soil; on others, not at all. If a soil contains a sufficiency of lime, then manuring with lime will answer no good end; for the plant, finding enough of this constituent already in the ground, requires no further addition of this substance. On the other hand, in land poor in lime or altogether without it, such a manuring may furnish extraordinary results, because it remedies an actual deficiency of this ingredient. From gypsum, plants may provide themselves with lime and sulphur; but it will only act beneficially in such soils as are destitute of both these substances, or at least of one of them. In bone-dust the principal constituents are nitrogen, lime, and phosphorus; when, therefore, it is placed upon a soil in which these elements are already present in sufficient quantity, it will be of little or no efficacy; whereas in a soil poor in only one of these constituents, it may produce remarkable effects.

To this it must be added, that all plants which we cultivate do not require for their nourishment an equal quantity of individual substances, more particularly of such as are inorganic or mineral. Thus, for example, the following quantities were found to be about those which are necessary to produce 1,000 lbs. of each of the under-mentioned articles of produce: —

| | Alkalies (Potash and Soda). | Earths (Lime and Magnesia). | Phosphoric Acid. | Silica. |
|---|---|---|---|---|
| 1000 lbs. of Rye, straw and grain, well dried, | 5 | 3 | 4 | 13 lbs. |
| " " Rape, straw and grain, . . | 10 | 13 | 10 | 2 " |
| " " Pease, straw and grain, . . | 10 | 16 | 9 | 2 " |
| " " Clover, as well-dried hay, . . | 27 | 32 | 3 | 2 " |
| " " Beet, roots and leaves, well dried, | 48 | 32 | 7 | 3 " |

Hence it is apparent, that, to produce an equal weight of each plant, very different quantities of potash, lime, etc. are necessary, and from this it obviously follows, that the action of any kind of manure will always vary according to the plants to which it is applied. Manuring with lime has perhaps no influence whatever upon rye, whilst upon pease or clover, in the same portion of the field, it exhibits a very excellent effect. In such a case we must suppose that the soil contained lime in sufficient abundance to meet the small requirements of the rye, but not so plentifully as to avail for a full yield of pease or clover; the first of which requires five times, and the latter ten times, as much lime as rye.

Similar differences occur, not merely in different kinds of plants, but also in the different parts of one and the same plant; a fact which teaches us that some of the constituent parts of our manures act more especially upon the leaves, others upon the seed, and others, again, upon the root. Thus, for example, there have been found (we use round numbers): —

| | Alkalies. | Earths. | Phosphoric Acid. | Silica. | Nitrogen. |
|---|---|---|---|---|---|
| In 1000 lbs. of dry rye, | 6 | 2 | 9 | — | 30 lbs. |
| " " " rye-straw, | 5 | 3 | 1 | 19 | 40 " |
| " " " pease, | 8 | 3 | 9 | — | 45 " |
| " " " pea-straw, | 12 | 22 | 9 | 4 | 20 " |
| " " " beet-root, | 24 | 12 | 3 | 1 | 20 " |
| " " " beet-leaves (dried green), | 60 | 40 | 10 | 4 | 45 " |

These figures can be admitted only as approximative, but they at all events show, although they do not coincide entirely with each other, that, as a general principle, the leafy parts and roots of plants chiefly require, besides nitrogen, alkalies and earths (potash and lime) for their full development; the seeds, again, phosphoric acid and nitrogen. To this conclusion the leaves of the beet form a merely apparent exception, because they were examined in a *green* or semi-matured period of their growth. In this condition they of course contain the materials from which the root, and, at a still later period, the blossom and seed, are to be formed. When completely matured, they contain less phosphoric acid and less nitrogen. In this state of things it will no longer seem strange that many manures, as experience demonstrates, occasion more especially the growth of stalks and leaves; and others an abundant production of seed.

*What are the constituent elements contained in manure?* This is the first and most important question the chemist has to answer, before he can furnish distinct information to the inquiries proposed by the practical agriculturist: How does manure operate? How quickly does it act? How long does its action continue? What is its worth? etc., etc. Manure operates only by means of the chemical substances it contains; these, therefore, must be accurately ascertained, before any exact intelligence can be afforded by the chemist as to its action and effects. Were this the whole inquiry, it might be conclusively settled; for chemistry is now so far advanced, as to be able to detect and define these elements even to a thousandth part. What advantage, however, does the farmer derive by being informed that such or such a quantity of potash, nitrogen, phosphorus, etc. is contained in the compost, if the chemist does not at the same time tell him how these substances operate, and what is their value?

On these points, so exceedingly important to practical agriculture, the chemist cannot at present reply with entire and well-grounded certainty; inasmuch as they are not of a kind to be determined by an investigation which is limited to his study and laboratory. The conclusive decision in these matters must be sought on the land of the farmer; the more, therefore, practical men coöperate in these investigations, the more quickly will their many deficiencies be supplied, — the more speedily and surely will theoretical conjectures be converted into practical certainties.

Our present knowledge, however, may still be productive of manifold advantage; more especially when theory deduces its conclusions, not from scientific speculations, but from the practical results of agricultural experience, and in doubtful cases propounds them simply as conjectures. This has been attempted in the subsequent observations.

*The following substances must be regarded as the most important constituents of manure:* —

1. *Nitrogen.* This article must beyond all question be considered the *most valuable* element in all substances employed as manure; inasmuch as it

more especially imparts to manure its so-called "driving" or "forcing power." It is necessary to plants, above all, in their earliest periods of growth, because it is at this time that they assume the type of their whole later development. If at this stage of their life they can make a vigorous start, then their stalks and leaves are from the first larger and stronger, and are subsequently able to put forth more blossom and seed. On the other hand, if plants are destitute of this means of nourishment during the first periods of their development, they remain stunted and weak, and the poor spring can only be followed by a poor autumn. The action of nitrogen extends no less to the strictly vegetable portions of the plant, than to its seed; it is equally essential to the vigorous cultivation of both. It follows, indeed, from our previous statements respecting the constituent elements of the seed and straw of rye and pease, that the latter when compared with the former is poor in nitrogen. This, however, is just what might be expected; for the amount of nitrogen must be lessened in *ripe* straw, because a large part of it passes into the seeds, and is appropriated to their formation. Hence the lower extremity of a straw culm is always poorer in nitrogen than the upper, and it would for this reason be more consistent with the end proposed to use the former as litter and the latter as fodder. The great abundance of nitrogen, as also of mineral ingredients, which the table upon page 51 shows to be contained in the leaves of the beet before they have attained to full maturity, accords entirely with this statement.

If, however, nitrogen is to be rendered fit for the food of plants, it must be first converted by putrefaction and decay into ammonia (or nitric acid), or, to speak more correctly, into ammoniacal salts (or nitric acid salts). These combinations are very easily and rapidly absorbed by plants; either by their roots, if the ammonia is found in the earth, or by their leaves, if it is contained in the air surrounding them. From this circumstance fresh bone-dust, undecayed animal excrement, undecomposed urinous liquids, etc., operate far more slowly than when brought on to the field after having previously undergone putrefactive fermentation. In the latter state they contain ammonia (putrid nitrogen) already formed, to which the plant can help itself at once; in the former case, this transformation of the azotized substances takes place in the ground, and the plant must wait until it is in progress, before it obtains ammonia. If this conversion, which will be more fully explained in the fifth and sixth chapters, is of long-protracted duration, — as is the case, for example, in very dry weather (from deficiency of moisture), or in very heavy soils (from deficiency of air), — then it may happen that this manuring produces during the first year no effect whatsoever; for if the favorable moment, that of most vigorous growth, has once gone by in a plant, the richest nourishment can no longer render it assistance. The extraordinarily rapid operation and forcing power observed in manuring with guano, soot, gas-water, drainings, or ammoniacal salts (sal-ammoniac, carbonate or sulphate of ammonia), is thus explained at once; all these substances contain ammonia ready made.

That putrid nitrogen or ammonia really constitutes the "forcing" element in guano and in other composts, the farmer may very readily convince himself by a few extremely simple experiments. A goodly number of plants with red leaves is often found in fields of rape or beet-root, chiefly in those places where the soil lacks power; for example, in the furrows and head-lands. If a few red leaves of this description are put into a tumbler with water, and a teaspoonful of hartshorn poured on in addition, a change of color will soon become evident; and in a few minutes the leaves will have become dark-green. It is the ammonia of the hartshorn which converts the hungry red color into satisfied green; for water alone produces no such change, and except this (and ammonia) no constituent elements are present in the hartshorn. The same alteration will be manifested if a quart of water to which one table-spoonful of this fluid (or one quarter of an ounce of any ammoniacal salt) has been added, or, again, a quantity of putrid drainings, or a weak solution of guano, is poured upon those patches of ground where the red leaves in question are produced. These experiments show very plainly what is wanting to the soil; the farmer says it is destitute of power, and the chemist might add, this power in the case before us is called ammonia.

Another experiment is the following. If the tuber of a hyacinth is wrapped round with a few thin horn-shavings, and put into the earth by the side of another without this envelopment, a plant will grow up from the former perhaps double the size of that produced by the latter. In horn-shavings there are, except nitrogen, no fertilizing constituents of much importance ; it must therefore be this substance to which the extraordinary increase in the growth of the hyacinth is properly due. In this experiment the forcing power is developed at a much later period than in that with the leaves of the rape or beet plant; because the nitrogen of the horn must be changed into ammonia, by putrefaction in the earth, before it can operate. The same effect is produced when the hyacinth, or any other plant which is cultivated in pots, is sprinkled with glue-water. In glue, likewise, there is no other powerfully fertilizing ingredient than nitrogen ; but this must be first set free by putrefaction, and for this reason even here the effect does not immediately happen. When, on the other hand, the glue-water is suffered first to become putrid, it operates more briskly; a fact which now needs no further explanation.

Further information upon the value of this important agent in manure, and the means of retaining it, will be communicated in our observations upon individual manures. To prevent misapprehension, we add here another remark. In our previous declaration, true as it is, that nitrogen is the most valuable ingredient of such substances as are used for manure, we do not intend to affirm that their remaining constituents — for example, potash, lime, phosphoric acid, etc. — are less important than nitrogen to the nourishment of plants. In this respect, indeed, all the separate substances, whether they be dear or cheap, scarce or universally diffused, which plants require for their development and complete formation, must be regarded as *equally important.*

The matter, however, assumes a different shape if the *value in money*, which these several ingredients may cost the farmer, is taken as the standard when the question is proposed, How might the farmer be able to procure this or that constituent in another manner at the cheapest price? From this point of view, very different values are assigned to these separate elements, and nitrogen must indisputably be pronounced by far the dearest and most costly amongst them. Upon this subject more precise information is contained in Chapter VII.

2. *Substances forming humus, or organic elements.* By these appellations are to be understood those constituents of manure which are composed of *carbon*, *oxygen*, and *hydrogen*, and which form the bulk of ordinary stable-manure. Without greatly erring, *vegetable* fibre, the most generally diffused proximate constituent of the vegetable kingdom, may be regarded as the exclusive producer of humus; inas-

much as all the vegetable matters we turn to account in the formation of humus consist mainly of vegetable fibre. Such, for example, are straw, leaves, saw-dust, moss, turf, and bog-muck. When these substances, as has already happened with turf and bog-muck, turn to putrefaction and decay, their color becomes dark, and they are converted into carbonic acid and water, which can now be absorbed by plants. As a strict nutrient for plants, the substances just named are of subordinate importance, because Nature labors under no deficiency in carbonic acid and water, and plants can imbibe these elements from the moisture of the soil, without which vegetation is in general impossible, as also from the air, in any quantity they require, provided only that they are supplied with the necessary mineral and azotized materials. Moreover, great anxiety on the farmer's part respecting the introduction of humus into the earth is uncalled for from the fact, mentioned in page 36, that Nature herself provides against its removal from the soil, when the farmer only takes care that it produces vigorous and abundant plants. In Saxony there are several large farms (for example, in Wohla and Lawalde, near Löbau), whose occupants have either altogether, or for the greater part, removed their cattle, and manured their fields, — in no respect rich in humus, — for ten or twelve years past, exclusively with bone-dust and guano; that is, with substances which supply directly to the land scarcely any humus.

Up to the present time they have obtained a yearly *increasing* produce, and this, too, to an amount which could hardly have been realized by the employment of the stable-manure produced upon their farms alone.

On the other hand, substances forming humus, or already partially transformed into humus, are of very great importance in improving the soil; since they are able to make binding and cold earth looser and warmer, and thin and dry soil, on the contrary, more binding and moist, as has been previously intimated.

3. *Alkalies* (potash and soda). Of these bodies, the *salts of potash* (potash in combination with acids, carbonate of potash for example) exert the most favorable and striking influence upon the growth of plants, especially in the formation of their strictly vegetable parts, or straw. This we see exemplified in the action of wood-ashes, which are rich in potash. According to its chemical nature, potash belongs to the alkaline bodies, and in this particular resembles ammonia. This similarity is manifested also in its action, which, equally with that of ammonia, is strongly forcing. Of the better known manures, the urinous secretions of our domestic animals abound particularly in potash, inasmuch as the alkalies contained in their food are for the greater part eliminated by the kidneys.

The fear has been expressed, that a soil, if the salts of potash are not given to it, may become sterile from want of these ingredients; but this apprehension is quite overwrought. Unless plants rich in potash (for example, tobacco, cabbage, turnips, potatoes, etc.) are sought to be grown in uninterrupted succession, ashes and urinous liquids are almost the only manures containing potash at the command of the farmer; of these, however, in the majority of farms, little, comparatively speaking, comes upon the land, and yet its fertility does not for this reason diminish, if in other respects it is well manured, and a judicious rotation is made in the crops. By a plentiful manuring with stable-manure, with which the drainings have not been especially incorporated, we give to the soil from twenty to twenty-five pounds of potash per acre; and a single good crop of clover, potatoes, or beet-root produces from forty to fifty pounds of this substance per acre. Here, at all events, the soil locks up potash; and it can do so, for almost all kinds of earth and stone contain considerable stores of potash in an insoluble state. A certain quantity of this is made soluble from year to year by weathering, and has a very beneficial influence upon plants. Spreading the fields over with burnt lime causes an increased production of potash, since lime possesses the power of breaking up rocks or stones containing potash, and almost always itself contains small quantities of this substance.

The *salts of soda*, amongst which common salt, carbonate of soda, and Glauber salts are the most generally known, influence the growth of plants in a less degree than those of potash. This may be explained from the fact, that plants, as the examination of their mineral constituents has already shown, absorb soda only in very inconsiderable quantities from the soil, although for the most part richer in soda than in potash. For this reason the salts of soda possess, as elements of manure, a lower value than those of potash, and are seldom wanting to plants, inasmuch as their diffusion is almost universal. By high winds and storms, sea-water converted into fine spray, and with it common salt, is scattered widely over the earth, and the latter ingredient is found, in greater or smaller quantities, in almost every spring. If the farmer believes that the application of salt will be beneficial to his fields, he will proceed most advantageously by mixing the salt with the food of his cattle. In this way he will procure a manure abounding in salt, and reap a twofold benefit. The so-called "manuring salt" of the salt-boiler consists in great part of gypsum, and its action upon the land may in many cases be ascribed to this substance rather than the salt.

4. *Phosphoric Acid.* This, next to nitrogen, must be pronounced the most important and valuable constituent of manure; because upon it the *formation of the seed* essentially depends, and because it is found only in scanty quantities in the soil, although everywhere present. If plants cannot absorb it in sufficiency from the ground, they bear little seed. The gain in quantity and weight of grain after manur-

ing with bone-dust must be principally attributed to this ingredient of bone. Phosphoric acid, in its free state, is soluble in water, but when brought into contact with lime combines with it to form a white, insoluble powder, called *phosphate of lime.* In this combination we find it as the chief constituent element of bones; in this combination it occurs also in the solid excrements of cows, horses, and sheep; and we discover the same combination in the seeds of plants. It enters into the same relations with magnesia, which always occurs in plants in association with lime, as with lime or lime-earth. Mixtures of phosphate of lime and magnesia are therefore called, in familiar language, for the sake of brevity, "phosphoric acid earths." Since these are insoluble, they only work more slowly in the mass than when they are made soluble by other substances. This is effected gradually by the matters engendered in the decay of manure, and rapidly by the action of strong acids; for instance, by sulphuric or muriatic acid. The latter method is now very generally adopted by English farmers, in order to obtain a more prompt and energetic action from bones. Their experience has shown that phosphoric acid more especially calls forth an exceedingly vigorous growth of the roots of plants, and for this reason vitriolized bones are considered the best manure for turnips, carrots, beet-root, etc. According to the results of numerous experiments, phosphoric acid produces its full effect only when azotized substances are present at the same time in sufficient quantity.

Any stone which contains phosphoric acid in considerable quantity may be turned to account, as an excellent addition to other composts, and more particularly to such as are rich in nitrogen. In England many such minerals, which have already imparted great benefit to agriculture, have recently been discovered; and in Germany, also, some of similar character might certainly be found, were they but sought for.

5. *Lime and Magnesia.* Both these earths are indeed absolutely indispensable to the growth of plants, but they belong to those mineral substances which are most universally distributed over the earth, and are accessible to the farmer wherever it supplies limestone, chalk, marl, or gypsum, or where oyster-shells can be obtained. Hence in all places he possesses the means of providing an abundant supply of these substances for the cultivation of his plants. On the numerous and diversified benefits which they impart, — partly as direct means of nourishment, partly as agents which improve or loosen the ground, or, on the other hand, as substances which neutralize acids or hasten decay, — more specific information will be given in our observations upon mineral composts.

6. *Silica.* All plants contain silica; many (as, for example, the various species of grain in their straw) in very considerable quantity. Hence we infer that it is an essential constituent of plants, and that they cannot dispense with it in their food. But it does not of necessity follow that the farmer must

bestow especial consideration upon this substance in manuring his land; inasmuch as it forms the principal mass of our solid earth, is absent in no soil (with the exception, perhaps, of pure humus or bog-earth), and is, moreover, contained in all spring and river water. His single care must be directed to the labor of insuring that the silica be rendered *soluble*, in order that it may be able to penetrate into his plants. He incidentally attains this end by deep ploughing, good manuring, or the application of lime, since in this way he affords to the soil ammonia, potash, lime, etc., which are solvents of silica. In most cases, however, the farmer is exonerated even from this care; for nature, which, by weathering, liquefies from year to year a portion of this earth, takes this labor off his hands. The solid excrements of animals are particularly rich in silica.

The same observation applies also to the remaining constituents of manure, — *oxide of iron*, *sulphuric and muriatic acids*, with other substances which have not yet been specified. They are so generally diffused in the earth and in water, that plants probably find in every soil as much of them as may be needed for their growth. Thus, for example, gypsum consists of lime and sulphuric acid; common salt, of soda and muriatic acid; but small quantities of gypsum and common salt are present in almost every kind of earth, and in all water.

Of the ingredients of manure which have hitherto been named, *nitrogen* is that upon which, in the generality of cases, the farmer must bestow his chief attention. First, because fields are most in want of this substance; and secondly, because stable-manure, the agent most generally employed to remedy this want, does not, under its ordinary management, contain the quantity required to feed plants so plentifully with it that they may furnish that maximum of produce which is, generally speaking, attainable. This attention is the more necessary, because the remaining constituents of manure, as many experiments have shown, can only produce their full effect when nitrogen is simultaneously present; again, because nitrogen is rare and expensive; and lastly, because it is far more readily lost than the mineral ingredients, inasmuch as it is capable, not merely of running away when liquid, but also of flying away, on account of its conversion into volatile ammoniacal gas through putrefaction and decay. Next to this element, *phosphoric acid* and the *alkalies* claim the greatest consideration, because they are the rarest amongst the inorganic nutrients of plants, and are needed in larger quantities for vegetable growth. If we wish to express the relative value of these substances in money, one pound of nitrogen may be valued at about 15, or when converted into ammonia at about 16; one pound of phosphoric acid, or of the alkalies, at something like 2; whilst the same quantity of organic matter, required to form humus, may be taxed at $\frac{1}{32}$d part of 1.

*How quickly does manure operate, and how long does its action continue?*

It is obvious that the farmer must be desirous to know whether the principal effect of a compost, which he thinks of applying to his land, may be anticipated in the first, second, or third year, or at a still later period. In common practice, great value is usually attached to the prolonged operation or endurance of manuring; and this is undoubtedly correct in the case of a manure which, like lime, exerts in the first year of its application an energetic action on the soil. On the other hand, in a manure which, in the majority of cases, does not begin to work actively until it has lain for one or two years in the ground, it is assuredly incorrect to consider this kind of endurance as a ground of special preference, for capital is invested in the land, of which during one or two years the interest, and indeed still more than the interest, are lost. The calculating farmer, who, like a merchant, accurately computes what a manure may have cost him, and the return, — in what space of time, and upon what surface, it may have given him a return, — will certainly subscribe, with entire conviction of its truth, to the following proposition: *The quickest-working manures are the most profitable, for they increase the business capital of the farmer.*

An English agriculturist relates, that, forty years before bone-manuring became general in England, ten or twelve hundred-weight of bones in *coarse* pieces were applied to the acre; subsequently, only six or seven hundred-weight, in the state of *fine dust;* but at the present day, only one or two hundred-weight, in a *soluble* (quickly operative) form, upon the same surface; and yet that by the latter inconsiderable quantity the same result is now attained, as in earlier times by from eight to ten times the quantity of bones. The farmer who manures with vitriolized bones (decomposed by sulphuric acid) is accordingly able to reap from four to eight times more land than formerly, with the same amount of capital; or what is the same thing, he can now accomplish as much with his money as in former times with a capital from four to eight times larger.

Composts whose action is quick and energetic will not of course be persistent; for if their constituents are absorbed in the first year by plants, none can be left for the following years. Uncalculating farmers often urge this want of persistent or long-continued action in quickly operative manures as an imperfection, while in other matters they admit the same principle to be perfectly natural; that the strength of a galloping horse, for instance, is sooner expended than that of a slow-pacing cart-horse, or that a quart of oil is consumed more rapidly by a large solar, than by a small kitchen lamp. A calculating farmer, on the contrary, will recognize at once that he occupies a better position when the capital buried in the land together with the interest can be recovered in a year, than when a period of several years is needed for this end.

The rapidity, then, with which a manure will exert its action on the soil depends upon the facility with which it passes into decay, or becomes soluble in the ground. The slower this process, the slower will its operation also be. Dry weather, heavy soil, and a coarse or compact condition of the manure, retard its decay and liquefaction, and accordingly its working, just as the opposite circumstances accelerate them. On this account, manuring substances when dissolved always operate more promptly than when solid. If a substance is wholly insoluble, and remains so in the ground, it excites no action, even when composed of the most powerfully fertilizing elements. This we see illustrated in the various kinds of coal, which are often very rich in nitrogen, and yet exert no forcing power, inasmuch as they continue lying in the earth without undergoing liquefaction or decay. On the other hand, the most active manuring elements may do injury instead of benefit, if applied in too strong or too concentrated a form; and this will occur when the manure decays and deliquesces rapidly, and finds but little moisture in the soil to dilute it. Drainings when applied to fields in dry weather burn up vegetation, but when mixed with water, or thrown upon moist soils, do not produce this effect; guano and rape-dust strewed too near the seed not unfrequently destroy its germinating power, whilst this injury does not occur when they are mixed with earth, or harrowed into the ground before the time of sowing.

On the *best time* for applying manures, and on the *quantity* in which they are to be used, practical experiments must decide. Climate, soil, situation, and many other circumstances demand various modifications, which can only be ascertained and established by experience. In the first respect it must be kept in view, that plants require the most abundant nourishment at the time of most vigorous growth. Hence it must not be withheld from them from the commencement to the blossoming, and in grain up to the time in which it shoots into ear, if the highest development is to be attained.

On the means we possess of improving a manure, hastening its action, and preserving its power, we shall speak when we treat of the several kinds of manure.

It may be desirable, in conclusion, to group together in a preliminary view the best-known materials for the formation of manure which are at the service of the agriculturist, in such a way that practical men may derive some advantage therefrom. This could be accomplished by arranging them according to their chemical constituents; for this would be identical with classifying them in conformity with their operation, inasmuch as the latter depends upon their chemical elements. In this attempt we unfortunately come into collision with difficulties of an insurmountable kind. The greater number of manures are complicated mixtures of three, four, five, six, and more elements; — which is the most important? Notwithstanding the thousands of experimental and practical deductions respecting manure, we still know nothing positive and irrefragable with regard to the action of the *separate* elements, and far less upon the question of how they comport themselves in combination with each other. One and the same substance may operate, moreover, in two, three, four, or more ways; its action varies according to its form, as also according to the soil to which it is applied, the kind of crop for which it is used, and so forth.

Although I know beforehand that in such an attempt an *extremely imperfect* result can alone be obtained, I will, nevertheless, essay its performance. What is imperfect may possibly yield something of advantage; but from nothing at all, no benefit can possibly accrue. I shall be thankful to any one who will communicate his help in producing something better from the imperfection which I acknowledge.

## Classification of the more ordinary Manures, according to their Ingredients and Action.

If in this table one and the same manure is exhibited in several divisions, it is to be understood that it is compounded of several chemical elements, and may operate in several different ways. In every separate division the order of succession is so arranged, as to display the richest manuring substances at the commencement, and the poorest at the close.

I. Manures rich in nitrogen (forcing).

1. *Substances containing ammonia* (very quickly forcing).
   - Ammoniacal salts of all sorts,
   - Good guano, urates, soot,
   - Putrid animal substances, e. g. blood, flesh, skins, etc.,
   - Poudrette, gas-water,
   - Putrid urine, draining-compost,
   - Fermented stable-manure, especially of sheep and horses.

2. *Azotized substances that are easily decomposed* (somewhat quickly forcing).
   - Horn-shavings, glue, boiled flesh,
   - Bones, liquefied by acid, steamed, and finely pulverized,
   - Oil-cakes of all sorts, malt-grain and the refuse of beer-breweries,
   - Fresh urine, drainings,
   - Stable-manure beginning to rot.

3. *Azotized substances that are decomposed with difficulty* (slowly forcing).
   - Bone-dust, coarsely powdered,
   - Woollen rags,
   - Fresh stable-manure.

4. *Substances containing nitric acid* (quickly forcing).
   - Nitrate of potash (the ordinary saltpetre),
   - Nitrate of soda, or Chili saltpetre,

Nitrate of lime, or decayed stable-walls (see page 40),
Rubbish of old clay walls,
Old compost-earth.

II. Manures rich in Carbon (forming humus).
Stable-litter, straw, foliage, weeds, etc.,
Forest-leaves, sawdust, lawn and garden trimmings,
Rotten mould, turf, earthy brown-coal,
Generally, vegetable substances of all sorts.

III. Manures containing Potash (strongly forcing).
Potash, nitrate of potash, malt-grain from beer-breweries,
Urine of breeding cattle, wood-ashes,
Foliage, stalks and leaves of all sorts, lawn and garden trimmings,
Building-rubbish, street-sweepings, compost,
Burnt clay and loam,
Marl of many sorts.

IV. Manures containing Soda (less visibly operative).
Common salt, refuse salt, Chili saltpetre,
Soap-boilers' lye, urine,
Certain sorts of manuring salts,
Soda felspar, and some other kinds of stone,
Soapsuds, dish-water.

V. Manures rich in Phosphoric Acid (seed-forming).
Burnt bones, bone-black, sugar refuse from refineries,

Phosphorite, and a few other kinds of stone,
Poor guano,
Raw bones, bone-dust,
True guano,
Animal substances of all kinds,
Oil-cakes, malt-grain from breweries,
Solid human and animal excrements,
Stable-manure,
Urine of carnivorous animals,
Wood-ashes, straw, leaves, etc.

VI. MANURES CONTAINING SULPHURIC ACID (partly direct manures, partly absorbents of manuring substances).

Gypsum, sulphuric acid,
Green vitriol, sulphur-coal,
Many sorts of brown-coal,
Ashes of pit-coal, turf, and brown-coal.

VII. MANURES RICH IN LIME.

Burnt lime, chalk, marl,
Gypsum, ashes of brown-coal and turf,
Building-rubbish, pond-mud, soap-boilers' ashes.

VIII. MANURES RICH IN SILICA.

Pit-coal ashes, as also ashes of all sorts,
Sand, straw, stable-manure, etc.

IX. MANURES THAT PULVERIZE THE SOIL.

Sulphuric acid, muriatic acid,
Lime, marl, humus, etc.

X. Manures that improve the Soil.
Lime, marl, loam, sand,
Pond-mud, vegetable mould, turf, etc.

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## IV. EXCREMENTS AND URINE.

There are, indeed, numerous countries and tracts of land in which the soil brings forth its fruits, and frequently in great abundance, without the application of any fertilizing substance. These are either regions where the sparseness of population demands of the farmer no anxious and diligent economy of the energies of his land, or which are so favored by Nature that the natural crumbling of the soil provides a supply of nutritive material sufficient for the growth of many harvests. That this supply is, however, not inexhaustible, is seen in America, where lands of the most fertile character have been so exhausted by the continued cultivation, for nearly a century, of tobacco and sugar, that they must now be manured, if they are to yield their usual produce. The northern countries of our globe do not belong to these highly favored regions, and if we would here *reap abundantly*, we must *manure abundantly*.

The beneficial influence which animal and human refuse, the *excrements* and *urine*, are capable of exerting upon vegetable growth, has made these otherwise worthless and loathsome substances, in very many localities, the exclusive means of manure for our fields. Hence it will be altogether in order if they are taken first into consideration.

How do the fæces of the several species of animals operate? For what crops are they the most serviceable manure? What amount is yearly obtained from a horse, a cow, a sheep, or from a given quantity of provender? What is the worth of these different excrements when compared with each other? These and similar inquiries of extreme importance to the practical agriculturist have been already answered with the greatest fulness of detail in agricultural writings, but the answers unfortunately differ so widely from each other, as to impart little assistance to the farmer; since in most cases he will be in doubt which of these statements is best entitled to belief. Fresh and accurate experiments are here greatly needed, in order confidently to decide which of the figures given as the respective equivalents of the food and manure, the quantity and quality of the latter, etc., rest merely on conjecture, and which are founded upon the results of actual experience. If, however, such experiments are to lead to reliable results, the *circumstances* under which they were instituted must be also specified with thorough exactness, and the *constituent elements* of the food and the fæces it produces must be no less carefully ascertained. The path leading to this goal is laborious, and many years will probably expire before the principal questions are discussed in such a manner as to enable us to deduce sure and certain rules for practical guidance; but it is the only one that will conduct to a knowledge of the truth.

That the excrements of our live stock are *derived from the food* which is given to these animals, every one is aware; as also that a large part of this provender, that, namely, which was appropriated to the nourishment and preservation of the animal, and, besides this, the surplus devoted to its fattening (that is, to the formation of flesh and fat), or to the production of milk, disappears during its passage through the living organism. Which, then, are the ingredients of the food that are converted into flesh and fat? which are removed by breathing and perspiration? and which, finally, are voided in the urine and excrements from the body? Is it not obvious that a clear insight into the nutritive processes, and a trustworthy opinion upon the proportion of the food to the fæces, can only be attained when their individual constituents are known, and the alterations can be learnt from them which the provender has undergone in the body of the animal? How will it be possible to form an accurate judgment respecting the differences of animal excrement and its effect upon the various plants in cultivation, if the first elements essential to this judgment, the constituents of the plant, the manure, and the soil are not known? Questions of this character can be solved by chemistry alone; this science must constitute the foundation of our inquiries, if the results ascertained by practical experience and experiments are destined to arrive at clearness, connection, and certainty. What has been already brought to light concerning these points by chemical investigations is in manifold respects still incomplete and defective; nevertheless we must be contented with what is incomplete, until something more perfect has been produced. Whatever is known will be communicated in the following sections.

### 1. Origin of Animal Fæces.

Here is a *potato;* of what does it consist, and what alterations must its constituent elements undergo when it is used as fodder for cattle? The potato has been subjected, one knows not how often, to chemical examination, and its constituent parts are perfectly known. It has been found to contain:

| Proximate Constituents. | Ultimate Elements. |
|---|---|
| Starch, Vegetable Fibre, Albumen. | Carbon, Hydrogen, Oxygen, Nitrogen. |
| Mineral Substances (Ashes). | Potash, Lime, Silica, Phosphoric Acid, etc. |

The potato, as well as the greater number of other substances employed in foddering cattle, has been already analyzed, and in the same manner the separate constituents of the bodies of these animals are very accurately known. If now the composition of the food is compared with that of the animal body, we find, that, of the proximate constituents of plants, some have the greatest similarity to the blood and flesh, others to the fat, others, again, to the bones. Hence we infer that these vegetable constituents are actually converted in the animal body into blood, flesh, fat, and bones.

Of the above-stated constituents of the *potato*, the vegetable fibre and starch have great similarity and almost identical composition with the *fat* of animals; the albumen, with the *blood* and *flesh;* and the mineral substances, with the *bones*.

A very large portion, however, of the food given to an animal *disappears*, as is universally known, during its passage through the body; for the dried fæces and urine weigh conjointly but from one third to one half as much as the food in a similarly dry condition. To know which elements of the food pass off in this manner, — partly through the skin, as perspiration or sweat, partly through the lungs and mouth, as air or breath, — must of course be extremely important in forming an opinion concerning the nutrient power of the aliment, and also concerning the strength of the manure that is generated from it. The following results have been deduced from those experiments which have been made, up to the present time, in regard to these points: —

| Of 100 lbs. of *Carbon* in the food | Were lost by breathing and perspiration | Remained in the manure |
|---|---|---|
| of a sheep, . . . | 44 | 56 lbs. |
| " horse, . . . | 63 | 37 " |
| " milch cow, . . | 46 | 42 " (12 lbs. in the milk). |

| Of 100 lbs. of *Hydrogen* in the food | Were lost by breathing and perspiration | Remained in the manure |
|---|---|---|
| of a sheep, . . . | 6 | 94 lbs. |
| " horse, . . . | 57 | 43 " |
| " milch cow, . . | 47 | 37 " |
| | | (16 lbs. in the milk). |
| Of 100 lbs. of *Oxygen* in the food | | |
| of a sheep, . . . | 48 | 52 lbs. |
| " horse, . . . | 56 | 42 " |
| " milch cow, . . | 51 | 41 " |
| | | (8 lbs. in the milk). |
| Of 100 lbs. of *Nitrogen* in the food | | |
| of a sheep, . . . | 7 | 93 lbs. |
| " horse, . . . | 15 | 85 " |
| " milch cow, . . | 13 | 65 " |
| | | (22 lbs. in the milk). |
| Of 100 lbs. of dry fodder in general | | |
| in a sheep, . . . | 40 | 60 lbs. |
| " hog, . . . . | 64 | 36 " |
| " horse, . . . | 60 | 40 " |
| " milch cow, . . | 40 | 48 " |
| | | (12 lbs. in the milk). |
| Of 100 lbs. of mineral substances in the food | | |
| of a sheep, . . . . | — | 114 lbs. |
| " hog, . . . . | 5 | 95 " |
| " horse, . . . | 2 | 98 " |
| " milch cow, . . | — | 94 " |
| | | (6 lbs. in the milk). |

As these figures show, the three substances first named are principally consumed in breathing and perspiration, whilst the nitrogen is wasted by these processes in a far more trifling proportion. The mineral ingredients, moreover, experience in individual cases an increase of quantity, which must, nevertheless, be attributed simply to the dust adhering to the provender. In young and still growing animals a considerable diminution takes place in respect of the latter substances, because they need such material for the enlargement of their bones and other bodily organs.

Should inquiry be made respecting the *form* in which the three elements first mentioned are withdrawn from the animal body, accurate experiments have demonstrated that this is effected by the assistance of the air inhaled in respiration, in exactly the same manner as by the process of combustion. The vapors and gases escaping by the skin and lungs have precisely the same composition as the steam and gases escaping by the chimney during the combustion of wood (vegetable fibre), starch, or similar substances. The changes of non-azotized food (composed of carbon, hydrogen, and oxygen), as they occur in the animal organism, may accordingly be regarded as a *slow combustion;* and now the source of the warmth we perceive in every animal body, so long as it has life, is no longer an enigma, but a very natural consequence of the process of combustion or digestion. For the quantity of heat which a body evolves during its combustion is always the same, whether this process be briskly or slowly conducted; only in the latter case it is gradually developed and distributed over a longer space of time. For example, if a pound of starch when burnt away in an oven evolved 1,000 degrees of heat during the length of fifteen minutes, the same amount of heat would be emitted during twelve hours, if the starch underwent the same physical alteration within twelve hours, as by its combustion in the oven; but it would, when evolved in an interval forty-eight times as long, be also forty-eight times feebler; or, what indeed is tantamount to this, it would be sufficient to maintain the body for the length of twelve hours at a temperature of nearly 21 degrees.

For this reason, those proximate constituents of provender which consist simply of the three substances carbon, oxygen, and hydrogen, are usually denominated *elements of breathing* or *respiration.* In moderate feeding none of these substances remain in the animal body; in excessive feeding, on the other hand, such as occurs in fattening stock, a part of the surplusage is converted into *fat* or *suet*, and laid up in the body. Those proximate constituents of plants which contain *nitrogen* in addition to the elements above mentioned must be regarded, on the contrary, as the strictly *nutritive* ingredients of food, because they alone can be transformed into flesh, skin, muscles, nerves, and other animal tissues. For this reason they are called *plastic* or *flesh-forming elements of nutrition.* As long as an animal lives, a constant renovation of its bodily organs takes place; inasmuch as these are made fluid, and removed by the excrements, and more especially by the urine. For this loss, the body receives compensation through the last-named means of nourishment. By very plentiful foddering with nutrients of this description, more flesh is produced than that which disappears by the formative and destructive processes we have mentioned: the animal is fattened, and in this case it increases not merely in fat, but also in *flesh.*

The integrants of the ordinary food of cattle may be thus arranged: —

1. Elements of respiration (the constituents free from nitrogen):
   Vegetable fibre, starch, gum, sugar, fat, and fat-oils.
2. Plastic or flesh-forming elements of nutrition (the constituents containing nitrogen):
   Vegetable albumen, vegetable caseine, and gluten.
3. Bone-forming substances (the mineral constituents):
   Potash, soda, lime, magnesia, silica, sulphuric acid, phosphoric acid, and muriatic acid (chlorine).

The first two classes are also called organic or combustible, in opposition to the mineral substances, which are also designated inorganic, incombustible, or ashy constituents of plants.

The non-azotized constituents predominate generally in plants, but their proportion to those containing nitrogen varies exceedingly in their different parts. As a general rule, the roots, stalks, and leaves are always much poorer in the plastic or flesh-forming elements than the seed; on this account, we enumerate the latter with the very invigorating and strongly nutritive, the former with the less invigorating and slightly nutritive kinds of food. The following examples will show this more plainly: —

| There are contained in 100 lbs. | Non-azotized constituents: Vegetable Fibre, Starch, Sugar, &c. | Azotized constituents: Albumen, Gluten, &c. |
|---|---|---|
| Of fresh beet-root, . . | 14 | 2 lbs. |
| " " potatoes, . | 20 | 2½ " |
| " " clover, . . | 1 | 3 " |
| " clover hay, . . | 66 | 11 " |
| " pea-straw, . . . | 66 | 12 " |
| " pease, . . . | 60 | 24 " |
| " wheat-straw, . . | 70 | 2 " |
| " wheat, . . . | 60 | 20 " |
| " oat-straw, . . . | 68 | 2 " |
| " oats, . . . | 70 | 14 " |
| " oil-cake, . . . | 56 | 26 " |

A mere glance at these figures will probably be sufficient to induce the intelligent farmer to associate with such means of nourishment as are poor in nitrogen (for example, roots, potatoes, &c.) others rich in this element (for example, bruised corn, coddled grain, or, what indeed is cheapest, oil-cake); and more so, as the full benefit derivable from the former is secured only when the proper proportion of the latter is present. This proportion may be considered about the same with that found in good meadow or clover hay, and in bread; namely, one pound of azotized to five or six of non-azotized ingredients. If the use of oil-cake is preferred for the purpose of strengthening the nutritious quality of weak fodder, then, in order to realize the same proportion, about two pounds of this substance should be employed for one hundred pounds of beet-root, and about twice that quantity for the same weight of potatoes.

The question still remains to be answered, Which constituents of the food, as also of those parts which have become effete and unserviceable in the animal body, are again removed from the living organism by the *solid* excrements, and which in a *liquid* form by the urine? To this inquiry the general answer may first of all be given: Whatever of these substances is capable of becoming fluid passes into the urine, and whatever remains insoluble into the solid excrements. This division, which will be discussed with greater precision in the following section, is of very great importance, particularly in respect of the mineral ingredients of the food, because it is connected not merely with the quantities, but also with the specific nature, of its constituents. Of the organic overplus, the two main ingredients, carbon and nitrogen, are voided in common by the fæces and the urine; the carbon in largest quantity by the former, and the nitrogen to the extent of nearly one half by the same channel, the remaining half in the urine. On the other hand, it is altogether different with the mineral constituents. Amongst these a few, the alkalies and alkaline salts (potash, soda, common salt, and many others) are readily soluble; they must, therefore, be looked for more especially in the urine, whilst those which are insoluble (to which class, in herbivorous animals, lime, magnesia, silica, and phosphoric acid more particularly belong) fall to the share of the solid excrements. Thus, for example, of the yearly food of a sheep there pass away,

| | By the urine | By the solid excrements |
|---|---|---|
| Alkalies and alkaline salts, . | 10 | 2 lbs. |
| Common salt, . . . | 1 | $\frac{1}{10}$ " |
| Lime and magnesia, . . | $2\frac{1}{2}$ | 13 " |
| Phosphoric acid, . | merely traces | 5 " |
| Silica, . . . . | merely traces | 23 " |

Both kinds of mineral constituents, the soluble as well as the insoluble, are derived from the plants which formed the food of the animal. In these plants their occurrence was not accidental, but *absolutely necessary* to their very existence; if, therefore, the fæces of animals are to minister in their turn to the production of fresh plants, they must supply to the latter both kinds of mineral ingredients. A plant enjoys its entire nourishment only when *both* are presented to it *simultaneously.*

## 2. Constituents of Animal Excrements, and their Value as Manure.

Since the excrements of our cattle are derived from the plants which served for their nourishment, their constituent elements, and no less their value as manure, must depend upon the nature, quantity, and excellence of the fodder, and must also vary with every alteration of the latter. Next to this, however, the species, the age, the tending, and service performed by animals, are each of great influence upon the quantity and quality of manure, so that different results are exhibited even by the employment of the same means of fodder. Under these circumstances, the isolated chemical analyses of animal excrements hitherto made known can lay claim only in an approximative manner to general acceptation. The following figures must accordingly be regarded *only as approximate*, although in individual cases they were ascertained with great exactitude.

1,000 *lbs. of Fresh Excrements contained:*—

| Constituents. | Of Cows (fed during winter). | Of Horses (fed during winter). | Of Sheep (fed upon hay, nearly 2 lbs. per diem). | Of Hogs (fed upon strong fodder during winter). |
|---|---|---|---|---|
| Solid dry substances in general, | 160 | 240 | 420 | 200 lbs. |
| Nitrogen therein, . . | 3 | 5 | 7½ | 6 " |
| Mineral substances therein, | 24 | 30 | 60 | 30 " |
| As: Alkalies (potash and soda), | 1 | 3 | 3 | 5 " |
| Earths (lime and magnesia), | 4 | 3 | 15 | 3 " |
| Phosphoric acid, . . | 2¼ | 3½ | 6 | 4½ " |
| Sulphuric acid, . . | ½ | ½ | 1½ | ½ " |
| Common salt, . . | 1/20 | traces. | ¼ | ½ " |
| Silica, . . . . | 16 | 20 | 32 | 16 " |
| Approximate value in money, | 54 | 90 | 135 | 96 for 1,000 lbs. |

1,000 *lbs. of Fresh Urine contained:* —

| Constituents. | Of Cows (fodder, hay and potatoes). | Of Horses (fodder, hay and oats). | Of Sheep (fodder, hay, nearly 2 lbs. per diem. | Of Hogs (fodder less strong, principally potatoes). |
|---|---|---|---|---|
| Solid dry substances (extract), | 80 | 110 | 135 | 25 lbs. |
| Nitrogen therein, . . | 8 | 12 | 14 | 3 " |
| Mineral substances therein, | 20 | 30 | 36 | 10 " |
| As: Alkalies (potash and soda), | 14 | 15 | 20 | 2 " |
| Earths (lime and magnesia), | 1½ | 8 | 6 | ½ " |
| Phosphoric acid, . . | — | — | ½ | 1¼ " |
| Sulphuric acid, . . | 1½ | 1½ | 4½ | " |
| Common salt, . . | 1 | 2 | 2½ | 5 " |
| Silica, . . . | $\frac{1}{10}$ | ¼ | traces. | traces. |
| Approximate value in money, | 120 | 170 | 200 | 45 for 1,000 lbs. |

Of these analyses, that only of the excrements of the sheep admits a strict comparison of the solid with the fluid matter excreted, because both were collected at the same time from one and the same animal; which was not the case in the others. A very striking difference is found in the excretions of the hog, whose urinary constituents appear of extremely small value when contrasted with those of the fæces; a fact explained by the great difference in the foddering of the animals concerned in the experiments.

On the action and value of the several ingredients of manure in general, the most important information has been already communicated in the preceding section; here, therefore, it is necessary to add only the following observations: —

1. The urine (excepting that of swine) is far richer in *nitrogen* than the solid excrements. A pound's weight of the former will therefore readily develop twice or three times stronger forcing power than the same weight of the latter. The azotized constituents (uric acid and urea) *dissolved* in the urine have, moreover, a greater tendency to pass into putrefaction than the insoluble constituents of similar nature contained in the fæces. Hence a very simple explanation, at once, why the former acts far more quickly than the latter. The less firmly and compactly the mass of excrement hangs together, and the more easily it may be distributed and diffused in the soil, the more quickly can the putrefaction and decay of the azotized matter take place. This is the reason why many manures (horse refuse, for example) are brisker and more heating in their operation than others (as, for instance, cow manure).

2. The solid excrements are indeed much richer in *humus-forming* substances (organic matter abounding in carbon) than the urine. Amongst all constituents of manure, however, these are least valuable to the farmer, as they are only converted into energetic manure by the addition of azotized and mineral ingredients.

3. Next to nitrogen, the *alkalies* and *alkaline salts* form the most valuable component part of the urine, and contribute importantly to its forcing power. Only trifling quantities of these bodies, comparatively speaking, are contained in the fæces.

4. *Phosphoric acid* in herbivorous animals passes from the food into the solid excrements, inasmuch as it unites with lime and becomes thereby insoluble. After nitrogen, it must be regarded as their most important and valuable ingredient. In mixed nourishment and animal diet, a part of this acid escapes also by the urine; for this secretion in men and swine contains phosphoric acid in the form of soluble salts.

5. The remaining insoluble mineral constituents of animal provender, *lime*, *magnesia*, and *silica*, are in like manner transferred for the most part into the solid excrement. They must be regarded as the least valuable constituents of manure.

*The solid excrements of herbivorous animals are therefore, comparatively speaking, rich in humus-forming (organic) and seed-forming substances (phosphoric acid, lime, and magnesia), but poor in forcing and leaf-forming substances;* they operate, moreover, but *slowly*, because the nitrogen they contain passes into putrefaction, that is, is converted into ammonia, but slowly. Hence the solid excrements alone, except, perhaps, on exceedingly rich soils, are incapable of calling forth a luxuriant growth; they cannot be deemed a "complete manure," because, in addition to the requisite quantity of easily soluble azotized substances, they are also destitute of the soluble mineral ingredients.

*The urine of herbivorous animals is, comparatively speaking, rich in substances forming stalks and leaves* (*nitrogen, potash, and soda*), *but is deficient in the seed-forming mineral nutrients ;* it operates, moreover, *very rapidly*, because the azotized matters it contains in abundant quantity have a great tendency to putrefaction, and are consequently very speedily converted into ammonia. Hence the fluid excrements alone, except, perhaps, on very favorable soils, are incapable of bringing forth a plentiful yield of seed ; in like manner, they cannot by themselves alone be deemed a "complete manure," because they are destitute of the insoluble mineral substances.

It is now clearly evident how advantageous it must be to the farmer to blend both kinds of manure, and carefully provide that, by means of the straw, the larger quantity of the urine is retained in the manure he obtains from his stable. What is wanting to the one is imparted by the other, and the mixture is by this means converted into a "complete or perfect manure"; i. e. a manure containing *all* the nutritive elements, soluble and insoluble, organic and inorganic, which are essential to the *vigorous* and *rapid* growth of plants.

The *peculiarity of the manure*, according to the species of the animal from which it proceeds, is likewise mainly dependent upon its constituent elements; occasionally, too, as has already been mentioned, upon the manner and degree in which the integrants of the mass are reciprocally coherent.

The *excrements of cows* contain the least quantity of nitrogen, and the greatest quantity of water, amongst the manures of which we have spoken. On this account, they pass but slowly into putrefaction, and are less heated by putting in heaps; for heating is exclusively a result of the putrefactive fermentation (which, like the process of digestion, is also a slow combustion), and is throughout most closely governed by this process. In addition to this, the mass of these excrements does not crumble by lying or desiccation, but becomes saponaceous and compact; for which reason, its distribution in the soil, as also its decomposition and liquefaction, is rendered more difficult. The slow but persistent action of this manure is thus explained at once.

The *excrements of horses* are richer in nitrogen, and less watery, than the preceding; they have a somewhat denser texture, and cohere but loosely. For this reason they are readily distributed, and pass quickly (and accordingly with a greater evolution of heat) into decay. In consequence of this facility of decomposition, the nutritious elements they contain can be more speedily appropriated and digested by plants; hence their operation is apparent immediately after their application to the soil, but from this circumstance terminates more quickly than that of manures whose action is more tardy.

The *excrements of sheep* contain still more nitrogen and still less water than those of horses. For this reason they are tolerably easy of decomposition, although possessing a closer and more compact texture than the latter. Their facility of decomposition is increased by the way in which they are usually treated; for they are suffered to lie long beneath the animals from which they proceed, and are continually moistened by their urine; so that for the most part decomposition commences in the pens in which they accumulate. By this admixture with urinous secretions, the action of these fæces, in and by themselves a very powerful means of manure, is of course very essentially enhanced.

The *excrements of swine* differ exceedingly in their quality, because the foddering of these animals is far more varied than that of horses, cows, or sheep. In Germany this manure is deemed the most feeble, and rightly so, when the animals are fed entirely upon uninvigorating food, as, for instance, on potatoes. In England, on the contrary, it is placed between that of sheep and horses; and here, again, correctly, because in that country bones, pease, grains, and other invigorating means of nourishment, are made use of in feeding these animals. From equal quantities of manure the following yields in barley were obtained by an English agriculturist: —

| | |
|---|---|
| Land, when unmanured, . . . | 159 lbs. |
| " manured with the excrements of cows, | 167 " |
| " " " " horses, | 226 " |
| " " " " swine, | 233 " |
| " " " " sheep, | 244 " |

In the *kinds of urine* above named, where all the manuring elements exist already in a soluble state, the operation is regulated entirely by the quantity of *azotized substances and alkalies* they contain. Arranged according to their excellence, as means of manure, they succed each other as follows: sheep, horses, cows, and swine.

The value in money which pertains, in conformity with their constituents, to these different kinds of excrements and urine, has been already stated. The following calculation may also show approximately the value of all the excrements which these four different animals furnish in a year.

| | Manure. | Value in Money. | | |
|---|---|---|---|---|
| | lbs. | £ | s. | d. |
| One *cow* furnished yearly: | | | | |
| In excrements, . . . | 20,000 | 4 | 10 | 0 |
| In urine, . . . . . | 8,000 | 4 | 1 | 0 |
| Total, . . . . | 28,000 | 8 | 11 | 0 |
| One *horse* furnished yearly: | | | | |
| In excrements, . . . | 12,000 | 4 | 10 | 0 |
| In urine, . . . . . | 3,000 | 2 | 5 | 0 |
| Total, . . . . | 15,000 | 6 | 15 | 0 |
| One *sheep* furnished yearly: | | | | |
| In excrements, . . . . | 760 | | 9 | 0 |
| In urine, . . . . | 380 | | 6 | 9 |
| Total, . . . . . | 1,140 | | 15 | 9 |
| One *hog* furnished yearly: | | | | |
| In excrements, . . . . | 1,800 | | 16 | 10½ |
| In urine, . . . . | 1,200 | | 4 | 6 |
| Total, . . . . . | 3,000 | 1 | 1 | 4½ |

In one year, moreover,

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | lbs. | | | lbs. | | |
| A cow | produced | from | 7,500 | of dry | provender | 3,600 | of dry | manure. |
| A horse | " | " | 7,500 | " | " | 3,000 | " | " |
| A sheep | " | " | 560 | " | " | 370 | " | " |
| A hog | " | " | 1,400 | " | " | 500 | " | " |

The preceding figures must in no respect be considered as exact; such can only be established by an extended series of experiments. They will simply serve to render the chemical constituents of various manures, and their importance to vegetable growth, more palpable to the practical farmer, and by this means to exhibit the relative value of different sorts of manure with greater precision than is possible by mere words. They may be held sufficient until others more entitled to confidence have been ascertained.

Of the manifold circumstances which exert a preponderating influence upon the *quantity and excellence* of animal manure, the following are of especial importance: —

1. *Quantity of the Fodder.* Every animal requires a certain quantity of provender, in order to continue in existence. This is called its life-supporting fodder. If the animal has to labor (as draught cattle), or to increase largely in flesh and fat (as stalled cattle), then, in addition to the food essential to its life, a further quantity must be given in order to produce strength, flesh, fat, or milk. This additional supply of nourishment is called fodder of production. The former furnishes excrements of far less value than the latter, because it is absorbed and used in far lar-

ger proportion in the animal body. Accordingly, the more abundant the nourishment, the more and better manure will the animal supply. Hence it is received as a rule, to keep only as much stock as can be *plentifully* nourished upon the quantity of provender at the disposal of the farmer; better three cows completely satisfied, than four only three quarters satisfied.

2. *Composition of the Fodder.* Invigorating food which is rich in nitrogen (for example, grain or seeds) supplies indeed a smaller quantity of manure, but as a compensation for this it is of excellent quality; whilst, on the contrary, only a feeble manure can be produced by such means of nourishment as are deficient in nitrogen. Experiments instituted upon this point gave for their result, that upon food of the first-mentioned kind (grain and hay) the quantity of urine collected in a day contained half as much again of solid substances, and nearly two and a half times as much nitrogen, as the urine generated from nutrients that are poor in nitrogen (straw, potatoes, roots, etc.). Whoever, therefore, wishes to obtain powerful manure from his live stock, will provide them exclusively with *invigorating* fodder.

3. *Digestibility of the Fodder.* Whether an article of nourishment is easy or difficult of digestion, that is, in other words, whether much or little of its constituent elements can be dissolved and absorbed in the stomach and intestines, must naturally be of considerable influence upon the nutritious properties of the provender, and the amount of manure which

is obtained from a definite quantity thereof. Among the constituents of vegetable nutrients, the principal obstruction to digestion is found in vegetable fibre which has become old and ligneous; this is met with in various over-ripened kinds of grasses and straw. As such kinds of provender are, as a general rule, poor also in azotized ingredients, and as these latter, moreover, are not so indigestible as the old vegetable fibre itself, so will the excrements they produce abound indeed in undigested fibre, but be deficient in nitrogen. Provender of this description will accordingly furnish large heaps of manure, possessing little power.

4. *Watery Nature of the Fodder.* The greater the quantity of water contained in the fodder, or the more an animal drinks, the more aqueous and thin will its excrements and urine of necessity become. 100 lbs. of urine from a horse, that took little fluid into its system, contained 21 lbs. of solid constituents with 2½ lbs. of nitrogen; whereas in the same weight of this secretion from another horse, only 11 lbs. of solid constituents and 1¼ lbs. of nitrogen were obtained. In another case, where a cow had been fed on hay and potatoes, ten per cent. of solid ingredients was found in the urine, but when fed on clover only six and a half per cent. was discovered. A load of manure, when derived from green fodder, cannot by any possibility contain more than half as much of the efficacious elements of manure as the same quantity when obtained from dry provender.

If, therefore, from green aliment more fæces are procured, they can never, from the great proportion of water they contain, be so rich in manuring substances as those generated from dry, nutritive matter.

5. *Age of the Animals.* Young animals require both organic and inorganic substances for their growth; these they take from the fodder, and hence a less proportion of these substances is discharged from their bodies. The manure of a young beast will accordingly, even with the same foddering, be always weaker than that of full-grown animals. In the urine of a calf reared upon milk, chemical analysis found in 1,000 lbs. only 1 lb. of solid substances with a mere trace of nitrogen, whilst in the same quantity of this secretion from a cow 80 lbs. of solid constituents and 8 lbs. of nitrogen were discovered. In like manner, in 1,000 lbs. of urine from a child of eight months, 3 lbs. of nitrogen were found; from a child of eight years, 7 lbs.; and from a full-grown man, 18 lbs.

6. *Employment of Animals.* The more labor and exertion an animal is compelled to undergo, the more it respires and sweats; the greater the quantity of nutritive constituents, however, which is removed from the body by the lungs and skin, the less of these can pass into the excrements and urine. A working beast will accordingly furnish, from the same amount of food, manure in smaller quantity and of less value than one at rest. Where rest and abundant provender are conjoined (as in the case of

stalled cattle), there will also the most invigorating manure be produced. In milch kine a by no means inconsiderable amount of the more strengthening constituents of the fodder (perhaps one third or one fourth as much as is contained in the solid and fluid excrements together) is eliminated by the milk; and hence it will appear quite natural, that the manure must be deficient in exactly that quantity of invigorating ingredients which is transferred to the secretion just named.

7. *Tending of Animals.* When an animal is long exposed to cold and moisture, it requires a larger quantity of provender; for it must generate a greater amount of heat in order to maintain its body at the requisite temperature. Hence warm and dry stabling leads, although not exactly to an important improvement in the quality of manure, yet to a more economical consumption of fodder.

8. *Quantity and Kind of Litter.* Straw contains far inferior manuring ingredients than the excrements of animals, as will be shown in Chapter VI.; by much straw the latter are therefore, as it were, diluted, a voluminous mass of little efficacy being thereby obtained. On the other hand, straw importantly assists in forming a very energetic manure from these excretions, because it absorbs and retains the urinous liquids. This end, the serving as a vehicle for the retention of the urine, cannot of course be subserved in the same degree by leaf-littering, which consists principally of dense woody and earthy

components, as by straw, and greater quantities of the former must therefore be employed to provide a dry bed for the animal. From this circumstance, as also from the inconsiderable amount of mineral ingredients contained in this litter, it is very easily explained why the manure procured from bedding with fallen leaves is so greatly inferior in its action on the soil to that obtained from straw.

### 3. Human Excrements and Urine.

The composition of human excrements, when derived from an invigorating but moderate quantity of animal and vegetable diet, may be assumed to be the following: —

| Constituents. | 1,000 lbs. of Fresh Excrements. | 1,000 lbs. of Fresh Urine. |
|---|---|---|
| Solid substances in general, . | 250 | 40 lbs. |
| Nitrogen therein, . . . | 7 | 10 " |
| Mineral substances therein, . | 16 | 11 " |
| As: Alkalies (Potash and Soda), | 3½ | 2 " |
| Earths (Lime and Magnesia), | 5½ | ¼ " |
| Phosphoric Acid, . . | 5½ | 1½ " |
| Common Salt, . . | ⅛ | 7 " |
| Approximate value in money, | 114 | 118 |

The relative value of the urine, when compared with the fæces, is more favorably shown than in the foregoing table, if the inquiry is proposed in the following terms: How large a quantity of manuring ingredients is *yearly* eliminated by one man in the solid excrements and urine respectively? Very accurate analyses have shown that the amount of *urine* contains double the quantity of phosphoric acid, four times as much azotized substances, and six times as much alkalies and alkaline salts, as the solid fæces. Hence, therefore, it follows that the former possesses a *far higher value* than the latter, and deserves to be most carefully collected. If the total value of the annual excretions of a man is assumed to be 11¼, then nearly 9 must be taken as the worth of the urine, and only 2¼ as that of the fæces. Upon a more liberal diet, such as is usual in the more wealthy classes of society, a larger quantity of manure, and of more invigorating quality, is of course produced; in this case, its yearly value may perhaps rise to from 13½ to 18.

From the preceding observations, it may be incidentally perceived what an immense capital is unprofitably lost in large cities, where the greater proportion of urine runs into the sewers and drains. To turn this to available use is indeed associated with considerable difficulty; since, apart from its collection, the conversion of the fluid mass into a dry substance (urate, urinous extract), capable of transportation, would demand a very heavy outlay and extensive apparatus.

The soil procured from vaults upon country farms is most judiciously added to *heaps of earth or compost*, as it then soon loses its disgusting odor, and is converted into a pulverulent mass, which, when mixed with earth, can be easily scattered, and at the same time equally distributed over the ground. The dried human excrements here and there met with in

9*

commerce, under the name of *poudrette*, are of such extremely diversified composition, that the farmer ought never to make use of them without previous chemical examination.

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## V. DRAININGS.

A farmer *who does not carefully collect and preserve the urine of his house and live stock, acts like a miner who throws away dull, rich silver ore, because it does not shine like white silver.*

*A farmer who buys guano, bone-dust, or other artificial manures, but does not look carefully after his drainings, is an extravagant farmer; for he brings the same thing into his yard at great cost, which he might have for nothing, if he did not suffer it to flow or evaporate uselessly away from the same.*

That drainings fertilize the soil, what farmer is ignorant, even from childhood? But how great is their power in this respect, and how much of this power may be lost by careless preservation and treatment, many farmers are still unaware. Were it otherwise, draining tanks commodiously placed would be provided, first and foremost, in every farm-yard; were it otherwise, one would find no longer on a farm great puddles of dungy and urinous drainings, which sun, moon, and stars can undisturbedly shine upon, and heavy showers fill even to an overflow; were it otherwise, there would no longer be villages in which a brown current of liquid guano streams forth from every farm inclosure, to be lost in the gutters or the village pond.

If this disregard of drainings originates in a mistaken estimate of their worth, and perhaps in part from the circumstance that their fluid form renders their preservation more difficult and their employment more inconvenient than solid manure, it should be expected that information respecting the constituents of this important portion of manure, as also upon its proper treatment and use, will assist materially in removing the indifference with which it has hitherto been regarded. For this reason, in my chemical lectures before agricultural societies it has generally formed the starting-point from which I have proceeded to the consideration of other portions of manure, as I am firmly persuaded that it must also form the starting-point in all improved agricultural establishments. For nothing can more nearly concern the farmer than the turning to most profitable account those fertilizing substances which are free from all expense, at his actual command. It has afforded me peculiar satisfaction to learn, that the counsels I have given on the occasions referred to have been subjected to trial and received confirmation. On this subject, therefore, instead of appealing to mere theoretical conjectures, I am able to cite facts which have stood the test of actual proof.

That a pound's weight of urine is, generally speaking, of higher value, as a means of manure, than the same quantity of solid excrement, follows very plainly from what has been said in the preceding chapter respecting its composition. Drainings acquire their great manuring value principally through the large amount of *nitrogen* and *potash* they contain. If the drainings were collected which a cow furnishes in a twelvemonth, and dried, about 6 cwt. of solid extract might be obtained from them, which in fertilizing power must be estimated as equal to Peruvian guano, now bought by the farmer in Saxony at from 14*s.* 6*d.* to £1 0*s.* 3*d.* per cwt. In this extract there is contained as much nitrogen alone as in 5 cwt. of the best guano, and so large a quantity of potash that by combustion more than 1½ cwt. of potash, worth in commerce £4 10*s.*, may be readily procured.

With these statements the agricultural experience of those countries where the true value of drainings as a manure has been longest known, and where they have accordingly been collected and employed with the greatest care, most entirely coincides. Thus in Flemish agriculture the yearly urine of a cow is taxed at three guineas, and this sum is actually paid for it there. And a celebrated English farmer relates, that, in manuring meadow-land, he has obtained a far greater effect from 160 cwt. of sewer-water from the city of Edinburgh (consisting for the most part of urine), than from 300 cwt. of stable-manure, and from 3 cwt. of guano, with which he manured three equal parcels of land, each an English acre in extent.

### 1. Alteration of Urine by Continued Keeping.

It is known that urine by long keeping (quickly, however, at warm seasons of the year) acquires a disagreeable, pungent odor, with an alkaline quality, and that this *putrid urine* can be used in the same way as soap, for washing and cleansing wool from fatty and perspiratory substances, as happens, for example, in the manufacture of cloth and in wool-spinning. The volatile and alkaline body is generated in the putrefaction of the urine from its azotized constituents (urea, uric acid, etc.), and is that which has already been frequently spoken of under the names of *putrid nitrogen* or *ammonia*.

Whoever will take the trouble of instituting a few experiments of a very simple character, for which he requires only a candle or a small spirit-lamp, a plated spoon, and a few saucers or wine-glasses, may readily make himself intimate with the properties of ammonia, that extremely important nutrient of plants, and draw from the results of his experiments very *profitable inferences for the rational treatment of drainings.*

*First Experiment.* — Some *litmus-paper* must first be prepared, which is needed as a test for the subsequent experiments. Put a small quantity of litmus into a saucer, pour over it half a teacupful of hot water, and let it stand for a few hours in some warm place. When it has acquired a dark blue color, pour off into another saucer the infusion from the slimy substance deposited at the bottom, and soak strips of fine printing or letter paper in it, in order to stain them blue. If the color of the paper when subsequently dried is still very faint, it must be soaked again. The *blue* litmus-paper thus obtained is an extremely delicate test of all fluids which are *acid* to the taste. If a small teaspoonful of vinegar, or two drops of sulphuric acid, are put into one or two quarts of water, and the blue paper is dipped in the mixture, it is almost instantly reddened. The chemist calls such tests *reagents*, and avails himself of the blue litmus or test-paper as the most accurate reagent for acids. Preserve these strips in a box, because they are gradually deprived of their color by the light.

Let another portion of the blue paper strips be passed through water weakly acidulated, and dried when they have acquired a distinct red color. For this purpose only from one to two drops of sulphuric acid, or, what is still better, from six to eight drops of lemon-juice, should be introduced into a pint of water. The *red* test-paper is the most delicate means of recognizing a class of substances opposed to acids, that is, *alkaline* or *basic bodies.* If some wood-ashes or burnt lime is scattered upon a strip of red paper, previously moistened, or if a piece of soap is pressed upon it, its original blue color will be restored after washing off the substances with which it has been brought into contact, — a proof that in these bodies alkaline matter is contained. In the freshly voided urine of a healthy man, blue paper becomes red, — it is therefore acid; red paper, on the other hand, undergoes no change whatever in its color. If this urine is allowed to stand in a vessel in some warm place, and is examined every day by means of the test-papers, it will be perceived that after a certain time the blue paper is no longer altered therein, but the red is; the change which this latter undergoes to blue, is a proof that an alkaline body has been generated in the urine. This alkaline body is the above-mentioned ammonia, belonging to the same class of bodies as wood-ashes and lime, but essentially distinguished from them by the circumstance that it is volatile, which lime and potash (the alkaline substance contained in wood-ashes) are not.

*Second Experiment.* — Pour, in the manner described on page 39, some *hartshorn* into a plated spoon, and hold it over the flame of a lamp, so that it will become hot, whilst the vapor ascending from it is allowed to mount into a large tumbler held over it: after some time, the tumbler will be filled with an invisible air, which possesses a very pungent odor, and a strip of red test-paper, previously moistened, on being put into the apparently empty glass, will in a few moments become blue. The gas escaping from the hartshorn upon heating is *pure ammonia;* for the liquid hartshorn is nothing else than water, into which a large quantity of ammoniacal air or gas has been introduced, and is thereby held in solution. This ammonia again evaporates, even at low temperatures, from the water, and it is from this circumstance that the hartshorn derives its pungent odor; if the heat is increased, the evaporation is increased, and for this reason the solution, in order that it may not lose its strength, must be kept in well-stopped phials and in cool situations. Putrid drainings possess the closest resemblance to this liquid, inasmuch as they also are to be regarded as a solution of ammonia in water; by evaporation, therefore, they will decrease in strength in proportion to the inattention paid to the coolness of their situation and the closing of the receptacles in which they accumulate.

If two equal quantities of hartshorn are put, one into an open flask, the other into a saucer which is left standing in the air or in the sunshine, it will be found, after one or two days, that the latter has entirely, or almost entirely, lost its odor, whereas the sample in the flask still smells strongly; for the ammonia, on account of the great surface exposed and the inconsiderable depth of the fluid, can evaporate more rapidly from the saucer than from the bottle. Precisely the same difference must also occur when drainings are allowed to collect in a large, *shallow puddle;* or, on the other hand, in a deep and generally *closed reservoir.* By long standing in the puddle they may readily lose (especially since they are in this situation more powerfully heated by the sun, or in summer-time by the warm atmosphere) the greatest part of their ammonia, that is, their most important manuring constituent, whilst in a good tank, on the contrary, this loss will be but trifling.

*Third Experiment.* — If the hartshorn is boiled in the spoon till the whole liquid is evaporated, the spoon will subsequently appear empty and clean, and exhibit no residue whatever, for the ammonia volatilizes in the heat, and the water also; hence nothing can be left. Pour now precisely the same quantity of *hartshorn* into a cup, and drop in cautiously, whilst stirring constantly with a wooden spatula, *sulphuric acid*, until the red test-paper is no longer turned blue by the solution. Should, on the other hand, blue paper be now reddened by the fluid, it is a proof that somewhat too much acid has been added; and for this reason more hartshorn must be introduced by drops, until the moment arrives in which the liquid produces no change of color in either kind of test-paper. This is called the point of neutralization. The pungent odor of the ammonia has now completely disappeared, and in the same way an acid taste can no longer be remarked. From the sharp caustic fluids, which could not have been brought without injury into contact with the lips, a new body, or *salt*, has now been produced, which may be tasted without any danger, and possesses a saline taste instead of an acid or alkaline one.

Wherever in nature an acid body meets with a basic one, and unites chemically (that is, most intimately) with it, a similar neutralization is produced, and coincidently with this an exactly similar disappearance of the acid, and also of the basic or alkaline properties of the constituents of both, although both are still present in the newly formed salt. Thus harmless common salt is formed from pungent muriatic acid and caustic soda, etc. Put now the neutralized fluid into the spoon, and allow it to evaporate; in this case a considerable white saline residue will be left, whereas previously the hartshorn alone evaporated without leaving any deposit. This residue is the newly formed salt, or *sulphate of ammonia*, in which the volatile ammonia is held so firmly by the sulphuric acid, that at an ordinary, nay, even at a tolerably high temperature, it *no longer* evaporates.

When *sulphuric acid* is dropped into *putrid drainings* the same process occurs, as the disappearance of the pungent odor when the point of neutralization is attained very plainly demonstrates. Here, too, the ammonia is so firmly held, that it can no longer fly off, and complete security, even in long-continued preservation of the drainings, is given against the loss of their fertilizing elements. By this means, indeed, even that volatilization which takes place in the ground where putrid drainings are poured, and which may be concluded, from the intensity of the stench that is thence emitted, to be far from inconsiderable, is entirely prevented. With 1 lb. of sulphuric acid thus mixed with drainings, full 1½ lbs. of sulphate of ammonia were readily procured, or, expressed in money, for 1½*d.* from 7½*d.* to 9*d.* worth are obtained. The sulphuric acid does not in any way obstruct the beneficial or forcing operation of the ammonia upon plants, but heightens it rather, as many experiments made in Saxony during the last few years abundantly show. A celebrated English farmer, Mr. Harcourt, who has instituted many experiments upon this point, remarks that he obtains the best results by adding 1 lb. of sulphuric acid to 150 lbs. of drainings, and has derived by an expenditure of £ 2 5*s.* in sulphuric acid an increase of hay amounting in value to £ 14 12*s.* 6*d.* above that from land treated with an equal quantity of drainings, but without sulphuric acid. This exceedingly commendable mode of manuring meadow-land has been employed with the happiest consequences in Switzerland from time immemorial, with the simple difference that *green vitriol* (sulphate of iron) is there substituted for sulphuric acid. With equally good effects, *gypsum* also might be used. Both these substances contain sulphuric acid in combination (the green vitriol 32 per cent., the gypsum 46 per cent.), which acts in the same way as when free or uncombined.

The strong effervesence which takes place upon the admixture of sulphuric acid with drainings proceeds from the escape of *carbonic acid*, a kind of air familiar to every one, inasmuch as, amongst other well-known properties, it occasions the foam or froth of bottled ale. In drainings this acid is combined partly with the potash and soda they contain, partly with the ammonia generated by putrefaction, and yields its place to the more powerful sulphuric acid. The question may, perhaps, be started, why this acid does not, like sulphuric acid, combine so strongly with ammonia as to deprive it of its odor and volatility. To such an inquiry we may answer, that carbonic acid is itself a volatile and at the same time very feeble acid, incapable of perfectly neutralizing the ammonia, and forming with it a salt which is volatile and of very pungent odor, — a salt in which the ammonia, as it were, still distinctly glimmers through. To be convinced of this, it is only necessary to smell the carbonate of ammonia, met with in commerce under the name of salts of hartshorn (which might also be called volatile-drainings salt), and to place a portion of it in some warm place; it has a very pungent odor, because the basic properties of the ammonia are not entirely concealed by the acid, and after some time the ammonia will fly off and escape, on account of the facility with which it can assume a gaseous or aerial form.

*Fourth Experiment.* — In order to obtain proof that the white salt acquired in the preceding experiment by the evaporation of the hartshorn when mixed with sulphuric acid, that is, the *sulphate of ammonia*, really contains ammonia, let it be brought into contact with some *quicklime*, in such a manner that a thick paste is produced; the strong, pungent odor which arises from this paste, as also the fact that a strip of red test-paper held over it becomes blue, will plainly enough demonstrate its presence. Lime is brought into contact, in its action, with sulphuric acid; it is a stronger basis than ammonia, and for this reason takes the sulphuric acid away from the latter, whereby the ammonia, set at freedom, becomes aeriform and escapes. Since, therefore, lime expels ammonia from the combinations it has formed, and this is then volatilized, it is obvious that putrid drainings, like rotten or completely fermented manures in general, should not be mixed with lime, whether soluble or not, unless their manuring power is sought to be considerably weakened. The volatilized ammonia is not indeed lost, but benefits the world; inasmuch as it is diffused in the air, and from this is again restored to the earth by rain, snow, or dew. A rational farmer will not, however, wish to be in this way a communist, but will rather seek to preserve the strength of his manure for his own fields alone.

The action of lime differs when mixed with *fresh* urine, or *fresh*, *unfermented* manure, in which no ready-formed combinations of ammonia, but only the materials for the same, are as yet contained. In this case the process of putrefaction is prevented by the lime, so that nitric acid, instead of ammonia, is generated from the nitrogen of the manure, which subsequently combines with part of the lime to form a salt, that is, *nitrate of lime*. *Nitric acid* is composed of nitrogen and oxygen, *ammonia* of nitrogen and hydrogen; the difference just spoken of, as occurring in putrefactive fermentation when the manure is mixed with the powerfully alkaline lime, consists simply in the circumstance that the nitrogen unites, not as in ordinary putrefaction (without lime) with hydrogen, but with oxygen, which is found in the air, in water, in all plants, and, in short, everywhere in nature. The same proceeding is adopted in the manufacture of saltpetre; only, in addition to lime, wood-ashes are also employed, because here nitrate of potash is sought to be obtained.

In many places it is a prevalent custom to throw a few bushels of quicklime into the empty reservoirs in which drainings accumulate, in order that the urine, as it flows into the receptacle, may always find lime. From the theoretical considerations just brought forward, it is not improbable that by this mode of treatment the manuring constituents of drainings are equally well preserved, since the nitrate of lime is not volatile, and is, we may conjecture, as efficacious a manure as the salts of ammonia. To be able, however, to speak with full certainty upon this point, more chemical examinations of the alterations thus effected, and further practical trials of the fertilizing power of these drainings, when compared with ordinary drainings on the one hand, and with those treated with sulphuric acid on the other, must be instituted. Experiments which I have already made, and which will be hereafter continued, have shown that lime really operates in a very conservative manner upon fresh urine; for human urine mixed with quicklime possessed, after eight weeks' preservation, no disagreeable or pungent odor, whilst another quantity of the same secretion kept for only eight days, without lime, emitted an extremely pungent and disagreeable smell.

## 2. Rational Treatment of Drainings.

The means which must be resorted to, in order to derive the greatest benefit from the employment of drainings, have been, in great part, incidentally mentioned in the preceding chapter, when considering the constituents of urine, and the changes which it undergoes during putrefaction. Hence it will only be necessary to refer the reader to these observations, and to add a few practical remarks upon matters of detail.

1. That the preparation of a *good receptacle for the drainings* must be the first step towards their careful employment, is self-evident; for if they can ooze away, escape by evaporation, or be washed away by heavy showers, not merely their separate manuring elements, but all will be lost. The requisitions here necessary are the following: — 1st. That the receptacle be water-tight. This is most certainly attained by lining the interior with hydraulic cement, or by a thorough fitting together of the planks, in the event of its being constructed of wood, and by firmly puddling a stiff layer, at least a foot in depth, of clay or

loam around the ground and side-walls. 2d. That it be deep rather than shallow, in order to preserve its coolness, and to expose a small surface of its contents. 3d. That it be shut out from the external air, or, in other words, well covered. Lastly, 4th. That it allow no access to the rain. The farmer may find more precise information upon this subject in the little work entitled, *Populäre Düngerlehre von Schlipf* (Popular Lessons on Manures, by Schlipf).

2. An addition from time to time of *sulphuric acid* is beyond all else to be greatly recommended, whether drainings are preserved for themselves alone, or are poured upon the manure-heap in order to keep it moist. It is difficult to propose for a definite number of stock the precise weight of sulphuric acid required for this purpose, say by the week, because the quantity of urine actually furnished to the reservoir, and likewise the condition of the urine itself, depending, as it does, upon foddering, littering, etc., must vary very greatly. As an approximative calculation, it may perhaps be held that a pound of the acid should be mixed with 250 pounds of urine. It would be extremely convenient if a scale of measurement was prepared for every receptacle, by means of which the weekly increase of the liquid could be easily ascertained, and the addition of sulphuric acid be accordingly regulated. In lieu of sulphuric acid, gypsum, green vitriol, sulphurous coal, or the ashes of pit and brown coal, might be made use of. These materials, however, from the circumstance that they

must be employed (with the exception of gypsum) in far larger quantities, are open to the objection, that great masses of solid substances would speedily collect in the reservoirs. Muriatic acid also could be used, but the cheaper and more powerful sulphuric acid is much to be preferred.

Here also the opportunity must be taken of calling attention to an important precautionary measure. Sulphuric acid is notoriously a very burning and corrosive fluid; that is, it chars and destroys most animal and vegetable substances; it has, moreover, the property of *uniting with water, causing the evolution of violent heat.* Hence very severe burns may be easily incurred, if any portion of this acid is attempted to be removed from the skin by the application of a small quantity of water. For this reason, when it comes into contact with the skin, the latter should first be wiped dry with any soft substance (as paper or cloth), and then be immediately washed with a *great* quantity of water.

3. The application of drainings to *dunghills* or *heaps of compost* must be also highly recommended, since by this means they can be readily brought into a very manageable form without sustaining a loss of their fertilizing power. If in collecting these heaps of compost all the refuse matters found upon a farm (as ought to be the case) are made use of, whatever their appellations (sweepings, rubbish, sawdust, ashes of all sorts, soot, path trimmings, road-grit, turf or coal dust, dish-water, soap-suds, blood, etc.), and the

mass is kept moist by frequent affusion or sprinkling of urine, very considerable quantities of the latter may be gradually brought to a dry form; inasmuch as the watery portions of the urine by degrees evaporate, and the ammoniacal combinations generated by its nitrogen are firmly held and absorbed, partly by the acids which are simultaneously formed in the humus, and partly by the earth. A part of the nitrogen occasions at the same time the production of nitric acid salts, which are not volatile. By occasionally stirring up the heap, this process is very essentially accelerated. Should a pungent odor of ammonia be remarked, some sulphuric acid diluted with water should be poured on, or some gypsum added to the heap. In this mode of using drainings, also, their previous admixture with sulphuric acid has proved very serviceable. Beyond all doubt, by the accumulation of such heaps of compost upon every farm, considerable advantages may be secured, since they furnish an external motive and obligation for the retention and employment of many substances, which, in conformity with general custom, are often thrown away.

4. The practice adopted in many farming establishments and districts, of *suffering the manure to lie under the stock*, is, so far as the drainings are concerned, exceedingly beneficial, since in this case they are for the greater part absorbed and retained firmly by the straw, as will be more particularly explained in the following chapter. The same remark applies

equally to their employment to preserve the *moisture of yard-manure*.

On the question, whether it is more advantageous to apply drainings to the soil in a *fresh* or in a *putrid* state, I do not venture to express a definite opinion, on account of the numerous conflicting statements which I have received from practical farmers with regard to their experience upon this point. Theoretically considered, it must seem most consistent to apply drainings, as also stall-manure, in a *fresh* condition to fields and meadows, because then putrefaction takes place in the earth, and the products of putrefaction are retained beneath the ground; whilst by long-continued keeping in the yard, a part of the manuring elements escape into the air, and must therefore be lost. If, however, sulphuric acid is from time to time introduced into the draining-tanks, or reservoirs, the putrefaction of their contents will then occur without any such loss, and the agriculturist has then in his putrid drainings a means of manure, which, like all ready fermented, putrefied, or decayed manuring substances, is distinguished by a very rapid operation on the soil, resembling that of dissolved guano, and less readily corrosive. The most certain means of preventing the corrosive action of drainings will always be that of bringing them upon the land only when it is thoroughly sodden with moisture, or, if this cannot be waited for, by diluting them previously with water.

The putrefaction of fresh drainings proceeds, moreover, very rapidly, when, as usually happens, they are placed in contact with such as are already putrid, or when the sediments at the bottom of the reservoir are from time to time stirred up.

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## VI. STALL-MANURE AND STRAW.

### 1. Alteration of Stall-Manure by Keeping.

Ordinary stall-manure is a varying mixture of animal excrements, urine, and straw-litter. It is strong, in proportion to the quantity of urinous liquid it has absorbed; weak, in proportion to the small amount of urine and the large quantities of straw it contains. With this circumstance also its greater or less facility of decomposition entirely coincides. Amongst these ingredients the urine has the greatest tendency to putrefaction and decay, and straw the least; manure rich in urine will, therefore, pass more rapidly into fermentation, and arrive more quickly at what is called "ripeness," than when poor in this constituent.

Fresh manure is, however, no means of nourishment to plants; it becomes so only by what is termed fermentation, that is, by a previous *putrefaction and decay.* The changes which manure undergoes by these processes of disintegration extend chiefly to its organic or combustible constituents; inasmuch as these are transformed into a brownish-black, pulverulent mass (the well-known humus), whilst a part becomes at the same time aeriform, and escapes into the atmosphere. Coincidently with this, a quantity of water is also evaporated; and from these two volatilizations it is easily understood why fermented manure is of less weight than fresh. If the matter so escaping was exclusively water, this diminution in bulk and in weight would be advantageous and desirable; for the farmer would thereby save expense in transportation, as he would employ a drier manure, and would possess in a load which had lost half its weight by desiccation the same fertilizing power that is contained in two equal loads of fresh manure.

The true state of matters is, however, wholly different.

It has been already stated in one of the earlier chapters, that of the proximate constituents of plants two leading classes are distinguished, the combustible (organic), and incombustible (inorganic); of these, the first alone are capable of fermentation and putrefaction, the latter not.

It has further been shown, that amongst organic substances a distinction is made between such as contain, and such as do not contain, azote or nitrogen, and that the former must be regarded as more scarce and valuable, as well for foddering animals as for manuring plants. Now it is precisely these azotized constituents that are always first changed; for they introduce and transfer to the other ingredients the putrefactive fermentation, by the intervention of visible and invisible animals of all kinds (infusoria, maggots, worms, etc.). If by this means their nitrogen finally enters into a volatile combination, in other words, into ammonia, then it is evident that the farmer who carelessly abandons his stall-manure to the process of putrefaction, will in the generality of cases lose considerable quantities of the manuring elements it contains, and of these elements, precisely those which have the highest value. With the ammonia other volatile combinations of sulphur and phosphorus (sulphuretted hydrogen, etc.) are simultaneously generated, and these likewise escape in an aerial form. They possess an extremely offensive odor, the same as that of rotten eggs, which is strong in proportion to the activity of the putrefactive fermentation. Hence from the strength of the stench emitted during the putrefaction of animal manure a tolerably accurate conclusion may be drawn with respect to the loss of strength which may be feared. The old maxim of the peasantry, "Whatever stinks is good for manuring," is perfectly true; the more, therefore, stinking gases (containing nitrogen and sulphur) and vapors escape from a dung-heap into the air, the less of course can it continue to retain.

Those parts of plants which contain little or no nitrogen (for instance, straw, wood, sugar, starch) emit no disagreeable odor during putrefaction; this kind of change is called, by way of distinction, *fermentation.* Animal substances are richest in nitrogen, and amongst vegetable matters the seed; hence the great difference in the odor, where potatoes, sawdust, sugar, etc., or flesh, cheese, pease, etc., which have been sprinkled with water, are left standing until they pass into fermentation or putrefaction.

*Heat* is generated by most chemical processes, and in most considerable degree by those which resemble combustion. Digestion and respiration have been shown to be such processes; so also are putrefaction and decay. For this reason, we perceive a visible and spontaneous evolution of heat, wherever considerable quantities of animal or vegetable matters putrefy, decay, or rot. Hence soil rich in humus (for humus must be considered vegetable fibre undergoing decay or slow combustion) will always preserve a greater amount of warmth than soil which is poor in this ingredient, and this the more, because on account of its dark color it absorbs a larger proportion of the rays of the sun than a soil of lighter color. The heating of stall-manure is thus explained at once; it will be stronger in proportion to the larger masses heaped on each other, and to the abundance of azotized substances they contain, inasmuch as these latter produce a brisker putrefaction; in the first case, however, the heat is better kept together, and is constantly generated anew, because with increasing temperature the putrefactive process is more energetically carried on.

Next to heat, *air and water* have an essential influence upon the progress of putrid disintegration in organic matter. Substances from which all water has been removed by drying, do not suffer this decomposition, as is exemplified in dried fruits, seeds, leaves, etc., which we can preserve for years, whilst in a moist state they soon become corrupt. With a moderate degree of moisture, decomposition proceeds most rapidly and successfully. An excessive quantity of water retards it, because when substances are entirely covered with water their heating, and at the same time the access of air, are prevented.

The exclusion or non-exclusion of *air* from fermenting vegetable and animal remains, occasions a great difference in the nature of the decomposition. In the first case, as, for example, in the decomposition of animal manure when piled together in large and compact heaps, and of urine in the drainings' reservoir, in the steeping of flax, in the fermentation of potted cheese, etc., gases and vapors of highly disagreeable odor are generated, which may be regarded as partially putrefied or partially consumed substances; they are produced from want of air, or, more accurately speaking, of oxygen. This decomposition is called, simply, *putrefaction.* It has the greatest analogy to charring or dry distillation, where, as, for example, in the manufacture of common illuminating-gas, or in charcoal piles, from deficiency of air, half-burnt, strong-smelling combinations, tar, ammoniacal gas-water, pyroligneous acid, etc., are likewise generated in large quantity. On the contrary, when the air can freely enter, these offensive gases and vapors combine with more oxygen, and now undergo *complete* putrefaction or combustion; and the products so eliminated are destitute of smell. This kind of decomposition, which is most analogous to complete combustion, and, like this, takes place with abundant air and a proper draught, is called *decay*.

Why putrid drainings and putrid manures, when applied to meadows or fields, diffuse at first a powerful odor, but lose this smell a short time afterwards, is therefore very simply explained: they lose their odor, because they can now absorb oxygen in any quantity from the air, and from the process of putrefaction can make a further transition into that of decay.

If moist vegetable or animal tissues lie in a room from which the air is entirely or partially excluded, — for instance, in a cellar which has no ventilation, or in a chest, etc., — then in the undisturbed, damp air a decomposition takes place, consisting partly of putrefaction, partly of decay; — the well-known process of *mouldering*, recognized mainly by its close smell and simultaneous production of mould, fungi, and spongy excrescences. By the addition of water, this kind of decomposition may be converted into putrefaction; by the introduction of a current of air, into decay; or, lastly, it may be brought entirely to a close, if by means of ventilation all moisture is evaporated, and the decaying body becomes completely dry.

In common conversation, the words "putrefaction," "mouldering," and "decay" are deemed synonymous in meaning, and the one or the other of these words is used at the pleasure of the speaker to designate the changes under our consideration. In the majority of cases, it is indeed a matter of indifference, and in a strict sense not at all incorrect, inasmuch as in most decomposing bodies all three processes are of simultaneous occurrence; externally, with free access of air, decay; internally, with exclusion of air, putrefaction; in the midst, between both, mouldering. Here, however, reference must be made to a distinction in these processes, the knowledge of which is important in a practical respect; we mean, the fact that we have to consider putrefying and mouldering substances only as a half-prepared or half-finished nutriment for the plants in cultivation; *decaying substances, on the contrary, as a fully prepared or perfected vegetable nutrient.* By the putrefaction and mouldering of manure its constituent elements are put in training for a brisk decay, but by decay are first transferred to those combinations which are consumed by plants for their nutrition. Putrefaction and mouldering may be compared, in this respect, to the soaking, maceration, or parboiling of our food; decay, on the other hand, to its full and finished dressing. Peat is composed of putrefied vegetable organs; pond-mud is equally rich therein; in the same manner, we very frequently find in the subsoil considerable quantities of putrefied or mouldering vegetable tissue, for instance, what is called moor-earth, etc. All these substances must notoriously lie a longer or shorter time in the air, before they are serviceable to plants. The transformation they thereby undergo follows from what precedes; they pass over from a putrefied or rotten state into that of decay.

In arable land the decay of manure can only take place in its upper surface, so far as this is loose and accessible to air. If, therefore, a rapid operation is desirable, it must only be superficially ploughed in, especially in heavy soil. The deeper it is introduced into the ground, and consequently excluded from the air, the more tardy and slow must be its decay, and therefore its operation.

### 2. Rational Treatment of Stall-Manure.

Two courses must be adopted by the farmer who wishes to lose none of the fertilizing elements of stall-manure; *he must either apply it fresh to his land and plough it into the ground before it has passed into putrefaction and evolved volatile substances, or he must take care that, during its putrefaction in the stable or in the yard, these volatile substances are firmly held and cannot escape.*

1. That the farmer, by carting this manure upon his fields in a *fresh, unfermented, strawy state*, just as

under ordinary treatment it leaves the stable, turns it to better account than by leaving it without further attention to rot or ferment upon the dung-heap, can no longer be doubted, since practical agriculturists, by repeated trials and by comparative experiments carried out upon a large scale, have very decisively shown it to be true. What practical experience has established as indubitable, will always accord with sound theory; so also here. Science explains this more profitable employment of fresh manure in the following manner. When it is introduced fresh below the earth, its putrefaction and decay take place under a protecting cover, which, like all porous bodies, has the power of absorbing and firmly retaining the gases and other volatile substances thereby set at liberty, until they are taken up by the roots of plants. In this manner those manuring elements are placed at the disposal of plants, which, in the common dunghill, fly off during fermentation, and are often lost in large quantity by being washed away. How considerable is this loss is shown by the fact, that, in agricultural experience, 100 cwt. of fresh manure shrinks, by lying, to some 80 cwt. in a mellow or partially decomposed state; to some 60 cwt. in a saponaceous state; and to some 40 or 50 cwt. in a thoroughly decomposed state. According to chemical analysis, it may be assumed that, in the customary mode of treatment, during the progress of this disorganization of 100 cwt. of fresh manure (i. e. stall-manure), there are lost of its most valuable constituent, nitrogen,

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| In the first | case, | 5 lbs., | whose | approximate | value | is | 4*s*. 6*d*. |
| " second | " | 10 " | " | " | | " | 9*s*. |
| " third | " | 20 " | " | " | | " | 18*s*. |

if the 100 cwt. of fresh manure is supposed to contain 40 lbs. of nitrogen. A load of unctuous manure will indeed excite a somewhat greater action on the soil than a load of fresh manure (both being assumed to be of equal weight); but the increased operation is in no case so considerable as the increased cost of the former. If a load of fresh manure is valued at 9*s*., then a load of unctuous manure may be reckoned at 15*s*. (since to obtain the latter $1\frac{2}{3}$ loads of the former were required), without any reference whatever to the loss incurred by the volatilization of manuring elements, which is of course to be added to the estimate in a calculation of its price.

Fresh manure is further distinguished from rotten by the circumstance, that it renders the soil *looser* and keeps it *warmer* than the latter; the first, because its strawy parts prevent the baking of the clods, and by breaking them to pieces render them penetrable by the gases set at freedom; the latter, because the heat of fermentation is generated in the soil and communicated directly to it, whilst in manure rotted previously upon the dung-heap it was liberated and radiated in the air. Accordingly, fresh manure will prove especially serviceable to cold and heavy land, — for instance, clay and loam soils, — since here, in addition to its chemical action as a manure, it exerts a salutary operation in the improvement of the physical constitution of the soil.

On the other hand, fresh manure is inferior to rotten in the rapidity of its action, for the simple reason that it requires time to putrefy and to decay, and that its operation therefore does not commence until these processes of decomposition are in full career, whereas rotten manure has already passed through these preparatory stages, and consequently contains a part of its constituents in that condition which is needed for the nourishment of plants. Fresh stall-manure, on this account, is better suited to plants of lengthened vegetation than to those which require only a few months for their development, — to winter than to summer crops. If in the latter case dry weather occurs after ploughing in the manure, its effect may endure through the whole of the first year, particularly when the constituents of the manure do not become, through decay, soluble and digestible by plants until the time in which they can no longer absorb and assimilate them. In grain this period arrives when the plants have finished shooting into ear. A manure which ripens slowly will indeed work slowly, but in return for this will be more enduring in its effects; fresh manure comes on more slowly than rotten, because it requires a longer time for its decomposition in the soil; it is, therefore, quite natural that it should possess, as experience has shown it does, a greater persistence in its action than the latter. The older manure is, the more will its principal operation happen during the first year, whilst, on the other hand, the action of fresh manure extends rather to the second, and even to the third.

The pith and marrow of these observations may be embodied in the rule: *Cart stall-manure, if anywhere, directly from the stable on to the field.* Theory and practical experience coincide in teaching that this is the most certain mode of obtaining from manure its completest effect.

2. If we wish, or are compelled, to keep manure for some time before carting it on the land, the next inquiry is, whether it is more profitable to let it lie in the stable until carted, or in places specially provided for this purpose.

Upon this question, the opinions of practical farmers, as also those of theorists, are still divided. Nevertheless, it would seem that the system of *preserving manure in the stable under the stock* finds every year more acceptance amongst reflective agriculturists; proof enough that the disadvantages incidental to this course of procedure cannot be so momentous as they are frequently supposed to be, and more particularly by theoretical men. That this method is universally pursued in Belgium is well known, and even in Germany there are not wanting districts where it has long been in vogue. In the kingdom of Saxony it has become very general in Upper Lusatia, and is so greatly approved, that no farmer there entertains the idea of its abandonment.

On the contrary, many agriculturists in the other provinces of Saxony meditate its introduction, and the favorable testimonies of such as have already led the way will not fail speedily to call forth a wider imitation.

Thus much is certain, that manure kept under stock in the stable possesses a *stronger manuring power* than that preserved upon dung-heaps in the ordinary manner. The cause of the difference consists in the fact, that the former absorbs and retains a far larger quantity of urine, and that the fermentation or putrefaction of the bulk of straw or manure, when continually pressed together by the weight of the cattle, takes place but slowly, and with the escape of few volatile elements.

The compact condition of the mass prevents the penetration of the external atmospheric air, as likewise in a high degree the escape of the vapors and gases generated in its interior by means of putrefaction; and both circumstances together, in connection with the tolerably equable temperature of the stable, are more effective in promoting a gradual and undisturbed rotting of the manure than a lively fermentation. If it is further taken into account, that manure in the stable is protected against the desiccating action of the sun and the soaking lixiviation of rain, as also against draughts and wind, which greatly accelerate the volatilization of the aeriform products of putrefaction; and that, of the ammonia set at freedom by the rotting, but detained mechanically in the solid mass, a large portion is again chemically united with and firmly held by the humus that is simultaneously formed; the more energetic operation of manure produced and preserved in the stable, when contrasted with that of the ordinary dung-heap, receives a very natural explanation.

It follows also, from what has been already communicated, that the apprehension of injury to the cattle from the vitiated air engendered in the stable by the retention of the manure is quite unfounded, and it has, moreover, been contradicted by experience. In carefully kept stables, where the depth of manure sometimes amounted to four feet, or even more, I have perceived no more noticeable impurity of the air than in others from which the manure was daily removed. A disagreeably pungent, ammoniacal odor was only remarked when the stalls were used at the same time as manure-puddles, that is, when the drainings running from the manure were allowed to stand in the stable; it was, however, due to the excess of putrid drainings, not to the stall-manure. If provision is made, as ought to be the case in stabling of this kind, for the proper passage of the urine not absorbed by the straw into the drainings-reservoir, cattle standing therein will be just as healthy as in ordinary stables. Admitting that a more increased development of ammoniacal exhalations may really happen, — for example, in hot summer weather, — a cheap and simple remedy lies within reach of every farmer. A pound of sulphuric acid or of green vitriol, mixed in a tub-full of water and poured from a watering-pot over the manure, will at once bind the ammonia and remove the smell. In relation to this point, I have occasionally heard complaints that the milk of cows, in consequence of the warm litter in summer time, very readily curdles, and hence becomes unfitted for transportation to a distance.

3. If a *dung-pit* outside the stable is employed for the preservation of manure until it is put upon the land, a considerable part of its strength may be very readily lost by defective attention and supervision. Hence every farmer, whether he may possess much or little ground, ought to regard *the preparation of a suitable dung-pit, and the proper management of its contents, as one of his primary and most important tasks, and the expense it may entail, as one of his first and most necessary disbursements;* for by a trifling expenditure of money and labor he can acquire a capital which is otherwise wholly and unprofitably lost.

For the preparation of a dung-heap and the management of the manure, the following rules must be observed: —

1st. *Care must be taken that the dung-pit be tight below and at the sides,* in order that neither the urine contained in the manure, nor the fluid derived from the access of rain or snow, may ooze away; and that the water dammed up, as well as that furnished from springs or the soil, may not be able to penetrate from without into the pit. In the first case, the most valuable constituent of the manure is directly lost; in the second, an unprofitable weight of moisture is added, to augment the cost of carting. The injury occasioned by a permeable, and more particularly by a light, porous soil, may lead, during continuously wet weather, to a complete washing out of the manure; and what is lost in this manner is generally of greater value than what remains behind. The simplest means of securing a water-tight bed is displayed to us by Nature herself, in ponds, water-pits, and marshes. Pond-mud, a substratum of clayey or loamy earth, restrains the subsidence of water into the depth below; hence it is only necessary to cover the bed and sides of the dung-heap with a stout layer, some foot in thickness, of clay, loam, or stiff earth, and to stamp it down as tightly as possible, in order to render it impervious to liquids. A paving over of this layer with stones will of course subserve the end in view, and also facilitate the carting of the muck. It scarcely needs express remark, that rain-water descending upon the other part of the yard, and that which falls from the roofs of surrounding buildings, must be fended off; and this is effected most simply by the intervention of a paved gutter, some six to eight inches in depth, around the heap.

2d. *A slight fall should be given to the bed of the dung-pit, and a drainings-tank of sufficient size constructed at its deepest part*, in order to collect the fluid that, more particularly in damp weather, accumulates in abundant quantity at the bottom. If this arrangement is omitted, the lower portion of the heap lies often for a long time entirely in the wet, a circumstance which is disadvantageous, and in continued rains à part of the fluid may easily run over and escape.

3d. *The manure should always be kept sufficiently moist*, in order that it may undergo as uniform a decomposition as possible. For this end a pump should be placed in the drainings-reservoir, and the liquid brought thence over the manure whenever it begins to dry. If this is not done, the upper part of the manure is readily parched in warm, and especially in windy weather, and the mass remains there undecomposed; which, with substances that are disorganized with difficulty (for instance, straw), and most particularly in the employment of leaf-litter, is prejudicial, in so far as time passes by unserviceably, during which these matters might have undergone the preliminary changes for their necessary rotting and decomposition. Drainings accelerate this decomposition, not only by maintaining the moisture of the mass, but also by the abundance of azotized substances which they contain. By adopting this proceeding, another advantage is also to be looked for; that the strength of stall-manure will be increased in the proportion in which drainings are incorporated with its mass. If care is taken that no ammonia flies off, only the watery portions of the liquid pumped upon the muck-heap evaporate, and the subsequent expenditure of labor is considerably reduced, inasmuch as then the water of the drainings needs not to be carted, but merely the elements of manure.

4th. *Care must be taken that the manure lies closely packed*, in order that the air may not drive through and desiccate it too strongly, as is the case when it is piled but loosely. This is, perhaps, attained most simply by letting out the cattle from time to time upon the heap; they will soon tread down its masses, and render them sufficiently compact.

5th. *The volatilization of valuable elements, more especially of ammonia, from the dung-heap, should be carefully prevented.* Whenever a dunghill diffuses an odor, or, in plain English, stinks, it is a certain token that volatile and powerfully manuring substances are escaping from it. A good farmer will exert himself to retain these substances on his premises, and, what is more to the purpose, on his muck-heap. Porous bodies have the capability of absorbing and firmly holding ammonia. Coating over the manure with earth, especially with such as contains humus acids (that is, moor-earth, peat, and earthy brown-coal), seems, therefore, very proper for this object. To scatter gypsum or ashes, which contain this body (for example, the ashes of turf or brown-coal), over the manure, is also serviceable; inasmuch as sulphuric acid is present in the gypsum, which has the power of fixing ammonia

12*

and depriving it of its volatility; but it acts only in this way when a large amount of moisture is simultaneously present. The inefficaciousness, so frequently remarked, of strewing gypsum in sheep-pens, is hence explained at once; the quantity of water essential to its action is wanting.

Sulphuric acid and green vitriol will be here most advisable and convenient, because they can now be everywhere obtained, and at moderate cost; occasion no expense in their transportation to and fro, like the earths above mentioned; and are far more energetic in their operation than gypsum. A few pounds of sulphuric acid mixed in water or drainings, and poured upon the dung-heap, will, in a few moments, firmly combine with and fix all free ammonia, and be paid for two or three times over by the ammonia which is thus preserved. Since, moreover, this acid alone is not without manuring value, the gain accruing from its use is proportionally enhanced. Green vitriol (copperas), being composed of sulphuric acid and iron, and dissolving readily in water, acts just as quickly as the free sulphuric acid; and in one respect, indeed, still more completely, in so far as iron possesses the capacity of decomposing and depriving of odor the sulphuretted gas (sulphuretted hydrogen), which is equally generated in the putrefaction of manure, and occasions the disagreeable stench of rotten eggs.

In Switzerland this salt has long been generally employed for the preservation of drainings, and more recent experiments in France are affirmed to have shown that stall-manure, when mixed with green vitriol, has produced upon limy soils an increase of one third in crops of grain, and upon grass-land even five times more hay than common manure of equal quality and age.

6th. On the *height* to which manure may be stacked upon the heap, it is somewhat dangerous to lay down a precise rule; inasmuch as it may vary with the kind and management of the muck, the season of the year, locality, etc. Practical men of approved fidelity prescribe, in consonance with the results of actual experience, that a height of from four to five feet should not be exceeded. The larger the masses of manure, and the higher they are piled, the greater will be the difference, in respect of the stage of their decomposition, between the upper and the lower layers; below they are perhaps already unctuous, in the centre merely mellow, and above altogether strawy. As an intermixture is impracticable upon the heap itself, the farmer must endeavor to bring it about, so far as possible, upon the field, whilst scattering it. Such as is least rotted will, as a general rule, prove most serviceable for winter grain and more binding kinds of soil; that which is more completely rotted, for summer grain, and also for lighter lands.

In general, the dung-heap is an evil, which in most farms is deemed a "necessary" one. The shorter the interval during which manure remains thereon, the less danger is incurred by the farmer of losing its most important constituents. Putrid manure has this great superiority over fresh, that it commences to operate *more quickly* in the ground; but this advantage will be bought too dearly, and become an injury in all cases, where the process of putrefaction is not skilfully conducted and carefully supervised; that is, where care is not taken that no efficacious substances may fly away, and no inefficacious ones be added during its progress. The farmer will always adopt the safest course, who suffers his manure, not to putrefy, but simply to *commence* this process, upon the muck-heap. According to the opinion of practical men, this period has set in when the straw assumes a somewhat brownish color, and has become so tender as to be torn readily by the fork in loading. Theory may be represented as agreeing with this decision. The loss sustained by stable-muck from its fresh state up to this stage of rotting is usually estimated at one sixth of its weight. Six loads of fresh manure will therefore furnish five in a state of incipient putrefaction.

In conclusion, we simply add a few remarks in relation to *the management of manure upon the field.* The *surface-spreading* of manure, and more particularly suffering it to lie *in small heaps* upon the land, *cannot*, from a theoretical point of view, be justified, except perhaps in winter, when the moisture congeals and the manure freezes stiff. The reasons for this supposition are very obvious, and have been several times brought forward. If the manure remains moist, it will continue to decompose, although less actively than on the dunghill, and in the milder form of decay; and the gases hereby evolved (carbonic acid, ammonia) are for the most part lost, since nothing is present which retains them, and they therefore can escape unimpeded into the atmosphere; especially when the air is agitated, for then their evaporation and volatilization are materially accelerated. If, on the other hand, the manure becomes completely dry, or frozen, decomposition will be entirely interrupted, and it will lie inactive on the ground; its action, slow enough without this additional delay, will therefore be still more protracted. The most advantageous course will always be that of ploughing it as quickly as possible into the land, in order that the products of decay may be held firmly by the soil. If this is impracticable, the loss will be lessened by piling the manure in large, but not too lofty heaps, and covering them with earth. When a considerable height is given to the heaps, it is then certainly very advantageous to apply intermediate layers of earth, varying from twelve to eighteen inches in thickness.

*The addition of slaked lime to rotten manure* is altogether objectionable, because lime possesses the power of again liberating the combined and fixed ammonia (page 110), as the powerful and pungent odor, which is by this means evolved, makes sufficiently evident. Nevertheless, it may be objected, that experience teaches that a farmer often enjoys better results from manure mixed with lime than from that which is unlimed, particularly in cases where a rapid vegetation (for instance, in manuring for winter crops, such as turnips, winter-rape, etc.) is sought to be obtained. This apparent contradiction will receive immediate solution. The cause of the better results derived from the addition of the lime is simply, that the ammonia set at freedom by the lime, of which a considerable quantity invariably remains behind, can be forthwith absorbed by the young plants, and appropriated to their growth. The lime, therefore, anticipates the labor of the plants, and by facilitating the absorption of nourishment occasions their more rapid vegetation. Through this accelerated growth the farmer can often bring forward a late sowing so considerably, as to allow his plants to acquire sufficient strength, before the setting in of winter, to endure the rigor of the climate and weather far better than they could do were they less advanced.

The farmer, however, ought not to resign himself entirely to this beneficial operation of lime, but to adopt a course of action by means of which the same result is obtained *without loss.* This is effected *by suffering the admixture of lime with the manure to take place in the soil;* for then that portion of the valuable ammonia will be retained, and benefit his plants, which is lost by volatilization where the mixture is made upon the dung-heap, or *upon*, instead of *in*, the field.

## 3. On the Separate Manuring Value of Straw and Leaf Litter.

Besides the excrements and urine of animals, the third factor of stall-manure, *straw-litter*, still remains to be considered. What share this may have in the fertilizing strength and value of stable-muck is a question that, at the present day, when, in addition to natural manures, other analogous agents are supplied by commerce to the farmer, is in a practical point of view of especial significance, inasmuch as it may importantly affect the whole arrangements and management of a farm.

I cannot conceal that I have hitherto intentionally abstained, in my oral and written compositions, from treating upon the importance of straw-litter as a manure, because I feared that the result arrived at by the chemist might appear suspicious and incorrect to all those practical farmers who still do homage to the opinion, that straw is to be considered the most valuable constituent of muck. And this opinion is still exceedingly general. "Straw is always straw"; — how often is this expression heard from the lips of old, practical farmers, as the pith and marrow of their experience in relation to manure! "Buy straw," is still recommended, almost universally, as the most reliable means of raising the condition of neglected farms, and "selling straw" is yet most earnestly and emphatically deprecated in the majority of farm leases. Under such circumstances, it seems hazardous for me, in a matter where the ground for chemical confidence ought to be laid by practical men, even at the very commencement, to touch upon a theme of such uncertain issues. Now, however, when chemistry has gained sympathy from many agriculturists, and numerous results of various character derived from practical experience are extant, which show that the improvement of poor land may be effected in other modes, and indeed with greater advantage, than by buying straw, — nay, more, that fields are to be preserved in full vigor even without straw, — an opinion deviating from traditionary belief will not straightway be considered heresy, but the reasons advanced in its support will at least be subjected to trial before it is entirely thrust aside.

Since all manures act only through the elements of which they are composed, the preliminary question in an attempt to estimate the manuring value to which straw can lay claim will therefore be, What constituents does it contain? To this the chemical analysis of the best-known kinds of straw gives the following reply.

In 1,000 pounds of perfectly dry straw we find: —

| Constituents. | Wheat-straw. | Rye-straw. | Barley-straw. | Oat-straw. |
|---|---|---|---|---|
| Organic substances, . | 960 | 970 | 955 | 950 |
| Nitrogen therein, . | 4 | 3 | 3 | 3 |
| Inorganic substances, . | 40 | 30 | 45 | 50 |
| Potash and soda, . | 6 | 5½ | 12 | 14 |
| Lime and magnesia, . | 3 | 3½ | 5 | 5 |
| Phosphoric acid, . | 2 | 1¼ | 2 | 1½ |
| Silica, . . . | 27 | 18 | 23 | 25 |
| Approximate value as manure, . . . | 144 *d.* | 133 *d.* | 144 *d.* | 148 *d.* |

The remaining less important and invariable, yet minute, inorganic constituents (for example, common salt, sulphuric acid salts, etc.) have not, for simplicity's sake, been specified.

Without greatly erring, 1,000 pounds of perfectly dry straw may be deemed equivalent to an ordinary shock (thirty trusses); consequently one shock of straw-litter, as manure, will have, according to its constituents, a maximum value of twelve shillings. If now it is estimated that a cow receives annually two shocks of straw (about six pounds per diem) for littering, and that all its solid excrements with half its urine are absorbed thereby, the following proportion of prices is exhibited:

| | £ | s. | d. |
|---|---|---|---|
| 20,000 lbs. of solid excrements from a cow have a value of | 4 | 10 | 0 |
| 4,000 " urine, " " " " | 2 | 0 | 6 |
| 2 shocks of straw, " " | 1 | 4 | 0 |

The manuring value of straw amounts, accordingly, to scarcely *one sixth part* of the stable-muck, and by increasing the littering to eight pounds per diem would be raised only to one fifth. A load of fresh stall-manure, weighing 15 cwt., would have, in accordance with this calculation, a value of 9*s.*, of which 7*s.* 6*d.* must be allowed for the animal excrements, and 1*s.* 6*d.* for the straw of the manure.

Straw, strictly speaking, operates as manure less by its organic and humus-forming ingredients and by its nitrogen than by its *mineral constituents* (potash, phosphoric acid, and lime). My conclusion is drawn from the following examination of two marsh plants, one of which (reed-mace), according to the experience of a Saxon farmer for many years, is a very powerful manure, whilst the other (great club-rush) has no manuring energy at all.

1,000 lbs. contained: —

| Constituents. | Of the Reed-mace. | Of the Club-rush. |
|---|---|---|
| Organic substances, . . | 950 | 980 |
| Nitrogen therein, . . . | 6 | 5½ |
| Inorganic substances, . . | 50 | 20 |
| Potash and Soda, . . . | 10¾ | ⅔ |
| Lime and Magnesia, . . | 16 | 4⅛ |
| Phosphoric Acid, . . . | 2¾ | 1 |
| Silica, . . . . . | 4 | 11 |

The humus-forming substances and nitrogen are nearly equal in both plants, and they cannot, therefore, explain the difference of operation; on the other hand, the reed-mace contains sixteen times the quantity of alkalies, nearly four times more lime, and three times more phosphoric acid, than the club-rush. Hence it may be inferred that the far greater abundance of mineral substances possessed by the former plant is the cause of its greater manuring power. What obtains here of these twoplants is certainly valid with straw also. Azotized matters exist in such trifling quantity in straw, and decompose, like the straw itself, so slowly, that their operation on the soil must be all but imperceptible.

By this statement the superiority of the old time-honored straw as an excellent material for litter, for the absorption and distribution of manure, and likewise as a means of improving binding soils, etc., ought in *no* respect to be considered as impugned; I have only sought to show that it has not, as, strictly speaking, a manure, so high a value as that which, in conformity with tradition, is very frequently attributed to it; that a farmer may obtain great crops more cheaply and quickly by powerful composts than by buying straw; and that a tenant does not ruin the fields intrusted to him, but rather improves them, when he sells straw for £20, and in its stead procures for £10 guano, bone-dust, or oil-cake.

*Leaf-litter* has, again, far less value as a manure than straw; first, because it is much less capable of absorbing urine, inasmuch as it lacks the reedy character of straw; next, because it is poorer in manuring ingredients; and, lastly, because it is far more difficultly and slowly decomposed. In respect of its mineral constituents, the following difference was exhibited in the chemical examination of the litter formed within twenty years in a grove of fir-trees (age twenty years).

There were contained: —

| Constituents. | In 1000 lbs. of dry leaf-litter. | In 1000 lbs. of dry rye-straw. |
|---|---|---|
| Inorganic substances, | 12 | 30 lbs. |
| Potash and Soda, | $\frac{4}{5}$ | $5\frac{1}{2}$ " |
| Lime and Magnesia, | $4\frac{1}{2}$ | $3\frac{1}{2}$ " |
| Phosphoric Acid, | $1\frac{1}{2}$ | $1\frac{1}{4}$ " |
| Silica, | 4 | 18 |

Leaf-litter is, accordingly, very poor in soluble substances, especially potash and soda; hence a prompt and energetic operation cannot be expected from it.

Nevertheless, the fallen leaves and plants of the forest, of which leaf-litter is composed, contain in a fresh state much more potash and other soluble matters; but these are washed away in the course of time, and are again absorbed by the soil on which they lie. For the forest this is a fortunate circumstance, since without it the removal of the litter would be far more prejudicial to the growth of its trees than, beyond all doubt, it generally is. In this lixiviated state leaf-litter contains little more than the same insoluble constituents which are found in the solid excrements of cows, but lacks exactly that which is deficient in the latter (potash and azotized substances that readily disorganize); it cannot, like straw, absorb these missing elements in considerable quantity from the urine, since it takes up but little of this secretion. Hence it is clear that, for these reasons, the manure obtained from leaf-litter must be considered very imperfect.

If the forest-soil is not exceedingly vigorous, the farmer acts very foolishly who deprives his trees of nourishment, and the ground on which they grow of its cover and natural means of protection, in order to provide his grain with a miserable food. The harm thus accruing is, generally speaking, far more considerable, and the benefit much less, than he imagines. A poor, sandy soil, that is left entirely untouched, obtains with difficulty in fifty or sixty years a layer of humus from half an inch to an inch in depth, a weak upper covering; by once raking off this litter, therefore, the farmer abstracts, perhaps, from this poor soil the toilsome acquisitions of half a century, which form the indispensable groundwork for a second and more vigorous generation and for a progressive enrichment of the ground. If he introduces a judicious rotation of crops, and buys artificial manures for a few years in addition, he will soon be in a position, as many instances in Saxony have shown, to dispense altogether with leaf-litter. And by this means his wood, his field, and his purse will be in all respects in a better situation.*

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## VII. IMPORTANCE AND VALUE OF ARTIFICIAL MANURES.

There are probably few farms on which natural manure is produced in such plentiful quantity as to suffice for *perfectly* manuring their surface, and for manuring so richly that no further increase of their

* The leaves of the fir-tribe form, however, the most meagre kind of leaf soil; most of the other trees of the forest, when well decayed, produce a carbonaceous substance of considerable value in the compost-heap as an absorbent and retainer of ammonia. And here I would observe, that all carbonaceous substances of this nature are extremely tenacious of moisture, and will retain a portion of it at a heat even above that of boiling water. This character is, of course, very valuable on light, sandy soils, and particularly during summer droughts, and renders this substance of inestimable importance in the compost-heap. — J. E. T.

fertility can be imagined possible. It may, perhaps, be objected, — Are there not many such farms? Do not most farms, indeed, belong to the class of those that are restricted to natural manures, and nevertheless yield abundant, very abundant crops? To this I reply, Abundant, very abundant crops, are probably, nay even certainly, not the *most abundant* that are in general possible. Were as much again manure as he himself produces placed at the disposal of an intelligent farmer, who has brought his land into the best condition attainable by the usual mode of farming, I believe that he would still know how to use it to advantage. Let it even be assumed that his land already yields the largest *harvest-produce* that, with the ordinary rotation of crops, is in general possible, ought he not with a superabundance of manure to have it in his power to increase essentially the *money-produce*, by being able so to change the alternation of his harvests, as to reject from their turn in the succession such crops as need less manuring, and are, as a general rule, less profitable, and to introduce in their place those which require a more vigorous manuring, but bring in a higher compensation? A farm will not have reached its highest point of cultivation, till the land is brought into such a state of vigor, as to bear not merely the first and second crops (say rape and wheat), but also the after-crop (oats, etc.), in the greatest perfection; nor till the farmer manures in general for every crop that requires manure, and as strongly as may be necessary for attaining the maximum of result.

As long as a farm has not reached the *highest point of cultivation*, every means must be pronounced acceptable, which puts the farmer in a position to provide his fields with more liberal dressing than he is able to give them from his own supply of home-produced natural manure. Whoever seeks to arrive *quickly* at this state of cultivation must make extensive use of those *auxiliary* or *artificial manures*, that are now offered to him by commerce.

As long as these powerful agents for increasing the productiveness of land were unknown, an advantageous alternation of crops was indeed the only means of insuring a large yield from the farm, — and this leads slowly yet surely to the result; now, on the contrary, it is in the farmer's power, by buying additional manures, to attain his object with far greater rapidity. A Saxon agriculturist, who has made many practical experiments in relation to this point, expresses himself in the following terms: — "The more extended employment of artificial manures is an advance in farming, that has already opened up a new era. By this means the business of a farmer is becoming more closely approximated than formerly to that of a manufacturer. For whilst formerly our farming arrangements were conducted in the manner which the quality of manure produced on the farm itself prescribed, we are now free to cultivate, as may seem most profitable, every plant which is suited to the soil. Yea, still more; we can produce, as it were with a single effort, fine harvests from worn-out and poorly manured land; — we can in such a case secure in two or three years the same results for which formerly ten or twelve years were required." The farmer should avail himself of artificial manures: —

1. To render new land speedily productive;

2. To improve quickly the condition of land already much exhausted;

3. To raise fertile land to the maximum of productiveness in general attainable, or, what is the same thing, to make the occupation of farming as *intensive* as possible;

4. To be able to command uninterruptedly the most profitable rotation of crops in a pecuniary point of view;

5. To strengthen and reinvigorate poor and backward sowings, or such as have been hurt by the severity of winter;

6. To obtain in the shortest possible time a more abundant production of natural manure.

The last observation will more especially comfort those farmers who have hitherto imagined that artificial are about to supplant natural manures; a supposition which will of course be seen to be untenable, when it is considered that the former, when they have rendered proper service, will rather displace themselves and make their own employment uncalled for. For if by the agency of artificial manures fields are speedily brought into a state of greater productiveness, more straw and fodder will also be produced; and by their assistance the stock can be so increased, and the supply of natural manure so enlarged, that the importation of artificial manures is no longer necessary.

Whoever is now contented with the harvest which a half-exhausted or but partially manured field produces, surrenders of his own free will the *full* income desirable from his land, and acts not much unlike a man, who, to spare half his fuel, keeps his lime-kiln but partially supplied with heat. The farmer, it is true, requires a larger capital to carry on his business than in the usual mode of farming, but when the money which he invests in the land is soon and surely returned to him with abundant interest, it is then indeed most advantageously employed. And this capital is more safe in the land, than when locked up in exchequer-bills or in the public funds, or even than when placed in a pot and buried in the earth, and yields a far higher interest. If more decisive testimony still is needed to the very great advantages which the intelligent farmer may derive from subsidiary manures, I would direct attention to the practical experience of thousands of farmers within a period of little more than ten years in Saxony. Saxon agriculture now annually consumes some 30,000 cwt. of guano, more than 100,000 cwt. of bone-dust, and in still more recent times very considerable quantities of oil-cake also; and the increased produce obtained by the use of these agents, going hand in hand with the improved condition of the soil as respects its cultivation, has already effected a reduction in the importation of grain to the extent of one half the quantity which would otherwise be necessary. Consequently, it is not merely probable, but absolutely certain, that the importation of foreign corn will entirely cease, if an equal advance is made during the next few years; and Saxony, a country with 7,000 inhabitants to the square mile, and with a soil and climate for the most part very unfavorable to agriculture, will herself produce a sufficient supply of the necessaries of life to satisfy her wants. And yet, in opposition to such facts, complaint is made of over-population in Germany, and faith is placed in the necessity of emigration!

Results of still greater importance have been produced in England by means of artificial manures; but I pass them over now, from a belief that what has been actually tested and proved in German soil, under German climate, and by German hands, concerns German farmers still more nearly, and will inspire greater confidence than any conclusions drawn from the experience of more distant countries. In Germany the period of artificial manures is but commencing. Guano, bone-dust, and rape-meal are the only agents of the kind, that, up to the present time, have attained a *considerable* employment. But we are advancing with rapid strides towards a time, in which here, as in England, manuring compositions of the most various character are about to become articles of commerce, and purchasable in the market. How great a choice in this respect is proffered to the English farmer may be learned from the following list, taken from one of the most esteemed agricultural journals in England, and printed afresh in every number.

*Price-Current of English Artificial Manures.*

| | | £. | s. | d. |
|---|---|---|---|---|
| Guano, Peruvian, . . . . | Per cwt. | | 15 | 8 |
| " Bolivian, . . . . | " | | 15 | 8 |
| " African, . . . . | " | | 10 | 6 |
| " Artificial, by Potter, . | " | | 13 | 6 |
| " " " Hunt, . | " | | 13 | 6 |
| " " " Boast, . | " | | 14 | 8 |
| " " " Gregory, | " | | 11 | 10 |
| Urate from the London poudrette manufactory, . . . . | " | | 6 | 8 |
| Urate-poudrette, by Hunt, . . | " | | 10 | 6 |
| Bone-dust, . . . . . | " | | 11 | 10 |
| Superphosphate of lime (with bones decomposed by sulphuric acid), . . . . . . | " | | 11 | 2 |
| Do. by Fothergill, . . | " | | 12 | 6 |
| Humus, . . . . . . | " | | 6 | 0 |
| Rape-cake, . . . . . | " | | 10 | 6 |
| Woollen rags, . . . . . | " | | 6 | 3 |
| Sulphate of ammonia, crude, . | " | 1 | 16 | 0 |
| Muriate of ammonia, crude, . | " | 1 | 11 | 6 |

| | | | £. | s. | d. |
|---|---|---|---|---|---|
| Saltpetre, crude, . | Per cwt. | | 2 | 0 | 6 |
| Chili saltpetre, crude, | " | | 1 | 8 | 6 |
| Mineral manure by Boast, | " | 9*s.* to | | 18 | 0 |
| Alkaline manure, . . | " | £2 0*s.* 6*d.* to | 2 | 18 | 6 |
| Manuring salts, . . | " | | | 2 | 2 |
| Rock-salt, . . . | " | | | 2 | 10 |
| Glauber salt, . . | " | | | 9 | 0 |
| Soda, . . . . . | " | | | 16 | 4 |
| Soap-boilers' ashes, . | " | | | | 10 |
| Gypsum, . . . . . | " | | | 2 | 0½ |
| " by Fothergill, . | " | | | 2 | 6 |
| Chloride of lime, . . | " | | | 9 | 0 |

The great variety and number of manures displayed in this table may serve to dispel apprehension as to what is to happen when guano is exhausted, and bone-dust and rape-meal in Germany are insufficient to meet the demand. When this period arrives, instead of fertilizing the soil with the nitrogen of these manures, the nitrogen of pit-coal, which is now in a large proportion unprofitably lost, will, as in England, be substituted for it. And what, when this also is exhausted? In that event, we shall derive heat from water, and manure the ground with air. However chimerical this assertion may sound, it is, nevertheless, far from being improbable. For it has been already shown that a kind of air, hydrogen gas, which is combustible and possesses a heating power eight times greater than that of wood, is obtained from the decomposition of water, and all that is wanting is simply a method of rapidly and cheaply decomposing this fluid. That, again, we may advance so far as to manure our fields with air will no longer seem incredible, when it is considered that four fifths of the atmosphere are made up of nitrogen, and that this nitrogen, if it can be compelled to combine with hydrogen to form ammonia (or with oxygen to form nitric acid), will assuredly prove as good a manure as the ammonia in guano, in drainings, etc. On a small scale and by a somewhat complicated process this is already possible; why, then, may we not attain to the solution of this problem in a simpler method, and turn it to practical account on a scale of greater magnitude? If an actual necessity only once exists, science will disclose the way, and experience make it a practicable means of satisfying that want.

The inquiries relative to artificial manures which chemistry has to answer, are identical with those that were formerly proposed when treating of natural manures.

1. *How do these manures produce their effect? For what kind of soil and for what kind of crops are they especially adapted?* This is learned by reducing them accurately into their separate constituents, and by subsequently comparing these constituents with those of the plants to which they are proposed to be applied as fertilizing agents. For an absolutely certain conclusion, an examination of the soil is indeed

required; but in most cases a knowledge of its external qualities will here be sufficient. In the excrements and urine of those domestic animals which produce the ordinary stall-manure, the farmer finds *all* the elements united, that plants in cultivation require for their nourishment; hence he rightly regards them as a universal manure. It is otherwise with artificial manures, whose constituents are extremely various, and in which are seldom found *all* the substances necessary to the food of plants, but, as a general rule, only a few individual ingredients. Hence the farmer should not regard them as representatives or substitutes for stable-muck, but rather as *supplementary and accessory agents*, by which he is enabled to heighten and increase the power of the latter. Every practical agriculturist is aware that he cannot supplant stall-manure by lime, gypsum, manuring salts, ashes, brown-coal, and the like, but may probably strengthen its action; so, too, precisely, with most artificial manures; and it must accordingly be of great importance to the farmer, if he does not wish to make experiments at random, and thereby sustain considerable loss, to know beforehand the principal constituents of the artificial manure he proposes to employ, in order that he may be able to form a judgment concerning its probable mode of operation.

2. *How rapidly does it act?* Upon this point the chemical analysis of a manure can in many cases furnish a conclusive reply. Those constituents that are soluble in water, or become so by a prompt

and energetic decay, will benefit plants in the first year of their application; those, again, that are soluble in acids, or decay with less readiness, not till the second or third; and those, lastly, that are wholly insoluble, or decay still more slowly and with greater difficulty than the preceding, cannot be absorbed by plants till a still later period. For this reason, analysis may properly arrange these articles of manure in three distinct classes: 1st. Substances soluble in water; 2d. Substances soluble in acids; 3d. Substances insoluble in water and in acids; — because the farmer is thereby placed in a position to deduce for himself a tolerably correct conclusion respecting the time and duration of the effect to be expected. To this rule, however, such manures as are composed principally of undecayed or undecomposed vegetable or animal matters form an exception; they do not become soluble, and consequently capable of being absorbed by plants, until they have undergone the process of decay. Rape-meal, bone-dust, and woollen rags, for example, contain but few elements, the latter none whatever, that are soluble in water; yet a great error would be made in pronouncing them collectively manures of very slow operation. In such cases, practical experiments must decide, and it will soon be shown that rape-meal passes readily, bone-dust with less facility, and woollen rags with still greater difficulty, into decay. If bones are made easily soluble by means of an acid, or rags by means of lye (that is, water saturated with an alkali), that effect is speedily obtained which is slowly obtained by natural decay, and both these manuring agents are brought into such a condition that their principal action now happens in the first, instead of the second or third year after their application to the soil.

3. *What is the best mode of applying the manure?* In what form? At what time? In what quantity? The replies to these questions must be left to practical experience, which will soon discover the right course. In many cases theory can certainly give useful intimations, but not special instructions, inasmuch as climate, soil, situation, and many other circumstances, make various modifications necessary, which can only be ascertained and established by experience.

4. *What is the value of the manure?* This inquiry is evidently of great moment to the farmer, especially in times when he is in danger of buying a manure for twice, nay, three or four times, as much as, when compared with others, it is actually worth. How, then, is the farmer to protect himself against losses of this description? We answer, by interrogating chemistry. In deciding upon the value of artificial manures, external signs and evidences are wholly insufficient and insecure; they must be subjected to a keener and more thorough scrutiny, to wit, a chemical analysis. If this, however, is to benefit the farmer in the manner above stated, he must be able to deduce, in a simple and intelligible way,

the pecuniary value of the manure. To do this, he must first ascertain what each separate chemical constituent is worth; this being known, it is simply necessary to calculate by the rule of three the corresponding value for each separate constituent, and add together the separate sums. As chemical analyses are always estimated for 100 parts, the sum total gives the price for the hundred-weight of manure, this being assumed at 100 pounds.

The chief difficulty consists in finding a trustworthy and accurate criterion, by which the price of the *individual* chemical substances that form the constituents of manures may be determined. Many of these substances (for example, nitrogen) are not met with as articles of commerce, and have accordingly no definite marketable value. Other substances (for example, potash, soda, sulphuric acid, etc.) occur, indeed, in commerce, but only in the more or less purified state in which they are used for other operative or domestic purposes. The commercial value they possess, when so refined, cannot of course be assumed as a basis for our calculations, inasmuch as it would be greatly too high. Finally, most substances recognized as manuring agents, even when they form an article of trade, are commonly united with each other; whence a distribution of the money value between two, three, or more elements, for which no sure foundation is possessed, becomes absolutely necessary.

In this want of certain principles, I have sought to gain assistance by proposing the question, How could the ingredients of the manure, whose value is to be determined, have been procured most cheaply in another way? Hence I have looked around for such materials as are met with in abundant quantity upon the earth, and by means of which one or another of the manuring constituents could be furnished at the lowest possible cost. From the market value of these materials, the price to be placed upon the individual ingredients was then ascertained; but this, in many cases, must again be modified, for if it is taken as the groundwork for calculating the worth of those manures that are actually met with in commerce, and possess a fixed market value, a disproportionate price, differing widely from the assumed commercial value, is established. A perfect unison between the actual and the theoretical price cannot therefore be always obtained by this mode of computation; nevertheless, I maintain that the differences which will occur in the calculations to be presently brought forward, by way of illustration, are of such a character, that the theoretical price, obtained by the method of reckoning here adopted, is entitled to be regarded as *more accurate* than that actually exhibited in the present state of trade.

It is impossible to specify the reasons in detail which have induced me to increase the price of one substance and to reduce that of others, because the entire valuation depends in general more upon a reciprocal comparison, a counterbalancing, experimenting, and practical knowledge, than upon fixed principles, and must therefore be contingent upon circumstances. If the prices specified are shown on further examination to be untenable, they must be altered; they cannot lay claim to permanent weight, *inasmuch as they are subject to the same fluctuations* as those of other articles of trade. If from this kind of computation, in general, a beneficial result for practical guidance merely is to be expected, it must then be treated in the same way as the merchant deals with his price-current; that is, the prices must be revised from time to time, and, when necessary, altered.

The *individual substances of manures*, for which specific valuations were calculated, are the following:—

1. *Putrid nitrogen* (*ammonia*):—1 lb. = 1*s.* 3*d.* This price may, perhaps, appear somewhat high, but it is not so in truth. I believe that it would rather bear a further addition than a reduction, since in the cheapest ammoniacal salt (crude sulphate of ammonia) it costs from 2*s.* to 2*s.* 2*d.*, and in the cheapest nitric acid salt (crude Chili saltpetre), from 1*s.* 6*d.* to 1*s.* 9*d.*

2. *Nitrogen* (*not putrid*):—1 lb. = 11*d.* The lower price of nitrogen, when not putrid, is justified by its *slower* operation. In rape-meal it is computed, according to the present market value, at from 9*d.* to 11*d.*; in woollen rags, at from 5*d.* to 7*d.* only. The

latter, however, cannot be regarded as furnishing a criterion, since rags are not to be procured in so large a quantity as to satisfy a general demand; and the nitrogen they contain is, moreover, held in such firm combination, that, without a previous process of decay or decomposition, which again costs money and labor, it cannot be rapidly absorbed by plants.

3. *Organic or humus-forming substances:* — 1 lb. = about half a farthing. Here those substances are to be understood that undergo combustion by long-continued heating of the manure, irrespectively, however, of the nitrogen they contain, which, on account of its very peculiar importance, is calculated by itself, as just mentioned. It would be still more accurate to ascertain and value separately that most important ingredient, carbon; but to do this, in examining manures for practical purposes, would involve too great minuteness of detail and too much loss of time. The error which may be produced from this circumstance is, moreover, extremely insignificant, since, in calculating the price of a hundred-weight, it would amount, at the most, to a few farthings. In estimating the price of these substances, the cost of straw-litter and wood-fibre was taken as our basis. In the form of brown-coal, earth, peat, etc., the organic ingredients would be reduced to a much lower price. In this calculation, the nitrogen must, in strictness, be previously withdrawn; but this subtraction may be omitted without causing an inaccuracy worth mentioning.

4. *Salts of potash:* — 1 lb. = 2*d.* The potash or potash salts met with in commerce are, perhaps, nearly three times as dear as here represented; but in this case considerable expenses are incurred in manufacture and purification, which the farmer must not, of course, include in his reckoning, inasmuch as crude wood-ashes, by which the above price was determined, possess for his purposes the same, and indeed a still higher value, than a corresponding quantity of a purified salt (for instance, carbonate or sulphate of potash). It is fortunate for agriculture, that the cheaper carbonate of soda may in very many cases, in ordinary life, be substituted for the carbonate of potash; since from this circumstance wood-ashes remain at the service of the farmer. Nevertheless, the important problem of discovering other sources for procuring potash salts than those already known, is still to be solved by agricultural chemistry. Many minerals and rocks contain potash in considerable quantities, and all that is necessary is a simple method by which it may be rendered soluble, and so capable of contributing to the nourishment of plants. If, in a chemical analysis, potash is exhibited as such (that is, not as a salt), one pound may be taxed at 3*d.*

5. *Salts of soda:* — 1 lb. = 1¼*d.* This price has been derived from that of crude common salt and manuring salts. Were the salt-tax removed, this estimate might be further and materially reduced.

6. *Phosphate of lime* (bone-earth): — 1 lb. = 1¼*d.*

Here I fear the objection that this calculation is too low. I have sought to raise, and even to double it; but then, in estimating the price of the most familiar artificial manures, a value so disproportionately high was introduced for several, that they could be brought into no sort of agreement with the operation of the latter, as ascertained by experience. Bad guano, which often consists in greatest part of phosphate of lime, would then acquire nearly the same value as the best, whereas experience speaks loudly to the contrary. In support of my assumption; it may be alleged that in England nearly the same price is regarded as correct, as may be inferred from the experiments instituted and made public by Mr. Lawes, respecting the action of the natural phosphate of lime (phosphorite). Hence it would rather follow, that even in Germany the price above specified may be still somewhat reduced, inasmuch as bones, with which, in the experiments referred to, the action of phosphorite is compared, fetch in England a higher sum than with us. In sugar-refiners' refuse the price of the phosphate is likewise something lower than that above mentioned.

If phosphate of magnesia is more particularly exhibited in the analysis, it must be reckoned at the same price as phosphate of lime. So, too, when both combinations are taken together under the designation of *phosphoric acid earths*.

If phosphoric acid and lime are individually valued, then 1 lb. of *phosphoric acid* may be estimated at 2*d*., and the lime carried over at an additional rate.

7. *Sulphate of lime* (gypsum) : — 1 lb. = a farthing. At this price powdered gypsum may now be obtained for agricultural purposes (in Saxony).

8. *Carbonate of lime* (pulverized limestone) : — 1 lb. = about half a farthing. This is about the average price of burnt lime in Saxony. If this latter is suffered by long exposure to the air to become changed into carbonate of lime, the price must then be reduced to one third of a farthing, — a sum which may be imposed upon those manures that are very rich in lime (for instance, marl, gas-lime, etc.). In most artificial manures the lime is of subordinate importance, and the difference that would be produced in the total price by assuming one third, instead of half a farthing, is scarcely worth consideration. The *carbonate of magnesia*, if specially mentioned in the analysis, may be reckoned at the same sum with that of the carbonate of lime.

Such are the substances and the prices I have to propose in defining the value of artificial manures. The additional ingredients usually exhibited in chemical analyses, alumina, silica, and oxide of iron, have been disregarded in the computation. I have not brought forward a specific calculation for sulphuric and muriatic acid, because to appraise these specially would involve in a chemico-agricultural analysis, for the most part, an excessive prolixity of detail, and too great a sacrifice of time. They have not been entirely passed over, inasmuch as they are included in the estimate given for the salts of potash and soda, and also for gypsum; in the first case, it is granted, for the sake of simplicity, only in the lump. Much might, indeed, be far more strictly looked into, but *too minute investigations might be injurious to the simple views I have taken.*

*Mode of appraising the Price of Artificial Manures.*

For this purpose the following valuation may be useful. The price affixed is that of 1 lb. of each substance named.

| | *s.* | *d.* |
|---|---|---|
| 1. Nitrogen, as ammonia (or nitric acid), | 1 | 3 |
| 2. Nitrogen, which has undergone no alteration by putrefaction or decay, . . | | 11 |
| 3. Organic or humus-forming substances, | | $0\frac{1}{8}$ |
| 4. Salts of potash, . . . . . . | | 2 |
| Or potash separately, . . . . | | 3 |
| 5. Salts of soda, . . . . . | | $1\frac{1}{4}$ |
| 6. Phosphate of lime, or phosphoric acid earths, . . . . . . | | $1\frac{1}{4}$ |
| Or phosphoric acid, separately, . . | | 2 |
| 7. Gypsum, . . . . . . | | $\frac{1}{4}$ |
| 8. Lime, . . . . . . | | $\frac{1}{8}$ |

If a farmer desires that a manure met with in commerce should undergo examination, he will act wisely in proposing to the chemist who is to institute the analysis, the following distinct questions: 1st. What quantity does it contain in 100 parts of

(1.) nitrogen, (2.) organic substances, (3.) salts of potash, (4.) salts of soda, (5.) phosphate of lime, (6.) gypsum, (7.) carbonate of lime (in connection with magnesia)? 2d. In what combination is the nitrogen principally present? as an ammoniacal salt? as a nitric acid salt? as an organic substance of easy or of difficult decay? By the reply to the first inquiry he is placed in a position to calculate the approximate value in money of the manure in question, whilst from the subsequent answers he acquires tolerably certain information as to the slow or rapid action that may be anticipated from its use. Having obtained the analysis, he can then compute, with the aid of the preceding valuations, the price to be attached to each separate substance, and add together the single sums he has previously obtained.

The following examples may contribute to greater perspicuity, and also serve for a comparison of the present market value of the better-known artificial manuring agents with their value as ascertained by this method.

| | 1. Peruvian Guano. | | | 2. Patagonian Guano. | | |
|---|---|---|---|---|---|---|
| | In 100 lbs. | s. | d. | In 100 lbs. | s. | d. |
| Nitrogen (as ammonia), | 12¾ lbs. | 14 | 2 | ¾ lbs. | 0 | 11 |
| Organic substances, . | 59 " | 0 | 6 | 9 " | 0 | 1¼ |
| Phosphoric acid earths, | 25 " | 1 | 10¼ | 60 " | 4 | 3 |
| Salts of potash, . . | 3 " | 0 | 6 | trace. | 0 | 0 |
| Salts of soda, . . | 1 " | 0 | 1¼ | 4 " | 0 | 4 |
| Gypsum, . . . | — | 0 | 0 | 5 " | 0 | 1¼ |
| Estimated value of 100 lbs., | | 17 | 1½ | | 5 | 8½ |
| Commercial price, | | 18*s.* to 19 | 6 | | 13*s.* 6*d.* to 15 | 9 |

| 3. Bone-Dust. | | | | 4. Rape-Meal. | | |
|---|---|---|---|---|---|---|
| | In 100 lbs. | s. | d. | In 100 lbs. | s. | d. |
| Nitrogen (not putrid), | 5 lbs. | 4 | 3 | 4½ lbs. | 3 | 10 |
| Organic substances, . | 26 " | 0 | 2½ | 77 " | 0 | 8¼ |
| Phosphoric acid earths, | 51 " | 3 | 7¼ | 3½ " | 0 | 4 |
| Salts of potash, . . | — | 0 | 0 | 2¾ " | 0 | 3¾ |
| Salts of soda, . . | ½ " | 0 | ½ | — | 0 | 0 |
| Carbonate of lime, . | 9 " | 0 | 1¼ | ½ | 0 | ¼ |
| Estimated value of 100 lbs., | | 8 | 2½ | | 5 | 2¼ |
| Commercial price, | 6s. 9d. to | 9 | 0 | 3s. 4½d. to | 4 | 6 |

| 5. Manuring Salts by Kötzschau (*the Manufacturer*). | | | | 6. Manuring Salts by Dürrenberg. | | |
|---|---|---|---|---|---|---|
| | In 100 lbs. | s. | d. | In 100 lbs. | s. | d. |
| Salts of potash, . . | 3 lbs. | 0 | 6 | ½ lbs. | 0 | 1¼ |
| Salts of soda (common salt and Glauber salt), . | 12 " | 0 | 11 | 1½ " | 0 | 2 |
| Gypsum, . . . | 66 " | 1 | 0½ | 78 " | 1 | 2½ |
| Carbonate of lime, . . | 5 " | 0 | ¾ | 6 " | 0 | 0¾ |
| Estimated value of 100 lbs., | | 2 | 6¼ | | 1 | 6½ |
| Commercial price (in Saxony), | | 1 | 11 | | 1 | 7 |

Note. — These prices and values can only be considered here for the purpose of comparative estimation, as the prices in Germany of the separate ingredients, as well as of the guano and all artificial manures, differ so much from those in this country. But the scheme of attaining an approximate valuation of all may be adopted here with great facility.

The European quotation of bones, Nov., 1852, was 95*s*. to 97*s*. 6*d*. sterling per ton. — J. E. T.

## VIII. GUANO.

Of those auxiliary manures that are at the command of the German farmer, *guano* occupies the first and most important position; not merely because it is the most expensive and the most powerful, but also and more especially because it forms an excellent addition to all other manuring agents, natural as well as artificial, by imparting to them a greater activity, that is, by causing them to be *more rapidly* and *certainly* efficacious. In most German states guano is still almost unknown as a manure, although the extraordinary results which English agriculture has achieved by its instrumentality ought to excite zealous imitation. A manure that has already sustained in England a trial of ten years, and in procuring which English farmers have expended yearly from £1,000,000 to £1,500,000, must not be considered so unpractical and unprofitable as many German agriculturists continue to believe. It is not saying too much, when it is affirmed that two means contributed to carry English agriculture successfully through the crisis occasioned by the abolition of the corn-laws; and that these two means were *guano* and *draining*.

But even in Germany there are individual districts which testify that German agriculture, in precisely the same way as English, may derive the most extraordinary advantages from the employment of guano. In this respect the kingdom of Saxony may be considered the first; for during the past year this country consumed more of this manure than all the remaining states of the German confederation together, its annual consumption being about 30,000 cwt.; and an experience of nine years has already brought it into such extensive use, that thousands of farmers may now be found who manure with guano. In the face of such facts, the objections most frequently urged against manuring with this agent — that it is too expensive, and evanescent in its action — must lose their weight. Guano is expensive, to be sure; but if one hundred-weight of this substance produces an effect equal to that of three or four loads of ordinary muck, it is obvious that it will remunerate as well as the latter, and even still better; its operation is indeed quickly over, but if it acts so vigorously, that, even in the first year of its application, the capital expended is restored with abundant interest from the soil, then its slighter after-operation is, it may be presumed, not so great an imperfection after all.

Besides these objections, I have often heard from farmers that the reason why they did not employ guano was the apprehension that they might obtain bad, spurious, or adulterated merchandise. This fear is certainly well founded; but equally well founded is the statement, that chemistry offers a means by which the farmer may easily and confidently protect himself against disappointments or frauds of this description, if he will only take the trouble to institute a few simple tests, such as are specified at the conclusion of this chapter.

## 1. Sources and Constituents of Guano.

Guano is composed of the excrements of sea-birds, which have accumulated in the lapse of time, in layers of greater or less depth, upon uninhabited islands and cliffs. *Good guano* comes to us from those zones of the earth in which it never, or at least extremely seldom, rains, and from such islands as are sufficiently elevated to prevent the overflowing of sea-water; for if either happened, the best and most efficacious portions of the guano would be dissolved and washed away. If a dung-heap is suffered to lie without attention for only a few years, with the sun shining upon it, the air driving through it, and the rain washing it away, what will at last be left of it? Not much beyond a few earthy or mineral substances, which could not be dissolved or volatilized. Such *washed-out* and *worthless guano* is very often found in commerce, and against it the farmer must be upon his guard. Amongst these are the cargoes which come to us from Chili and Patagonia, since these countries are inundated with heavy rains. In like manner, those kinds of guano *now* met with under the name of "African" must be enumerated here; whereas the guano brought two or three years since from Africa, which bore the name of "Ichaboe guano," might be admitted as a good intermediate variety.

The best guano comes from the rainless region of Peru, which lies beneath the 5th and 20th degree of south latitude. Here it covers the rocky surface of the cliffs and islands in layers of very various thickness, in a similar way to our own clay strata. The depth or thickness of these layers varies from one or a few yards to twenty and thirty, and sometimes even more. In the first year in which a layer of guano is deposited it has a white color, and is called *guano blanco;* this is generally acknowledged to be the best, and is bought from the Peruvians, who esteem it highly, at double the price which is given for the brown. It possesses nearly the same constituents, and produces the same effects, as our pigeon-manure; but its action is still more energetic, because it is richer in azotized substances. The reason of this difference consists in the difference of food. The marine birds, whose excrements furnish guano, live upon fishes, whilst our pigeons take only vegetable nourishment; an animal diet is always richer in nitrogen, and furnishes for this reason a manure that abounds more in this element than one furnished by a vegetable diet. The layers which succeed to the white have a light grayish-brown color; still deeper down, they become darker, and at the lowest part rust-colored; the lower layers, moreover, are invariably more compact than the upper. It is evident that the inferior layers are the oldest; putrid decomposition has advanced farther in them, and hence feathers, egg-shells, and similar remains are no longer found, whilst in the upper layers they are of frequent occurrence.

But will not these layers of good guano be speedily exhausted by the increasing demand? This apprehension I have already heard from many farmers, but it is not, after all, very urgent or alarming. According to the survey recently instituted by the Peruvian government, the deposit of guano now existing in South and Middle Peru contains a store of more than 500,000,000 cwt. This supply will hold out yet a considerable time.

The very apprehension, however, that the guano may come to an end, should impel the farmer to exert himself, that he too may participate in the advantages which rational agriculture is able to derive from this substance before it is too late. For it is beyond dispute that those countries which are first in securing its possession will obtain the greatest advantage, inasmuch as they will attain far more quickly to an increased revenue from the soil than those which follow later, and inasmuch as they will first arrive at that state of cultivation in which they can do without its assistance. This high cultivation will be attained when, through the augmented produce of fodder and straw produced by means of auxiliary manures, as much natural manure is produced as is requisite plentifully to manure the entire area of the farm. Saxony numbers already, particularly in Upper Lusatia, many farms of this description.

The guano at present met with in commerce is brought to us either from America or Africa; the American, under the names of Peruvian, Bolivian, Chilian, Sea-Island, and Patagonian guano; the African under the designation of Cape and Saldanha Bay guano. Of these varieties, *only the Peruvian* is to be regarded as *good guano;* all others are of little worth, and more or less washed out.

Until the last few years, as has been previously mentioned, a tolerably good or intermediate variety was brought to us from Africa, which bore the name of Ichaboe, and was distinguished by a very dark, brownish-black color. The importation of this guano has, however, ceased; and, according to recent and reliable intelligence, the deposit of it has been entirely exhausted for some two years past; hence it may here be dismissed without further notice.

Names are indulgent; they permit themselves to be attached to this or to that merchandise at the pleasure of the vender, and for this reason no confidence is to be placed in them in the commercial intercourse of life. To attain certainty in deciding upon the excellence of different varieties of guano, it must be known of *what constituents* they are composed, and *what quantity* of the more important ingredients they contain. What an extraordinary difference is found in this respect will be seen from the following analyses of those guanos that were brought within the last few years into Saxony.

In 100 lbs. were contained: —

| Constituents. | 1. Peruvian. 1850. | 2. Peruvian. 1851. | 3. Saldanha Bay. 1847. | 4. Chilian. 1848. | 5. Patagonian. 1850. | 6. African (of later date). 1850. |
|---|---|---|---|---|---|---|
| Moisture, . . . | 10 | 8 | 8 | 20 | 6 | 15 lbs. |
| Combustible, or volatile azotized substances, | 59 | 65 | 22 | 11 | 15 | 13 " |
| Phosphate of lime, . | 25 | 22 | 64 | 51 | 77 | 53 " |
| Salts of potash, . | 3 | 4 | — | — | — | — |
| Salts of soda, . . | 1 | — | 1 | 13 | — | — |
| Gypsum, . . | — | — | — | 2 | — | 13 " |
| Silica, sand, stone, etc., | 2 | 1 | 5 | 3 | 2 | 6 " |
| Total, . . | 100 | 100 | 100 | 100 | 100 | 100 lbs. |
| Nitrogen contained in 100 lbs., . . | $12\frac{3}{4}$ | $13\frac{1}{2}$ | $1\frac{3}{4}$ | $\frac{3}{4}$ | $1\frac{1}{4}$ | $\frac{9}{10}$ " |
| Value of 100 lbs. computed in accordance with the constituents, | *s.* *d.* 17 $1\frac{1}{2}$ | *s.* *d.* 17 11 | *s.* *d.* 7 1 | *s.* *d.* 5 10 | *s.* *d.* 7 4 | *s.* *d.* 5 3 |
| Present market price of 100 lbs., . . | 19 6 | 19 6 | 13 6 to 16 6 | 13 6 to 16 6 | 13 6 to 16 6 | 13 6 to 16 6 |

So, too, the *white lumps* and grains, which are frequently found in good, as also in bad guanos, are very variously composed, as is shown by the following summary of their principal constituents.

In 100 lbs. of *lumps* were contained: —

| Constituents. | In Peruvian Guano. No. 1. | In Patagonian Guano. No. 5. | In the more recently imported African Guano No. 6. |
|---|---|---|---|
| Combustible elements, . | 74 | 13 | 14 lbs. |
| Nitrogen therein, . . | $15\frac{1}{4}$ | $\frac{7}{8}$ | 1 " |
| Phosphate of lime, . . | 16 | 68 | 30 " |
| Gypsum, . . | — | 3 | 41 " |

An *adulterated guano* brought to us two years ago from England contained but 7 per cent. of combustible substances, with $\frac{2}{5}$ per cent. of nitrogen, and 89 per cent. of ash (of a yellowish-brown color); this latter being made up of 72 per cent. of silica, sand, clay, and stone: here, therefore, one part of Peruvian guano was mixed with from six to seven times the same quantity of clay and sand. Another lot which arrived this spring (1851) at Hamburg from England, in order to be sold to the good Germans, consisted of one third part good Peruvian guano, and two thirds fine sand; upon combustion, it furnished in like manner a brownish-red ash.

Of the above-mentioned constituents, *nitrogen* must be considered by far the most valuable; for it is this ingredient that imparts to guano that wonderfully strong forcing power, for which it is so highly prized and so dearly purchased. In the fresh excrements of the birds, nitrogen is contained principally in the form of uric acid, in precisely the same way as in the urine of cows, sheep, etc.; on the other hand, in the putrefied bird manure, as found in the guano, the uric acid has been already converted, as in putrid urine, into *ammonia*, or, to speak more accurately, into *ammoniacal salts*, which are readily soluble and digestible by plants. We are, therefore, to look upon guano as a manure that has undergone complete *putrefactive fermentation*, — as *putrid drainings in a solid form*; and it is owing to this circumstance that it attains its end *so quickly*, and begins to act *instantaneously*, when applied to moist lands. In good guano, nearly one half consists of salts of ammonia, whereas inferior varieties often exhibit mere traces of them. At the present day, guano, notwithstanding its high price, is still the *cheapest source for procuring ammonia* that is open to the German farmer; for a pound of this substance in bird manure may be reckoned at one shilling, whilst the ammoniacal salts to be purchased in the market cost at the lowest price from 1*s.* 11*d.* to 2*s.* 1*d.* As long, therefore, as German fields are brought to a high degree of productiveness by means of ammonia, and as long as we possess no cheaper means of obtaining it, so long must guano be advantageously employed as a powerful agent in the improvement of German agriculture.

At ordinary temperatures, the ammoniacal salts contained in guano are not volatile, since the acids present, which are generated at the same time with the process of putrefaction (humus acid, oxalic acid, etc.), operate in the same way as sulphuric acid in fixing the ammonia. Hence it need not be apprehended, that guano will lose greatly in strength by long-continued preservation. Upon being heated, on the other hand, the substances fly off.*

Next to nitrogen or ammonia, *phosphoric acid*

* This evidently refers to guano packed for transportation; if well secured in tight barrels, it will travel any distance without material depreciation. On this subject see note on a succeeding page.— J. E. T.

must be considered the most valuable constituent of bird manure; it is found here invariably in combination with lime, and hence, in analyzing, it is usually defined and represented, for the sake of greater simplicity, as *phosphate of lime.* When guano is subjected to heat, it is left as a residue in the ashes, since it does not undergo combustion and is not volatile. The more phosphate of lime (ash) and the less ammoniacal salts (combustible substances) contained in a guano, the lower must its pecuniary worth be estimated. Good Peruvian guano contains from one fourth to one third phosphate of lime; the washed-out and comparatively worthless varieties (African, Patagonian, etc.), from three fourths to four fifths. The assertion is frequently made, indeed, that the remarkable efficacy of guano must be attributed chiefly to the phosphate of lime which it contains; but guano itself most positively refutes this assumption, for, were it true, then inferior guanos must be far more efficacious than those of better quality, since they contain from twice to three times the quantity of phosphate of lime. That they are not, however, so effective, has been demonstrated by hundreds of practical experiments made in Saxony by farmers, who, in order to save *2d.* or *3d.* in purchasing bird-manure, have made use of Patagonian or African guano.

The remaining constituents of guano — *salts of potash*, *salts of soda* (Glauber salt, common salt), and *gypsum* — exist in such inconsiderable quantity in good bird-manure, that, in examining for agricultural purposes, they may be wholly omitted. The last two deserve especial consideration only when they occur in greater abundance; for in this case they must be regarded as used, on account of their low price, for adulterating guano. As a guano so adulterated by soda salts, that marked above as No. 4, and as a guano adulterated by gypsum, that represented as No. 6, may be pointed out.

## 2. Operation and Employment of Guano.

On account of the great abundance of easily digestible nitrogen, that is, ammonia, in guano (only, however, in the good), it must be deemed the *most forcing* and *most rapidly efficacious* manure at the command of German agriculture. For this reason, it is above all others adapted for *auxiliary manuring*. In it the farmer possesses an excellent means of *improving common stable-muck*, and increasing its effect. Stall-manure is poor in nitrogen, for one load contains scarcely more of this element than half a hundred-weight of guano. This nitrogen is again incapable of being taken immediately as food by plants, for it has not yet, or at all events only in very trifling proportion, undergone putrefaction; it becomes gradually fit for vegetable nutriment by lying in the earth. Here a small addition of guano will produce an extraordinary effect; inasmuch as by its instrumentality nourishment is furnished to young plants, until a further supply has been made ready from the stall-manure, and they can consequently take on from the first a more vigorous and rapid growth. In this way, then, the farmer rears a *vigorous seed plant.*

Another advantage, besides, is, that unfavorable weather or climatic influences are less injurious in their action upon such germinating plants; for it is a natural inference that a vigorous plant should suffer less from these circumstances, than one which is feeble. Saxon farmers, moreover, like the English, have repeatedly observed that germinating seeds, when manured with guano, are less obnoxious than others to attack from worms and insects. Potatoes so manured are seldom attacked by worms, and in like manner fields that were manured during the preceding autumn with guano suffered but slightly from slugs, whilst other fields were greatly devastated by these vermin.*

Whether, in this mode of using bird-manure, it is introduced into the ground at the same time with the stall-manure, or at seed-time, or, again, is scattered over the already germinating plant, is a matter of comparative indifference, provided only it arrives in sufficient time for plants to make free use of it, particularly during their early growth.

* I have tried most of the insect pests of the garden with guano-water of various strengths. A strong infusion kills all of them, — weaker solutions produce various effects. A fair experiment with the Curculio in the early spring, for want of opportunity, has not been tried. It is recommended to the attention of those who suffer from this ravager of plums. — J. E. T.

The farmer should make use of guano, as the physician employs Peruvian bark, as a universally invigorating or strengthening remedy for sowings of all kinds that have suffered by the severity of winter, or which from want of power in the soil, or from any other cause, are backward in their growth. If in the early spring, or at least before the shooting into ear, such sowings are sprinkled over, according to their condition, with from 150 to 200 lbs. of guano per acre, an extraordinary result may be calculated upon in all cases, and more particularly in winter wheat, because its vegetation proceeds but slowly in the spring. The excess over the usual crop produced in this case by the bird-manure must naturally be regarded, after subtracting the cost of the guano, as a *pure increase of profit;* for the expense of sowing and tillage, the interest of farming capital, taxes, etc., must be computed in estimating the produce which would have been obtained from the field without an additional manuring with guano, and would have been the same if no increased produce had been gained. By "making such improvements," plants which are particularly backward in certain portions of the field may be so invigorated, that a very unequal condition of the crop may be converted into a state of exceeding uniformity of growth.

Employed in this way, even the farmer who possesses an abundance of stable-manure may derive advantage from guano; for amongst his natural manures none operate so speedily or can be so conveniently put on to the land. Old compost earth, when sprinkled frequently with urine, would approximate most closely to the action of guano.

As good guano consists of thoroughly decayed excrements, in which the manuring constituents, both the combustible or organic and the incombustible or mineral, are all simultaneously present, it can be just as properly applied *alone* as rotten muck; indeed, it will have decided advantages over the latter in all cases where a brisk and vigorous action is required.

Its employment is of the *highest benefit* to *oil-bearing plants* of all kinds, — to rape, beet-root, rocket, etc., — as also to *potatoes;* next to these, to *wheat* and *rye;* then to *barley*, *tares*, and *pease;* and finally to *oats*. The scale of diminishing utility here intimated is, however, in no respect so great, as to render the application of guano to the crops last mentioned otherwise than extremely advantageous.*

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* The oil-bearing plants alluded to here are: —

1st. The Rape, *Brassica napus*, var. *oleifera*, Dec.; this is the more commonly cultivated on the continent of Europe, and particularly in the eastern parts of France, where it is called *Colza*. It requires a rich, moist soil, and will grow well on the sea-coast in marshy spots; this is the *Räps* of the German.

2d. *Brassica præcox*, or Summer Rape. This, as its name indicates, is an early variety, and is harvested in June; the land is then ready for a second crop of some other vegetation. It will grow well on uplands and in mountainous districts, and is the variety alluded to above, of which the cultivation has been so much extended by the

Besides this, guano has proved extremely advantageous and profitable in its fertilizing influence upon the growth of *green crops*, *roots*, and of *grass* and *garden produce* of all kinds; for example, celery, parsnips, cabbages, strawberries, etc.

In its application to oil-bearing plants, bird-manure has proved so advantageous, because as a first crop, even with a very strong manuring, they are not easily lodged, and leave the soil in such a state of vigor, that wheat or corn thrives excellently after

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use of guano. It is the *Rübsen* of the Germans. A large quantity of rape-seed is annually brought to Europe from Calcutta.

3d. The Wild Rocket, *Camelina sativa.* This is not so much cultivated as the other two; it is the *Dotterkraut* of the Germans.

4th. Linseed, *Linum.* This is so well known, that little need be said on the subject.

The recent value of the oil expressed from these plants in the London markets is, —

| | | | | |
|---|---|---|---|---|
| Rape, common brown, | 33 | shillings | sterling | per cwt. |
| " refined pale, | 36 | " | " | " |
| Linseed oil, | 29 | " | " | " |

Rape cakes are freely purchased at 100 shillings sterling per ton of 2240 lbs. The seeds of these oil-bearing plants are pressed, and the residuum, after the oil has been separated, sold, as the oil-cake above quoted, for manure and feeding cattle.

That which has been well pressed is best for manure, that from which the oil has been expressed with less care is best for cattle; but the manure from cattle fed with oil-cake is always stronger and more efficient than that without this article of food. There seems to be no valid reason why these crops, particularly the rape, should not be tried here.

Quotations of oil-cake, Nov., 1852, in Europe: —

| | |
|---|---|
| Linseed cakes, best, | £ 8 8*s.* to £ 8 10*s.* per ton. |
| Rape " | £ 5 |

16 *

them. The remarkable extension which the culture of these crops has obtained in Saxony during the last ten years, is chiefly owing to this manure. Their cultivation reaches, in the rough Erzgebirge,* even to a height of 2,000 feet above the level of the sea. By the assistance of guano in the more mountainous districts, *summer rape* is raised on a far more extensive scale than was formerly the case. Since this plant requires a very short time to attain maturity, and is readily marketable immediately after its harvest, the money expended in manuring, together with the gain attained thereby, is returned in some three months, and the land is at the same time brought into a state extremely suitable to the reception of the winter sowing, yielding without any fresh manuring an excellent crop. In these hilly districts, guano furnishes an additional and altogether peculiar advantage in the sowing of winter rye on land that has had a single ploughing after growing grass for one or more years, and, if the soil is not too heavy and binding, it has proved of extraordinary service; for if the extent of these winter sowings was formerly contingent upon the quantity of manure actually present in the farm-yard, any extension that is desired may now be given to them by the assistance of guano.

It would lead us here too far to communicate the special results obtained by practical experiment in

* A chain of mountains extending between Bohemia and Saxony.

regard to the produce yielded by guano, as a guaranty for the assertion that this manure has proved profitable for *all kinds of crops and on all kinds of soil.* The fact may suffice, that, according to experience, 1 cwt. of guano is capable of producing in the *first* year 540 lbs. of rye, from 600 to 800 lbs. of barley, or from 320 to 330 lbs. of potatoes, etc. If the subsequent operation is added to the calculation, it may be affirmed with certainty that 1 cwt. of guano is able to produce 5 Saxon bushels (at least 800 lbs.) of rye, with the corresponding quantity of straw (at least 1800 lbs.), of which some 60 per cent. must be reckoned for the first year, 25 per cent. for the second, and 15 per cent. for the third.

The 30,000 cwt. of guano, which Saxon agriculture annually consumes, lead accordingly to an increased produce of 150,000 bushels (at 160 lbs.) of grain and 500,000 cwt. of straw, or to a corresponding quantity of other crops.

In *comparing* the fertilizing power of guano with that of the excrements of cattle, it may be assumed, from the results of practical experience in Saxony, that 1 cwt. of guano is equivalent to from 65 to 70 cwt. of the latter; that is, to three full loads. Of bone-dust, 2 to 2½ cwt. furnished the same result; guano, however, excels the latter, which is not equally well adapted to all soils, inasmuch as it has a decided advantage in the first year, whilst bone-dust, on the other hand, has a more enduring operation. Hence the thinking farmer will readily perceive *that it must be very judicious to add some guano to bone-dust*, in order that it may call forth even in the first year the most abundant produce. The same is true of oil-cake also.

For a thorough manuring, the average reckoning is 4 cwt. of guano to the Saxon acre, or a full 2 cwt. to the Prussian Morgen.* Yet this amount, according to climate and soil, more particularly in mountainous districts, is frequently exceeded; whilst, on the contrary, a less quantity may be sufficient where climate and soil are peculiarly favorable.

On the *mode of application* † the following remarks

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* Literally, as much land as a man can plough in a morning; — about an English acre.

† It would not be proper to pass over this mode of preparation without some further notice.

If a glass rod moistened with muriatic acid be held an inch distant from the surface of a saucerful of Peruvian guano just taken from the bag in which it is imported, a white cloud will be immediately perceived. This is formed by the union of the ammonia rising up and evaporating from the guano with the fumes of the muriatic acid, rendering it manifest that ammonia escapes from guano very readily at the usual temperature of the atmosphere, — of course more abundantly in hot than in cold weather. Hence it is evident, that the exposure during the pounding and frequent sifting here recommended must be very injurious to the guano, and cause the loss of much of its most valuable ingredient.

It is much preferable to start the bags on the barn-yard floor, and, after spreading out the guano an inch thick, quickly to cover it with powdered charcoal or fine burnt bone-black, the refuse of sugar refineries, or with dry gypsum, or with clay which has been rendered friable by exposure to frost and then broken up and dried moderately, must be made. First, the guano must be *prepared.* This preparation is very simple, and consists in reducing it to a homogeneous, pulverulent mass, and mixing it with earth. The first is effected upon a barn-floor, by sifting and thrashing. The finer portion is first sifted off; then the remaining lumps and fragments of larger size are thrashed, and again sifted, until they are likewise converted into powder. The last portions of the residue are often so yielding and viscid, that they flatten upon being struck with the flail, and will not pass through the sieve. In this event they may be either beaten together with a brick or stone, by which means they are easily reduced to powder, or they may be added to the compost-heaps which are absent on no good farm. The sifted guano should now be mingled with from twice to three times the same quantity of earth, or with a mixture of earth and ashes, and the whole shovelled together, until a thorough and entirely uniform mixture is effected. The earth must possess the ordinary state of moisture, in which it easily absorbs the guano without forming into balls or lumps. It is a

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or with all these substances together; thus spread layer upon layer alternately, and finish by covering up with the empty bags, and putting over these a final coating of any of these absorbing substances. In this way the ammonia will suffer very little diminution, and the mixture will be sufficiently incorporated when taken on to the land, and ploughed or drilled in, without the labor and loss attendant on turning over. The small lumps may be left in without prejudice; the few large ones may be easily separated by hand, and broken afterwards. — J. E. T.

good plan to make the mixture at least from four to six days before it is scattered over the soil; and still better to undertake its preparation at a convenient time, before work presses on the farm, for it very often happens that farming labor is crowded into sowing-time, and the mixture of the guano with earth is then executed hastily and unsystematically, or perhaps not at all, the consequences of which are very injurious. If, however, the mixture is already at hand, these prejudicial consequences are avoided. The scattering in the field is best managed in the same way as that in which lime is usually put upon the land, or by spreading from a seed-bag. It is well to strew it upon the last ploughing some two or three days before introducing the seed, and then lightly harrow; on a light soil, to roll, and after this to harrow in the seed. Moist weather, during its application to the soil (especially in spring or summer sowing), exerts a very beneficial influence upon the action of guano.

The addition of earth is beneficial in a great variety of ways. Pure and good guano is so rich in ammoniacal salts, as easily to corrode the tender roots of plants, more particularly in dry weather; by mixing it with earth, it is so enveloped and weakened that this injurious effect is no longer to be feared. In this way, moreover, just as in the covering over muck-heaps with earth, the possible escape of aeriform manuring elements from the guano is cut off, since the porous earth has the property of absorbing and firmly holding these substances. Finally, by the addition of earth a more uniform distribution of the mass upon the land is rendered practicable, and the flying off of dust during dispersion prevented; — an inconvenience that otherwise is likely to occur, and may occasion inflammation of the eyes and other annoyances to the laborer.

With *potatoes*, *green crops*, *roots*, etc., a handful of the mingled earth and guano may be given to every plant in dibbling or planting. A little more than a quarter of an ounce of bird-manure, costing the fourth part of a farthing, serves in this way as an exclusive manuring for a plant. With other manures a third or fourth part of this quantity, whose value will not therefore exceed the twelfth or sixteenth of a farthing, causes a very marked increase of growth. Equally certain results are obtained if the mixture of earth and guano is scattered with as great uniformity as possible in the ridges in which potato sets are laid, or if, in case the guano should not at that moment be at hand, it is strewed over the surface of the field after the young plants have already sprouted up but may still be passed over with the harrow; — a mode of treatment that is confessedly of great advantage when the potatoes have attained the height of some four inches above the ground, and must soon be earthed up. *Garden produce* may be treated in either of these methods; for such plants, however, as also for *grass* and *meadow land*, watering with a solution of guano may be strongly recommended. For this purpose, one part of bird-manure should be treated with at least from 80 to 100 parts of water; since, if too strong, the solution of guano exerts a corrosive action upon young and tender plants.

For top-dressing, which should be employed, as circumstances may make advisable, in the autumn or early spring, guano is in like manner most judiciously employed when mixed with earth.

### 3. Tests for Guano.

As the previous analyses show, a guano may be *perfectly genuine and yet miserably bad;* how great, then, the liability to disappointment, when *intentional adulterations*, which render a good guano comparatively worthless and a bad guano still worse, are superadded! Under these circumstances, it cannot be too strenuously recommended to the farmer, that, *if he does not wish to spend his money uselessly, he should buy guano from such sources only as are known to be trustworthy, or after a previous chemical examination.* If he is not afraid of a little time and trouble, he can institute a trial for himself with very great facility. Tests are now possessed of such simplicity as to require in their application scarcely more dexterity and attention than in roasting or boiling coffee, and yet sufficiently accurate to serve in doubtful cases as a reliable means of information.

1. *Drying and subsequently Washing with Water.* If the guano, as is generally the case with those va-

rieties that are brought from Peru and Chili, is a smooth and uniform powder, weigh out two ounces, spread it upon paper, and let it lie for two days in a moderately warm place, in summer in a dry and airy situation, in winter in a warm room or chamber, in order that the air may dry it. What it may then have lost in weight must be esteemed mere surplus moisture. Many sorts of guano are so moist as to lose by this gentle drying from three to four drachms (20 to 24 per cent.) in their weight.

If the guano, as mostly happens in the Patagonian and African varieties, is not a smooth and uniform powder, then, in order to obtain a mixture as uniform as possible, before weighing off and drying a given quantity, the lumps, which have frequently an altogether different composition from that of the powdery portions, must be broken in pieces and pulverized. In like manner pains must be taken that stones, feathers, etc., when they are present, be equally distributed throughout the entire mass. Since these stones are often so firmly stuck over with the guano that they can only be separated with difficulty from the latter by scraping, it is advisable to pour hot water over a distinct portion in some convenient vessel, and to let it soften by standing for a night, upon which stones and sand will remain behind after agitation and washing with water.

2. *Combustion.* Pour half an ounce of the guano to be examined into an iron spoon, and place it upon red-hot coals until a white or grayish ash is left,

which must be weighed after cooling. *The less ash is left behind, the better is the guano.* The best sorts of Peruvian guano yield, from half an ounce, only one drachm of ashes (30 to 33 per cent.); whereas the inferior guanos that are now so often offered for sale (for example, Patagonian, African, Saldanha Bay, and Chili guanos) leave a residue of from 2½ to 3 drachms (60 to 80 per cent.), and those intentionally adulterated a still greater quantity of ashes. Of genuine bird-manure, the bad as well as the good, the ash is always *white* or *gray;* a yellow or reddish color indicates an adulteration with loam, sand, earth, etc.

*This test is very simple, and at the same time very reliable;* it rests upon the fact, that the azotized combinations existing in guano, and forming, as has been demonstrated in a preceding section, its most valuable ingredients, undergo combustion and volatilization when subjected to heat. Here, too, the difference of odor during the combustion is extremely characteristic. The vapors ascending from the better specimens have a pungent smell, like hartshorn, with a peculiar piquancy, almost like old Limburg cheese (decayed); whilst those rising from inferior varieties smell, on the other hand, like singed horn-shavings or hair.

The combustion may be undertaken on any hearth or in any parlor stove, if there is no objection in the latter case to the disagreeable odor which will be diffused throughout the room. A brick should be firmly thrust down into the fire, and the spoon laid upon it in such a way that the handle rests upon the brick and the hollow with the guano hangs free above the fire. A piece of cork should surround the extremity of the handle, in order that the hand may be protected when brought in contact with the heated spoon.

3. *Lime Test.* Pour a teaspoonful of each guano to be examined into a wineglass, and upon this a teaspoonful of slaked lime; then add a few teaspoonfuls of water and agitate the mixture briskly. Lime liberates the ammonia from the ammoniacal salts contained in the guano, in just the same manner as from rotten muck and putrid drainings (page 113), and it escapes; *the more excellent, therefore, a guano is, the stronger will be the pungent ammoniacal odor which escapes from this guano paste.* This test does not indeed possess the accuracy of the preceding, but is still in many cases very convenient on account of its simplicity, and more particularly where it is desirable to pass a general and approximate opinion upon the quality of different kinds of guano. Under present circumstances, especially, its utility appears the greater, because bird-manure of intermediate excellence is now of very infrequent occurrence, and commerce presents us for the most part with remarkably good or remarkably bad qualities, in examining which the lime test can be advantageously used, inasmuch as the difference in the strength and pungency of the odor is really so remarkable, that it

cannot evade the detection of the most unpractised sense of smell.

In order to be able to apply this test at any moment, it is judicious to keep a portion of slaked lime constantly on hand. But that this may not lose its effect, it must be carefully excluded from the air, and should, therefore, be preserved in dry and well-stopped bottles.

4. *Treatment with Hot Water.* Half an ounce of the air-dried guano is placed in a filter made of blotting-paper, folded together into the shape of a cone, and this put into a funnel or wire filter, and scalding water poured over it until the water runs without color. If the paper with the moist guano is laid, when no more liquid drops from it, in a warm place, and the residue weighed when it has become completely dry, the deficiency from its original weight will show the weight of those elements which have been dissolved by the water. As a general rule it may be held, *the larger the quantity of a guano that is dissolved in water, the more ammoniacal salts does it contain, and the better it is.* Hence that guano must be preferred, as in the test by combustion, which, upon being so treated with water, leaves behind the smallest residue. In the best or Peruvian guanos the residue from half an ounce that is insoluble in water amounts to about 2 drachms (from 50 to 55 per cent.); on the other hand, in the comparatively worthless guanos from 3 to 3½ drachms (80 to 90 per cent).

Exceptions to this rule may, however, occur, when a guano contains many soluble mineral salts. Specimens have been met with in commerce, which consisted to the extent of one half or two thirds of sea-salt and Glauber salt; such guanos, upon being treated with hot water, would only leave a residue of from one to two drachms of insoluble substances, yet must, nevertheless, be regarded as any thing but good merchandise. In such a case most complete security is afforded against an erroneous decision by the use of the combustion test described above (p. 193); for then it would be found that a guano of the kind in question yields three drachms and more of ashes, and must accordingly be admitted as an inferior variety.

5. *Vinegar Test.* Pour strong vinegar over the guano to be examined, or, better still, some muriatic acid; if a strong effervescence ensues, an intentional adulteration of the guano with *lime* may be inferred. This substance may also be recognized by the combustion test, since lime remains behind in combustion and augments the quantity of ashes.

On the best sources for obtaining guano little positive information can be given, since bad and good varieties may both be carried everywhere alike, and since admixtures and adulterations may be made in every place. Good Peruvian guano can only come to Europe through a single English firm (Gibbs, Bright, and Company, London), who have concluded a contract with the Peruvian government which gives them the exclusive sale of this guano.*

Whoever may desire to obtain more precise information upon this important manure and the results it has produced in Saxony, will find it given in the little work entitled *Guanobüchlein*, which contains instructions for the use of German farmers upon the constituents, action, tests, and employment of bird-manure, written by A. Stöckhardt, Leipzig, and published by George Wigand, 1851.

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## IX. BONES.

Complaints are often heard, that, by the consumption of English cotton fabrics in Germany, thousands of English laborers are supported by German money. Germany has done far more; for nearly half a century it has given grain to English laborers by the exportation of German manure, German bones, and German oil-cake. According to trustworthy information, the produce of English fields since the importation of bones and oil-cake has been doubled. The revivifying power which has been lost to our

* The agent of the Peruvian government in New York is E. Riley, and in Boston, C. L. Bartlett. There are, however, respectable seed-stores in the chief cities of the United States, where guano may be purchased without risk of its being adulterated. — J. E. T.

father-land by this exportation of manures would assuredly have been preserved to it, if during this period the importance to agriculture of the constituents contained in bones and oil-cake had been clearly understood in Germany. This is the triumph of intelligence, that it makes powers serviceable which remain neglected and useless where intelligence is wanting.

That German bones exert a vigorous manuring influence upon German soil can no longer be doubted; for the results of practical experiment are now before us to a sufficient extent to convince every one who is open to conviction. Manuring with bone-dust has become general over all parts of Saxony during the last fifteen or twenty years, that is, after the produce obtained by its employment in Upper Lusatia had shown its extraordinary utility. How important an extension of this mode of fertilizing land has obtained in this part of Saxony more particularly, is revealed to us by the fact, that the first bone-mill constructed there by an intelligent farmer ground a total of 600 cwt. during 1837, but in the year 1848 some 15,000 cwt.; as also by the additional consideration, that in the last-mentioned year, in this province alone, some 50,000 or 60,000 cwt. besides were prepared and sold, yet without satisfying all demands.

The total quantity of bones which are to be obtained from the animals annually slaughtered in Saxony amounts, on an approximative calculation, to

100,000 cwt., and half this quantity, if not still more, is imported from the immediately adjacent countries. If, on a moderate assumption, the total produce which is gained from 1 cwt. of bone-dust is estimated at 2 Saxon bushels of rye, the quantity of this substance that is yearly consumed in Saxony leads to an increased yield of 300,000 bushels of rye.

## 1. Constituents and Operation of Bone-dust.

Bones consist of an earthy tissue of fine cells, in which an organic substance called gelatine is inclosed. The gelatine contains a great abundance of nitrogen, and readily putrefies when moistened with water and left standing in the air; in this way the nitrogen becomes fit for the nourishment of plants, and causes an extremely rapid and vigorous vegetation, as may be readily perceived by pouring glue-water or animal broth upon any flower. *The forcing power* which *finely powdered* bone-dust exercises upon vegetable growth *is owing to the gelatine it contains.* Gelatine does not take on the putrefactive process when air and moisture are excluded.

The earthy constituents of bones are composed principally of *phosphate of lime*, which in like manner exerts an exceedingly beneficial influence upon the growth of plants, and in especial is very favorable to the *development and formation of the seed.* Hence the *abundant produce of healthy grain* after dressing with bone-dust. Besides this substance, bones contain carbonate of lime, and also, for the most part, some fat. Both these substances, however, may be disregarded in forming a decision upon the manuring properties of bones.

Whoever desires a more precise acquaintance with the constituents of bones may institute the following simple experiments.

1. Place a beef-bone, previously dried and weighed, in a stove-fire, and take it out again when it has completely recovered its white color, which in heating at first passes into black; the gelatine burns up, the bone-earth, on the contrary, remains behind. The bone thus *burnt to whiteness*, and now a third part lighter than at first, consists of about nine tenths phosphate of lime and one tenth carbonate of lime. This proportion between gelatine ($\frac{1}{3}$) and bone-earth ($\frac{2}{3}$) is, however, not unchangeable, but varies in different animals, and indeed even in one and the same animal, according to its age and the nature of the bones.

2. Place a bone in a glass or stone vessel, and pour over it some diluted muriatic acid; the bone will by degrees become soft and transparent, and finally pass into a cartilaginous, semi-transparent mass. The muriatic acid dissolves the bone-earth, and the gelatine remains behind, since it is as insoluble in muriatic acid as in water. If the gelatine is withdrawn from the acid and boiled, after a previous washing with water, it is transformed into glue, and a solution is obtained that coagulates on cooling. If the muriatic acid, when poured off, is mixed with

ammonia (hartshorn), the dissolved phosphate of lime falls to the bottom as a white powder.

3. If a bone is heated for some hours in a crucible, which is well covered with a piece of tile, it assumes a black color, and is changed into *bone-coal* (bone-black, ivory-black). As the air, in this case, has no access to the bone, only an imperfect combustion, or a charring of the gelatine, ensues, and the carbon (coal) remains behind, mixed with the bone-earth, which is not volatilized by the fire. In two ounces of bone-black so prepared, only half to three quarters of a drachm of coal is obtained; but this, on account of its minute state of subdivision, possesses such a strongly purifying and bleaching power, as to be employed in sugar refineries for the purpose of depriving brown sugar of its color. This coal, after having performed service as a means of purifying sugar, is used also as a manure, under the name of *sugar refuse.*

4. In the preceding experiment the constituents of the gelatine are converted by the heat into gases, which are distinguished by a very disagreeable odor, and escape. To observe this more plainly, fill the bowl of a common clay tobacco-pipe three quarters full of chipped bone, close the remaining space with stifly-kneaded clay, and place the bowl with its contents in glowing coals. The vapors escaping from the extremity of the pipe-stem may be ignited, for they contain illuminating-gas; they possess, moreover, a pungent odor, and quickly turn a strip of red

litmus-paper to a distinct blue color, for they are very rich in carbonate of ammonia. *The heating when air is excluded causes the same change as putrefaction;* that is, it converts the nitrogen of the gelatine contained in the bone into ammonia. Should it be desired to condense the vapors by cooling, and to mix the ammoniacal solution so obtained with the bone-black left behind, a mixture might be exhibited which acts in the same way as *putrefied* manure or guano, and is of very rapid operation; whereas, fresh bones act like unputrefied manure, and more slowly in the mass, when they are coarsely broken or imperfectly pulverized.

The following analyses of several kinds of bone-dust employed in Saxony disclose the chemical composition of this material as it is found in commerce.

| Constituents. | 1. Bone-dust very Pure and Dry. | 2. Bone-dust from Butcher's Bones. | 3. Bone-dust from the Bone-gatherer. | 4. Butcher's Bones with Sinews. |
|---|---|---|---|---|
| Water, . . . . . | 5 | 11 | 14 | 9 lbs. |
| Combustible substances, . | 33 | 34 | 28 | 49 " |
| Nitrogen therein, . . | 5 | 4½ | 4 | 6½ " |
| Phosphoric acid earths, . | 53 | 47 | 50 | 36 " |
| Carbonate of lime, . . | 8 | 7 | 6½ | 5 " |
| Sand, earth, etc., . . | 1 | 1 | 1½ | 1 " |
| Approximate value of 100 lbs. | 9*s.* | 7*s.* 10*d.* | 7*s.* 4*d.* | 9*s.* |

In consequence of the great demand in Saxony during the last few years, the market-price has considerably advanced, and may be assumed to average at present 9*s.* per cwt., whilst formerly the highest quotation was 6*s.* 9*d.* Should it still increase, the value given at page 168 for phosphate of lime must be raised, since no other cheap source for procuring this body is at present open to the German agriculturist.

Bone-dust, when mixed with lime, sand, pit-coal ashes, etc., contains of course a less proportion of manuring constituents, and falls in value at a rate proportioned to the increased quantity of these inoperative substances. Some specimens I have examined consisted of from one fourth to one half, nay, in one case, of three fourths, pit-coal ashes, earth, and sand.

As has been already mentioned, *the action of bone-dust* as a manure depends chiefly upon the gelatine (nitrogen) and bone-earth (phosphate of lime) which it contains. In respect of its more important or principal constituents, it approximates somewhat closely to the *solid* excrements of animals and straw, but is, however, far richer in them, as the following table will show.

| Constituents. | 1000 lbs. of Bone-dust. | 1000 lbs. of the Fresh Excrements of Cows and Horses. | 1000 lbs. of Dry Straw. |
|---|---|---|---|
| Nitrogen, . . . . | 50 | 4 | 4 lbs. |
| Phosphoric acid, . | 240 | 3 | 2 " |
| Lime, . . . . . | 330 | 4 | 4 " |

Bone-dust contains, therefore, about 12 times more forcing elements, and from 80 to 100 times more seed or grain-forming ingredients, than straw or the fæces of animals.

Compared with good and bad guano, we find the following differences:—

| Constituents. | 1000 lbs. of Bone-dust. | 1000 lbs. of Good Guano. | 1000 lbs. of Bad Guano. |
|---|---|---|---|
| Nitrogen, . . . | 50 | 130 | 10 – 15 lbs. |
| Phosphoric acid, . | 240 | 120 | 240 – 380 " |
| Lime, . . . . | 330 | 120 | 250 – 400 " |

Whilst, therefore, bone-dust is 2½ times poorer in forcing substances than good guano, it possesses, on the other hand, double the quantity of those ingredients which form the seed or grain; and whilst it is from 3 to 4 times richer in nitrogen than bad guano, it is in turn greatly surpassed by the large amount of phosphate of lime that is present in the latter.

From the results of practical experience in Saxony, it may be assumed that the *entire* effect produced by 1 cwt. of bone-dust is equal to that of from 25 to 30 cwt. of stable-muck, and that from 2 to 2½ cwt. are necessary to develop the full effect of 1 cwt. of Peruvian guano. Accordingly, 1 cwt. of bone-dust would be able to produce at least 2 or 2½ Saxon bushels (320 to 400 lbs.) of rye grain, besides a corresponding quantity of straw. On soils which are not too binding, the action of *finely levigated* bone-dust may, on an approximative calculation, be so distributed as to amount, in effect, in the first and second years, to from 25 to 30 per cent.; in the third, to from 20 to 25; and in the fourth, to from 10 to 15. When coarsely powdered, the percentage is of course diminished, since the operation is extended over a longer series of years. As respects the *kind of crop*, bone-dust has been found just as good a dressing for straw and oil-bearing produce as for potatoes, etc.

In addition to the greater or less pulverization, various circumstances connected with the nature of the soil and the weather exercise a very marked influence upon the action of bones, as will be discussed in the course of the following section.

## 2. Application of Bones.

1. *Bone-dust.* Here it must be held as a first principle, that *such sorts only as are finely comminuted and powdered are to be employed.* Hence the farmer places himself in a better position by paying 9*d.* or 1*s.* more for a finely pulverized article, than by purchasing a coarsely broken sort at a lower price. If bones are introduced in the latter state into the earth, the small and exposed portions of gelatine upon their outer surfaces pass, it is true, into putrefaction, in so far as air and water can operate upon them; not so, however, the gelatine situated in their interior, because, from its being surrounded with bone-earth, which is nearly insoluble in water, it is protected against the penetration of moisture, and cannot, consequently, take on the putrefactive process. Ten, twenty, and more years may pass away

before fragments of bone, whose size may not exceed that of a pea or hazel-nut, and which are very frequently met with in the bone-dust of the shops, are completely disintegrated in the earth.

In Voigtland, near Oelsnitz, in Upper Saxony, a quantity of bones of the elephant and rhinoceros, and, indeed, entire skeletons of such animals, were lately discovered at the bottom of a clay-pit. They must have lain there a very great length of time, for the "oldest inhabitants" of that region cannot remember to have ever noticed the elephant or rhinoceros upon the plains existing in their neighborhood; and, according to the opinion of geologists, many thousands of years may have passed away since the primitive possessors of these bones were buried in the earth. Nevertheless, even these bones contain gelatine, so that antediluvian broth or old-world glue might be prepared from them; for upon being heated they became black, and diffused the same ammoniacal and empyreumatic odor as fresh bones. One specimen yielded, upon a chemical analysis, $2\frac{1}{4}$ per cent. of nitrogen, which answers to about 14 per cent. of gelatine. Had the bones of remote antiquity the same composition as those of the present day, the bones in question retain nearly the half of their original quantity of gelatine or nitrogen.

Hence it may be seen how slowly the decomposition of bones takes place in the ground, and more particularly in clayey and loamy soils. We can, therefore, no longer be surprised that no action whatever is perceived from coarsely levigated bones, while bone-dust finely powdered operates energetically. During the putrefaction of the gelatine, the bone-earth also becomes gradually soluble and fit for the nourishment of plants; the more rapid, therefore, the progress of decomposition in the earth, the sooner do *both* these constituents — the organic as well as the inorganic — develop their activity, and the more will their principal operation take effect during the first and second years, — an advantage that will be duly appreciated by the farmer.

From these facts, the result of many practical experiments in Saxony — *that bone-dust on soils of moderately binding quality, and when used for autumn sowing, is of far more certain and advantageous action than upon very heavy or very light lands, and when used for summer crops* — receives an obvious explanation. In very binding and damp soils, air is wanting, in very loose land, water; both these elements, air and water, must be present, if the decomposition and dissolution of this manuring agent are not to stand still. There are districts in Saxony where bone-dust produces no observable effect whatever, while guano works excellently, and where, indeed, the former, even when dissolved by sulphuric acid, shows no trace of operation till the second or third year. Whether, in addition to the physical condition of the soil, its chemical constitution also contributes to bring about this result, can only be decided by continued practical experiments, in conjunction with chemical investigation. If bone-dust is put on to the soil in autumn, the moisture of winter exerts a preparatory action, by which its dissolution is promoted, whilst by its application in the spring, and more particularly in dry weather, it may be inactive in the ground through the whole period of summer. For this reason, much larger quantities than those above specified, and more upon a heavy than upon a light soil, are always necessary; for this reason, also, care must be taken not to bury bones too deeply in the earth. Saxon farmers employ, as a complete dressing, from 8 to 20 cwt. of bone-dust per Saxon acre (about 2 English acres); smaller quantities only upon remarkably favorable soils, or in connection with some other manures. For top and after dressing it is of course unsuitable, except, perhaps, when dissolved, or in a state of incipient putrefaction.

It is certainly most advantageous to employ bone-dust, like all subsidiary manures, not as an exclusive manure, but in combination with stable-muck, whereby the latter is so strengthened, that one load now accomplishes as much as two without this addition. In a chemical point of view, this method of proceeding claims to be designated as the most rational and preferable, since it leads to a completeness and equalization of the ingredients, imparting to the mixture a higher value, and especially a more certain operation, than by adding each of these manuring agents to the land separately. For complete vigorous action, stall-manure lacks nitrogen, which it acquires by the addition of bone-dust, guano, or rape-cake; in bone-dust and guano, the alkaline salts are wanting, and these are given to them by the admixture of stable-muck, drainings, ashes, etc. Bone-dust and rape-meal must pass into decay before they can exercise a fertilizing action on the soil; but if drainings or some guano are added to these substances, they will provide the plants with nourishment until more is placed at their disposal from the bone or oil-cake. The same result is secured, if they are previously brought into a state of progressive fermentation or putrefaction, or are united with substances already putrefying (for example, with stable-manure or drainings), which operate contagiously, and effect a quicker decomposition.

A previous fermentation (incipient putrefaction) of bone-dust, by suffering it to lie in heaps, which are moistened with water or drainings, cannot, accordingly, be altogether rejected, as is so frequently the case. Even if it is granted that some proportion of the ammoniacal manuring substances so generated escape into the atmosphere, it may still be a question, whether the advantage which the farmer gains thereby, in making his manure more rapidly and certainly efficacious, and in procuring in this way a quicker return of capital, is not greater than the loss which he sustains by the volatilization of some portion of the elements in question. Let the farmer, in adopting this course, only make use of the means for fixing and combining the ammoniacal vapors that have repeatedly been mentioned; let him sprinkle the bone-dust, when it emits an odor, with some diluted sulphuric acid, and he can then avoid the loss without renouncing the advantage of this spontaneous fermentation. One pound of sulphuric acid, mixed with ten to fifteen pints of water, will generally suffice to deprive a hundred weight or more of bone-dust of the pungent odor of ammonia.

2. *Bone-dust treated with Sulphuric Acid.* Another method of making bones *quickly efficacious* has caused, in England more especially, a very great sensation, and attained to a very general use. I allude to what is termed the dissolution of bones in sulphuric acid, the pecuniary advantages of which have been already mentioned, at page 68.

If finely pulverized bones are allowed to stand for a few days in contact with sulphuric acid, they are converted into a white curd or paste; inasmuch as the lime of the bone-earth combines with the acid to form gypsum (sulphate of lime), which opposes no further impediment to the decay of the gelatine in the earth. This *dissolution* or *breaking up of the structure of bones* is frequently denominated a solution or dissolving of them; and this may constitute the reason of the belief which many entertain, that this admixture must be of a thin or watery character, and translucent, as also of their apprehension that the process has miscarried, if this supposed watery solution is not perceived. Such an assumption is erroneous, because the newly-formed gypsum remains as a fine powder in the mass, and makes it thick and pappy. To ascertain whether the intended softening of the bones is attained or not, rub a portion of the paste between the fingers, whereby hard grains, be they ever so few, will be detected, or wash the pap upon a fine tin colander, by which means, in like manner, hard grits, if existing only in small quantity, will be left behind. When, on the other hand, *muriatic acid* is employed in dissolving bones, a real and complete solution of the bone-earth is obtained.

By this treatment the two most important constituents of bones, gelatine (rich in nitrogen) and phosphoric acid, are reduced to a form so readily capable of dissolution and decay, that their operation may now be regarded as most vigorous in the first year. The dried mass, frequently mixed with earthy substances, and met with under the name of *sulphate of bones*, or *superphosphate of lime*, forms, at the present day, one of the artificial manures in greatest request in England, more particularly for the culture of turnips and other roots, and is there prepared, as an article of manufacture, in large establishments.

From many experiments which I have instituted, for the purpose of being enabled to recommend to farmers a simple mode of treating bones with sulphuric acid, that may be carried out on any farm, thus much first of all may be advanced, — *that a satisfactory result is to be attained only with finely com-*

*minuted, not with coarsely broken bones.* Manifold precepts have, indeed, been given for dissolving the latter also with sulphuric acid, and but a short time since one of these prescribed methods was designated as "very practical" by an English agriculturist, in accordance with which the bones should be broken into pieces of the size of half an inch, and half their weight of sulphuric acid then poured over them. All these instructions, whether more or less strong or diluted sulphuric acid be employed, lead only to a very unsatisfactory result; inasmuch as scarcely one fourth, or as a maximum one third, of the mass of bones is dissolved, the residue remaining behind in the form of solid and unaltered fragments. Bones prepared in this manner exert, moreover, a highly corrosive influence upon plants, because a part of the sulphuric acid continues uncombined.

In agricultural establishments the following method for the preparation of bones will be, perhaps, the simplest. Form from a mixture of sifted ashes (wood, pit-coal, brown-coal ashes, etc.) and earth, thrown upon a barn-floor, a mound of circular shape, whose interior is a pit capable of containing one hundredweight of bone-dust, and whose outer walls have been made by being trodden or flattened strongly with a shovel, so firm as not to yield in the subsequent stirring or turning over of the bones. Let the finer part of the bone-dust be previously sifted off, and placed aside. Pour what remains into the cavity, and sprinkle it, during continued stirring with a shovel, with three quarts of water by means of a watering-pot, until the whole is uniformly moistened; add gradually eleven pounds of English sulphuric acid, the agitation with the shovel being continued. A brisk effervescence of the mass will ensue, which will not, however, rise above the margin of the pit, if the acid is poured on in separate small quantities. After twenty-four hours, sprinkle again with three quarts of water; add the same quantity of sulphuric acid as before, with the same brisk shovelling of the mass, and leave the substances so brought into contact to act for another twenty-four hours upon each other. Afterwards intermix the finely powdered bone-dust previously sifted off, and, finally, shovel the ashes and earth of the pit into the resolved bones, until they are thoroughly and uniformly mixed together.

In this way a friable powder is obtained, which, if it is not mixed with stable-muck, can be easily and uniformly scattered on the field with the hand, or by means of a wooden shovel.

The quantity of sulphuric acid above prescribed (22 lbs. to 1 cwt. of bone-dust) is, indeed, considerably less than that employed in England, where from one third to one half the weight is added to the bone-dust; but I hold that it is in every way more prudent to employ too little than too much sulphuric acid; since in the former case, if the bone-dust is impure, or of too coarse quality, or, again, if the preparation is not perfectly well executed, less danger is incurred of obtaining a corrosive product. It will suffice, if but a part of the bone is dissolved.

Nevertheless, the operation above described is one, that, abstractedly considered, and on account of the destructive nature of sulphuric acid, requires great care and attention, and for this reason will not be within the reach of every farmer. It is, therefore, to be desired, that amongst us also, as in England, the preparation might be manufactured on a large scale, in chemical works, where, by the application of heat, a more complete dissolution of the bones may be accomplished. I have no doubt that it would meet with a very favorable reception in Germany, if it were supplied of undoubted quality and at a moderate price.*

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* Since the introduction of superphosphate of lime as a manure, Professor James J. Mapes, editor of the "Working Farmer," has invented an article which is in great demand, and is sold under the name of "Improved Phosphate of Lime."

The inventor found, after repeated trials, that Peruvian guano might be materially improved by the carbonate of ammonia being changed to a sulphate, and by increasing the quantities of ammonia, sulphuric acid, and superphosphate of lime. He therefore, in this new article, combines 100 lbs. of bone-dust with 56 lbs. of sulphuric acid, 36 lbs. of Peruvian guano, and 20 lbs. of sulphate of ammonia.

This compound, owing to the excess of sulphuric acid, contains no free carbonate of ammonia. Indeed, all the volatile salts, being changed into sulphates, are no longer volatile; they will therefore last in the soil until used up by plants. Unlike guano, it does not injure the roots of plants by immediate contact, and being slowly soluble, it is supplied as rapidly as required by them.

Many hundred tons of this material have been sold during the past

3. *Bone-dust from Steamed Bones.* In Saxony this preparation is known by the name of *Strehla bone-dust*, and, on account of its more rapid operation on the soil, is in very general request. It is obtained from the chemical manufactory at Strehla on the Elbe, where it is made from bones which have previously lost part of their organic elements in the manufacture of glue.

For this purpose bones are treated with steam at a great tension, which completely penetrates them, and renders soluble a part of the gelatine contained in their interior. After this treatment they are so soft as to be easily bent and compressible, but when cold again become hard and brittle as before, so that they can now be much more readily and completely

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year, and many thousand tons are now in preparation, for sale in the spring.

The method adopted by Professor Mapes for ascertaining the requisite amendments for increasing the economy of guano, was the following. Strips of ground were dressed with variable quantities of guano, and these strips were crossed by dressings of superphosphate of lime, sulphuric acid, sulphate of ammonia, and of each of the other constituents of guano. An accurate map was made of this plot of ground; its squares, like those of a checkerboard, could easily be traced on this map, and the accurate quantities of Peruvian guano, as well as of each other constituent, could be ascertained. The plot of ground was then planted with a crop, and those squares containing the previously mentioned preparation were found to produce the largest yield.

Professor Mapes has used this manure exclusively for five years, end during the last year he succeeded in causing some capitalists to establish a manufactory on a large scale, for the purpose of supplying it to the farmers at a cost materially less than it can be manufactured in small quantities. This establishment is located at Newark, N. J.

pulverized than in their natural condition. They are ground into a powder, which is in part impalpable, and are brought in this form into the market as a manure.

*Composition of Strehla Bone-dust.*

| | |
|---|---|
| Water, . . . . . . . . . | 10.0 |
| Organic substances, . . . . . . | 20.2 |
| Bone-earth (61.5 phosphoric acid earths, and 8.3 carbonic acid, both combined with lime), . . . . . . . . . | 69.8 |
| | 100.0 |
| Contents of nitrogen, . . . . . | 2.3 |
| Present market price, . . . . . | 7*s*. 2*d*. |

A theorist will be forthwith prepared to pronounce this judgment respecting the worth of this bone-meal: "It is less valuable than the powder prepared from crude bone, because a great part of its organic elements (nearly the half), and consequently of its nitrogen, has been withdrawn." But the practical farmer is also ready with his opinion, and this, based upon an experience of a several years' trial, is of the following tenor: "Steamed bone-dust is of more prompt and vigorous operation than crude, although not quite as persistent in its effect upon the land, and is for this reason more valuable to the farmer than the latter." *Little and quick* accomplish here, as so often in other things, just as much as *much and slow*, and even more. In consequence of these favorable practical results, farmers in Saxony prefer to buy it, although at a somewhat higher price than that given for ordinary bone-dust, and the manufactory at Strehla has received for many years past more applications than it could satisfy.

That practical experience is right, follows as a matter of course, and it now remains for science to disclose the reason of this unexpected operation. I believe it to be this. In crude bone every individual particle of gelatine is surrounded with an almost impenetrable covering of bone-earth, that prevents the insinuation of water and air, more particularly as the fat, with which bones are interpenetrated, offers resistance to water; hence putrefaction, especially in coarser fragments, can only advance by extremely slow stages from the exterior to the interior of bones. By treating bones with steam at a high pressure, which thoroughly penetrates their tissue, the fat and a part of the gelatine is extracted, and their mass now becomes so porous, that the moisture of the earth can force its way into the interior, and cause the putrefaction of the gelatine that is situated there. The dissolution of the bone-earth now goes on in close accompaniment with the putrid decomposition of the organic matter. Over and above this, more rapid solubility is promoted by the very minute state of subdivision, since the Strehla bone-dust is very much more finely levigated than the best specimens of other varieties that are met with in commerce.

The steaming of bones has recently attracted the attention of farmers in England, and the Highland Agricultural Society of Scotland now publicly recommends this method as of all others the best for finely pulverizing bones. Theoretical objections are still urged against this mode of procedure, but its superiority may be corroborated and justified in Scotland, as in Saxony, by the results of practical experience.

4. *Bone burnt to Whiteness, Bone-black, and Sugar-Refuse.* Wherever these substances can be procured at moderate prices, they may indeed be employed as valuable manuring agents; but in using the two former it must always be kept in view that they *no longer contain gelatine and nitrogen*, and can accordingly exercise a forcing action on the soil only when conjoined with azotized manures (guano, rape-dust, drainings, etc.). Their two principal constituents are *phosphoric acid* and *lime*, two substances, therefore, that are of great importance to plants in the formation of their seed. They can, however, develop their seed-forming power only when the plants to which they are applied are supplied at the same time with substances that form their strictly vegetable parts, and more particularly with such as contain nitrogen or ammonia; inasmuch as plants must vigorously put forth stem, leaves, etc., before they can produce good and plentiful seeds. Individual instances may, indeed, be found, which show that bones burnt to whiteness and bone-black alone have brought forth a very vigorous vegetable growth; but it is more than

probable that in these cases the soil was already sufficiently provided with azotized substances, and, on the other hand, labored under a deficiency of phosphoric acid or lime. The latter, moreover, act beneficially upon what are termed the mineral ingredients, inasmuch as they render soluble such of these as by themselves are wholly insoluble. An attempt has been made in England to make burnt bones soluble, in the same way as bone-dust, by means of sulphuric acid; and this mass, when mixed with ammoniacal salts, furnishes an excellent substitute for bird-manure, which, under the name of *artificial guano*, has already met with very extensive application.

*Sugar-refuse* is a bone-coal that has served in sugar-refineries to deprive brown sirup of its color. It sometimes contains azotized substances in but small quantity, when only the albuminous constituents of the sugar have been left behind in it; and again in very large amount, when blood has been simultaneously made use of in the process of refining. A sugar-refuse of the last description, containing 8 to 10 per cent. of nitrogen, now brings in France far higher prices as a manure than fresh bone-black. Several specimens examined in Saxony contained only 1½ to 2 per cent. of azote, and produced no considerable effect on the land. As a means has now been discovered, in manufacturing sugar, by which the bone-black already used can be revivified, that is, made fit for renewed employment, whereby it acquires a higher pecuniary value than could be obtained from its sale as a manure, it will seldom happen that farmers can enjoy an opportunity of applying it extensively to the cultivation of the soil. Wherever it is offered in the market, certain and reliable information as to its nature and quality ought always to be sought from a chemical examination.*

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* There are two kinds of sugar-refuse: — 1st. Bone-black, which, after many times reburning, has at length lost so much of its power of decoloring brown sugar, that its use is no longer economical to the sugar-refiner. This is partly in a fine granular and partly in a powdery state, but dry. It may be here remarked, that, theoretically, fire exerts no action on, or rather produces no change in, phosphate of lime; therefore this ingredient of bones, however often passed through the bone-burner's retort, remains essentially, and to all purposes, the same phosphate of lime as that originally found in the raw bone. Consequently it is as good for the manufacture of superphosphate of lime as ever, although in practice the acid in sugar acts on a small portion of the phosphate or carbonate, causing some loss.

Besides the phosphate of lime, however, a portion of this dry sugar-refuse consists of the 33 per cent. organic matter of the table on the next page, carbonized, — of itself then a valuable addition to the substance, as it is a powerful absorbent of ammonia. This ingredient in burning suffers also some diminution.

This dry refuse, particularly the fine powdery part, therefore, is a highly beneficial ingredient of the compost-heap. I have found great benefit from spreading it alone on a sandy, light-colored soil, although I much prefer adding it with other ingredients to the compost.

2d. The sugar-refiner's *Scum*. This is fine bone-black mixed with all the impurities separated from the sugar during its clarification, and contains the greater part of the substances used in clarifying sugar. It is in a pasty, sticky, or hard-compressed state. When this is in heaps it begins to ferment, and produces a burning heat with injurious acids, and a considerable quantity of sulphuretted hydrogen gas escapes. In this state it is very hurtful to vegetation; trees, and other vegetation, have been completely destroyed by it. Under proper management it is, however, very valuable in agriculture, and the

Respecting the quantitative composition of these preparations, the following analyses will furnish information. On an approximative calculation 100 lbs contained: —

| Constituents. | Of Bones burnt to Whiteness | Of Bone-black. | O Sugar-Refuse (used in Saxony). |
|---|---|---|---|
| Water, . . . . | — | — | 8 lbs. |
| Organic substances, . | — | — | 33 " |
| Nitrogen therein, . . | — | — | 2 " |
| Phosphoric acid earths, | 85 | 76 | 44 " |
| Carbonate of lime, etc., . | 15 | 14 | 13 " |
| Carbon, . . . | — | 10 | — " |

## 3. Tests for Bone-dust.

The testing of bone-dust is far more simple than that of guano, as in very many cases the eye alone is sufficient to detect foreign intermixtures, more par-

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extreme fineness of its particles renders it very forcing and quickly available.

The method adopted and recommended by the writer is to spread it as thinly as its sticky nature will allow on the surface of an inclined piece of ground, in the autumn, so that it may be thoroughly exposed to the winter rain and snow. If stirred up frequently, all these injurious matters will be washed out, which can be easily ascertained by the facility with which it crumbles to powder. It will then be a very valuable addition to the compost-heap, and will probably have absorbed some ammonia from the rain and snow with which it has been in contact.

Both these substances may be purchased at all sugar-refineries, and will no doubt be enhanced in price, as experience proves their value. I have found a mixture of both of them with guano extremely efficient, particularly the latter, when well washed and dry; it acts the part of an absorbent of the ammonia of the guano, and adds thereto the valuable ingredient of phosphate of lime in its finest state of pulverization. — J. E. T.

ticularly when, as, unfortunately, still frequently occurs, the bone-dust consists principally of coarse pieces. The additions contained in this article, as it is to be procured in the market, are composed mainly of *lime*. This substance is usually intermixed during the comminution of the bones, especially when they are fresh, because, in consequence of their abundant contents of water and fat, they are greasy, and without the addition of some dry, pulverulent body, which is capable of absorbing the water and fat, they are not easily beaten to a powder, but ball together into a moist, dough-like mass. That the bone-dust is thus greatly lessened in value is obvious; inasmuch as two additions concur to deteriorate the excellence of the manufactured product: — first, the water contained in fresh bones, and, second, the lime, which by its powerful affinity for water enters into firm combination with it, and makes it, as it were, fixed. Fresh cylindrical or hollow bones contain from 3 to 7 per cent., and fresh flat bones from 12 to 20 per cent. of water. If, then, it be assumed that the average contents of water in a mass of fresh bones about to be converted into powder amount to 12 per cent., and the lime employed to take this into combination to 8 per cent., it follows that, in powder so obtained, 20 per cent. of heterogeneous and inefficacious substances are present; — that it is, therefore, one fifth less valuable than that which is prepared from dry bones, without any addition of lime.

It is, doubtless, exceedingly desirable that bone-dust should be brought into the market free from all admixture with lime; but this will, in all probability, remain an orthodox, but empty wish, inasmuch as the incessant striving of competition to produce cheaper and still cheaper imposes restrictions on the stability and uniformity of commercial operations. Under these circumstances, no other alternative remains to the farmer, if he would be protected against overcharges and imposture, than that of subjecting the powder to a previous scrutiny. For this object the following methods of making the examination are here proposed.

1. *Test by Drying and Washing.* Put the specimen to be tested into a dish, pouring over it enough water to convert it into a paste, and rub it perseveringly between the fingers, whilst a further quantity of water is gradually added, until the powdery parts are separated from the coarser pieces. Let the whole now stand undisturbed for a few seconds, and then pour the superincumbent cloudy water into a glass, to which water is added afresh, that, after renewed stirring and cessation, must again be poured off. This washing and separation of the powdery parts is to be repeated until the water is no longer noticeably turbid. The residue of the bone-dust thus washed off should then be spread out upon a sheet of white printing-paper; a close examination of it will reveal whether, and in about what quantity, heterogenous substances, such as limestone, sand,

etc., are present. Should entirely dissimilar bodies of strikingly different color (for example, pit-coal ashes, small pieces of brick, etc.), which have been whitened externally by powdering over with lime, have been intermixed for a fraudulent end in the specimen under examination, they will be detected at a glance. If the turbid fluids procured by the attrition of the bone-dust are allowed to stand for a short time free from all agitation, the powdery parts will be deposited at the bottom of the glass, and may in like manner be collected upon paper and an opinion arrived at respecting their quantity. Whatever proportion of this sediment is dissolved by strong vinegar is to be regarded as an admixture of lime. Any addition of clay or loam would be recognized at once by its appearance, and by the capability of kneading the partially dried precipitate. The quantity of *water* in powdered bones is ascertained by leaving a portion, which has been previously weighed, in some warm situation, and again weighing when dry.

2. *Test by Acids.* Pour one pint of strong vinegar over two ounces of bone-dust in a sufficiently roomy crucible, and place it for half an hour in a warm place; if there is any adulteration of lime, a remarkably brisk effervescence will ensue, and the lime will be dissolved. Let the whole be then poured upon a piece of fine linen stretched over another vessel, and rinse the vessel and the linen strainer a few times with water. Upon this, place the strainer with

the residue left thereon in some warm situation, to dry, and when completely dried, rub off and weigh the dry mass. The loss of weight will declare how much lime and water were present in the bone-dust. A good and dry specimen will lose by this treatment one drachm at the most.

Should the powder, after the vinegar has been poured off, begin again to effervesce when fresh vinegar is added, it must then be made warm and treated for the second time with a fresh quantity of vinegar. Any admixture of earth, sand, etc. will be easily perceived by the eye in the residue (in the event of its being necessary after a previous washing). In order to be assured of the presence of lime in the decanted vinegar, it is simply necessary to add thereto some sulphuric acid, whereby gypsum or sulphate of lime is formed, which from its great difficulty of solution falls as a white sediment to the bottom.

3. *Test by Combustion.* If half an ounce of bone-dust in an iron spoon is suffered to stand over red-hot coals until all the gelatine is burned away, and the residue has again become white, the quantity of the latter is learned by the loss of weight. Good and dry bone-dust loses by this treatment full one fourth of its weight; that is, from half an ounce, at least a drachm. When lime or other earthy substances are intermixed, less of course will disappear. This test is, however, by no means so well adapted for powdered bones as for bird-manure (pp. 193, 194),

because it is requisite to continue the action of heat for several hours in order to consume the whole gelatine; and from this circumstance the differences that are developed between good and bad specimens are much smaller, and consequently less palpable and clear, than in the various sorts of guano.

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## X. OIL-CAKE.

England imports at the present day nearly 1,500,000 cwt. of oil-cake for the purposes of feeding her cattle and fertilizing her fields. Of this amount Germany contributes full one fourth, and France at least half. In this way alone 400,000 cwt. of provender and manure are annually lost to German agriculture, which, if used exclusively as a means of manure, might yield, at the lowest estimate, 600,000 Saxon bushels of rye, besides a corresponding quantity of straw. Were this oil-cake employed, again, simply as fodder, at least 80,000 cwt. of meat, in addition to some 450,000 bushels of rye, etc. obtained from the surplusage by its conversion to manure, might also be produced. If this produce is valued at an extremely low price (1 Saxon bushel of rye at 9*s.*, the straw at one fourth of the pecuniary value of the grain, and 1 lb. of meat at 5½*d.*), it follows that the oil-cake exported from Germany would realize on the first supposition £ 337,500, or 1,500,000 dollars, and on the second, £ 450,000, or 2,000,000 dollars. But now Germany receives in compensation only some £ 67,500, or 300,000 dollars, and therefore voluntarily renounces a gain from five to six times greater, which it might derive from these exports.

These figures, which have been drawn not merely from theoretical speculations, but from the practical testimony and experience of agriculture itself, ought to convey to every German farmer, in a voice of warning, the following admonition: "*Keep what thou hast, and manure with thy wares, not foreign fields, but thine own.*" In Saxony this is done already, and the two years just elapsed have especially extended the practice of manuring with rape-meal, partly in consequence of multifarious information respecting the constituents and strength of this manure, and partly in consequence of the recurrence of a deficient supply of guano and bone-dust, which necessitated the employment of substitutes for them. The use of oil-cake as provender has also increased in a similar manner. Precise statistics with respect to the magnitude of the yearly consumption cannot indeed at present be brought forward; but no great error will be committed in assuming that Saxon agriculture itself now consumes again the residuum of the oleaginous seeds, whose cultivation in Saxony, and even in its mountainous regions, has received during the last ten years a very extraordinary extension, and in all probability it will import for some time to come more of the same kind of produce from neighboring countries. In several districts, a custom that deserves the highest commendation has been introduced very generally into trade, by which the farmer sends his seed to the oil-mill upon condition that the cake produced from it is returned to himself.

## 1. Constituents and Operation of Oil-Cake.

The following figures may, first of all, show in what way the seeds of oleaginous crops differ in point of chemical composition from their strictly vegetable parts, or straw: —

| Constituents. | 1,000 lbs. of Rape-seed. | 1,000 lbs. of Rape-haulm or Straw. |
|---|---|---|
| Organic substances, | 960 | 960 lbs. |
| Oil therein, | 360 | —— " |
| Nitrogen therein, | 36 | 5 " |
| Inorganic substances, | 40 | 40 " |
| Potash and soda therein, | 10 | 10 " |
| Lime and magnesia " | 10 | 18 " |
| Phosphoric acid " | 18 | 4 " |
| Silica " | ½ | 4 " |

According to this analysis, *rape-straw* is *richer* in valuable manuring substances than the straw of the various kinds of grain, whose composition has been stated in page 144. Besides the constituents just enumerated, it often contains considerable quantities of common salt and gypsum, which of course enhance its worth as a manure. As, however, from its woody nature, it is in its natural state incorporated with difficulty into the soil, and is but very slowly decomposed there, it is every way judicious to let it lie upon the dung-hill, or in firmly compacted heaps, which should be from time to time moistened with water or drainings, to which some sulphuric acid has been added, until it becomes sufficiently rotten.

*Rape-seed* possesses, in common with other seeds, great abundance of *nitrogen* and *phosphoric acid*, but, on the other hand, differs from those of the various kinds of grain, leguminous crops, etc., in the circumstance of its containing, in lieu of starch, another unazotized substance, namely, fat *oil*. In the use made of this seed in oil-mills, it loses chiefly oil, together with a trifling quantity of mucilage and albumen; all its remaining constituents are left behind. As the oil possesses no manuring efficacy, the cakes remaining after its removal must necessarily contain more manuring elements than the seed from which they were prepared, as is testified by the following analysis of several sorts of oil-cake that are made use of in Saxony as manure for land.

100 lbs. (perfectly dried) contained:—

| Constituents. | Linseed Cake. | Rape Cake. | Early Rape Cake. | Rocket Cake. |
|---|---|---|---|---|
| Organic substances, . . | 92 | 92 | 94 | 93 |
| Oil therein, . . | 8½ | 6 | 9½ | 7½ |
| Nitrogen therein, . . | 5 | 4¾ | 4 | 4½ |
| Inorganic substances, . | 7½ | 8 | 6½ | 7 |
| (Phosphoric acid and salts of potash predominant.) | | | | |
| Value of 100 lbs. as manure, when estimated by the constituents, . . | 5*s*. 10*d*. | 5*s*. 8½*d*. | 5*s*. 1*d*. | 5*s*. 3¾*d*. |

The preceding figures relate to perfectly dry oil-cake, and not to that met with in commerce. Such cake as is furnished by the oil-mills invariably contains water, and on an average calculation about 12 per cent.; consequently, the value above stated must be reduced about one eighth, and reckoned at from 4*s.* 3*d.* to 5*s.* 1*d.* per cwt. It will be seen that the difference in the sorts which may be regarded as most extensively used in Germany is of no great importance, and hence their *manuring value* may be considered *very nearly equal.* As the price for rocket-cake, which furnishes no agreeable food for stock, is usually lower than that of rape and early rape cake, they are especially recommended as a very cheap manure. According to the prices current in England, a hundred-weight of rape-cake is there bought at 10*s.* 1½*d.*, and is, therefore, more than twice as expensive as in Germany, where it can now be obtained for from 2*s.* 10*d.* to 4*s.* 3*d.* If English agriculturists find it worth their while, as must, indeed, be supposed, to purchase oil-cakes at this high price, it may surely be expected that the German farmer, who can procure them at less than *half the expense*, will derive a more than commensurate advantage from their use.

### 1*st.* *Oil-Cake as a Manure.*

From a cursory glance at the constituents of oil-cake, no doubt can be entertained which of its ingredients plays the principal part in its operation on the soil. It is certainly the *nitrogen*, or, to speak more accurately, the azotized substances (albumen, etc.), of which it contains nearly as much as bone-dust, and about one third as much as good guano. To develop the forcing action contingent hereupon, a previous putrefaction and conversion of the azotized into ammoniacal combinations is here again necessary; but this ensues more rapidly in oil-cake than in bones, because it is more easily penetrated by water and air, and hence it is not essential to induce putrefactive decomposition before ploughing it into the ground. Experience agrees entirely with the representation, that it acts more speedily than bone-dust, but, on the other hand, more slowly than guano; as also with the statement, that its principal effect takes place during the first year, except, perhaps, in a very dry season, in which it does not find in the earth the amount of moisture required for its decomposition.

After nitrogen, the action of oil-cake (in forming the seed) is due to its contents of *phosphoric acid.* Of this substance, however, it contains about five times less than good guano, ten times less than bone-dust, and twelve to fourteen times less than bad bird-manure. That, moreover, the other integrants met with — potash, soda, lime, as also the organic, humus-forming substances, and, in addition to these, the common salt and gypsum that may perhaps be present — increase the efficacious operation of oil-cake, cannot be denied; nevertheless, the same importance cannot be attributed to these ingredients as to the first, because they are contained in oil-cake in no greater quantity than in barley-straw, oat-straw, etc.

Respecting the *total strength of oil-cake as a manure, and its duration*, I am not yet able to adduce such precise figures as those placed at my disposal, by the practical experience of Saxon farmers, in relation to guano, and to some extent, also, in relation to bone-dust; since, notwithstanding numerous experiments, that establish the important power of this agent on the soil, few only have been instituted for the purpose of exact *comparison*, or prosecuted long enough to enable us to obtain a complete answer to these inquiries. It may be assumed to be very near the truth, that the *entire operation* of 1 cwt. of rape-meal is to be considered equal to that of 18 to 20 cwt. of stable-muck, 1 to 1½ cwt. of bone-dust, 1 to 3 cwt. of good guano; and that 1 cwt. of rape-meal is capable of producing in the whole duration of its action 250 to 300 lbs of rye, of which some 50 to 60 per cent. may be placed to its operation in the first year, 20 to 25 per cent. in the second, and 10 to 15 per cent. in the third.

The *oil contained in the cakes*, as already mentioned, contributes nothing to their fertilizing power; it rather, indeed, detracts from it, in so far as, like fat in fresh bones, it retards their decomposition. The assertion has even been advanced, that the non-germination of seeds, which is occasionally remarked when they are introduced into the earth at the same time

20 *

with the powdered cakes, is due to the oily parts of the latter, because they envelop the young germ and exclude it from the air. The farmer who desires to employ oil-cake exclusively for manuring his land must, accordingly, give the preference to those sorts from which the oil has been most completely expressed. The cakes prepared in Saxony contain about one fourth to one sixth of the quantity of oil contained in the seed, and sometimes, more particularly in linseed-cake, as much as one third. In England, the cakes imported from Germany and France should be made, by means of very strong presses, to give up from 4 to 5 per cent. of oil, before they are made use of in manuring the soil.

### 2d. *Oil-Cake as Provender.*

When oil-cake is employed *in foddering stock*, those sorts that are *rich in oil* must be preferred to those from which it has been more completely withdrawn, since oil, like fatty substances in general, plays an important part in the digestion and nourishment of animals, and especially favors their fattening. In England this consideration has been recently pushed so far, that linseed, coarsely ground, is used directly for feeding stock; and many farmers in that country, who have made numerous experiments in this respect, assert that the economical advantages attained thereby are greater than those secured by expressing and selling the oil, and using only the cake for purposes of fodder. Here, also, their nitrogen must be acknowledged to be the most important constituent of oil-cakes; inasmuch as it is the substance which converts them into an invigorating, or flesh-producing food, whilst their oil, on the other hand, occasions a most abundant production of fat or suet (page 82).

The following calculation may show how great is the advantage which the farmer may derive from the use of oil-cake as a subsidiary fodder. From the results of experiments made in England, it may be regarded as a proposition which is generally true, that, of 5 lbs. of nitrogen contained in provender, 1 lb. in fattening animals is converted into flesh, whilst the remaining 4 lbs. pass in great part into the excrements, and that from the 1 lb. of assimilated nitrogen, at least 25 lbs. of flesh are produced. Of $4\frac{1}{2}$ lbs. of nitrogen, which, upon an average, are contained in 100 lbs. of oil-cake,

About $\frac{1}{2}$ lb., value 0*s*. 6*d*., is lost by breathing and exhalation.
" $\frac{4}{5}$ " " 8*s*. 6*d*., are converted into flesh.
" $3\frac{1}{5}$ " " 2*s*. 8*d*., remain in the excrements.
The value realized from 100 lbs. of oil-cake must accordingly, on this supposition, be estimated at 11*s*. 2*d*.

Should a still lower calculation be preferred, the pecuniary return acquired from feeding with oil-cake may be computed at 9*s*. at the lowest, which is nearly double its cost, and from one fourth to one third more than when it is employed directly for manuring. In foddering cows, it may be assumed that 120 lbs. of milk (in round numbers 60 Saxon cans or English quarts) are produced, at the lowest computation, from 100 lbs. of oil-cake.

These figures, which were obtained, not by thinking at a desk, but from the results of practical experiments, speak loudly enough, as may be presumed, in favor of the great advantages which the German farmer may derive, both in the stable and the field, from the employment of oil-cake, and more particularly now, when it can be obtained at prices that render it the cheapest material for fodder and manure.

## 2. Employment of Oil-Cake.

When used by itself for manuring the land, twelve to sixteen hundred-weight of rape-meal are allowed in Saxony to the acre; and more is given to a heavy than to a light soil, because the decomposition of the cake proceeds more slowly in the former than in the latter. The fertilizing effect on the soil produced by this dressing is of course seen to be more persistent in heavy than in light land.* In many places no operation whatever has been perceived from oil-cake in very binding soils; but experiments that have been prosecuted for several years on the University farm in Tharand show, in opposition to this experience, that it acts very satisfactorily, even in the

* This arises, of course, from the great power of the clay to retain the valuable portions of this efficacious manure; and this expression here is one of the unsought for proofs of the value of the recent important discovery of the retentive character of clay. — J. E. T.

heaviest clay bottoms, provided an excessively dry weather does not happen during the first period of vegetation. Very moist and very dry fields or meadows seem least adapted to this manure.

To attain the greatest possible certainty, the same course should be adopted with this substance as with bone-dust; that is, *some guano should be added*, particularly when it is intended to use it in manuring summer crops. So, too, it is very judicious to combine it, when employed as an auxiliary manure, with stable-muck, in order to excite a more energetic putrefaction. For the same reason, a mixture of oil-cake, guano, and earth is certainly better suited for top-dressing meadows, etc., than oil-cake alone, and more especially in all those cases where the manure is not applied until the spring. In many places the joint employment of oil-cake and *lime* has produced excellent results.

As regards the *crop* for which oil-cake may be most advantageously used, it may at once be inferred from the statement of its composition, according to which it contains *all* the substances plants need for their nourishment, and the most valuable of these (nitrogen, phosphoric acid, and potash) in considerable quantity, that it is adapted to *all* plants; and this has been already verified by the results of experience. In Saxony it has proved beneficial for grain and oily crops, no less than for grass, potatoes, etc. If in this respect one kind of crop is to be placed above all others, it might perhaps be the *oleaginous plants* themselves, for which, indeed, the largest amount of benefit may be expected, because they find in it all the substances they require for the formation of their seeds, and, moreover, in the proportionate quantities in which they require them.

Since, as already mentioned, experience has sometimes shown, that, in the event of direct contact between oil-cake and seed, when both are deposited in the earth, the latter may lose its germinating power, it may be best to harrow the oil-cake lightly into the ground before sowing. In England, the powdered cake and seed are generally sown at the same time by the drill, without the injurious consequence just described. Hence it appears, that it is only to be feared under some peculiar circumstances, or with a great excess of cake.

In Belgium, oil-cake is most usually employed as a *liquid manure*, inasmuch as it is thrown into the drainings-reservoir, and poured on to the land when it has softened and commenced putrefaction. By this means the manuring ingredients of the oil-cake are brought into such a form as *at once* to take effect. It is granted, that the duration of their action is not considerable; but this is not demanded by the Belgian farmer, if the dressing has remunerated him in the first year of its application, since, in compensation, *he manures every year afresh*, and can thereby calculate every year upon a *full* harvest. The amount of produce is, in truth, astonishing, which is understood to be obtained from the land in this country by means of that liquid mush, which has become known and celebrated under the name of "Flemish manure," and to which the solid excrements of animals are also added. Adulterations of oil-cake have not yet, in all probability, been introduced into Germany; should they be suspected, the simplest method of testing would consist in burning to ashes a certain quantity that had been previously weighed. If earthy substances — for example, lime, loam, sand, ashes, etc. — have been intermixed, they will, of course, augment the quantity of ashes, inasmuch as they are not volatilized by heat.

## XI. MALT-GRAINS, OR REFUSE FROM BREWERIES.

Malt-grains possess, in point of composition, the greatest analogy with oil-cake, but are far more speedy in their operation; because, in consequence of their tender and delicate structure, they decompose with exceeding facility in the soil. To the farmer they are of much less importance, because they are not to be obtained in large quantities, since in breweries, which form the only source whence they can be procured, only 3, or at most 4 lbs. of dry grains are derived from 100 lbs. of barley. In analyzing some barley and malt-grains, which latter were produced from the same sample of barley, I found the following differences in their chemical constitution.

1,000 lbs. (perfectly dry) contained: —

| Constituents. | Barley. | Malt-Grains. |
|---|---|---|
| Organic substances, . . . . . | 975 | 915 lbs. |
| Nitrogen therein, . . . . | 24 | 40 " |
| Inorganic substances, . . . . | 25 | 85 " |
| Potash and soda therein, . . | 6 | 20 " |
| Lime and magnesia " . . | 3 | 9 " |
| Phosphoric acid " . . . | 8 | 14 " |
| Silica " . . | 7 | 36 " |

Malt consists partly of the rootlets of the young barley plant; they are the first parts of plants which appear in the awakening of the vital force which slumbers in the seed, because it is their destiny to purvey nourishment for the other vegetable organs; and it is for this reason, also, that they are, as is shown by comparing the preceding analyses, so very much richer both in nitrogen and mineral substances than the grains of barley. Hence it may be very clearly perceived how necessary abundant food is to plants in their very earliest youth, and how important it is, therefore, to take due care that they may at this period find it in the soil.

When employed as manure, malt *very promptly* develops — as might be concluded from its abundant contents of nitrogen and potash, as also from its great facility of decomposition — a *strongly forcing operation.* Whoever is still unacquainted with its action has only to sprinkle it over a grass-plat, and he will soon be able very clearly to perceive it. That its principal operation takes place during the first year, and that its persistent effects are very inconsiderable, it is now scarcely necessary to mention, and just as little the testimony of experience, that a strong manuring with it may easily induce the lodgment of the corn. The manuring value of malt, as met with in commerce, must be regarded as about equal to that of oil-cake. In Saxony it is now purchased at from 2*s.* 6*d.* to 3*s.* 4*d.* per cwt., and is more particularly used as a dressing for meadows and garden-grass, or as an addition to stable-muck; more rarely as the only manure, in which case from 10 to 12 cwt. are allowed to the (Saxon) acre. When employed as fodder, the strength of stable-manure is increased by its means in no insignificant degree.*

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* The enumeration of the article of brewers' refuse malt-grain as an article of manure must be considered here as arising from the fact, that Germany is a great beer-drinking country. Beer is the usual beverage of the middling and lower classes; hence the quantity manufactured there is very large, and of course the quantity of brewery-refuse considerable. The simple, yet altogether scientific views of Dr. Stöckhardt on this subject, however, must make its value intelligible to our farmers, although they may be totally unacquainted with the article. — J. E. T.

THE END.