STATE OF CONNECTICUT.

ANNUAL REPORT

OF THE

CONNECTICUT AGRICULTURAL

EXPERIMENT STATION

FOR 1877.

PRINTED BY ORDER OF THE LEGISLATURE.

NEW HAVEN:
TUTTLE, MOREHOUSE & TAYLOR, PRINTERS.
1878.

OFFICERS

OF THE

Connecticut Agricultural Experiment Station,

1877.

STATE BOARD OF CONTROL.

ANNOUNCEMENT.

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION is established in accordance with an Act of the General Assembly, approved March 21, 1877, "for the purpose of promoting Agriculture by scientific investigation and experiment," and succeeds the Station that was organized in 1875, for a term of two years, under the management of the Trustees of the Wesleyan University at Middletown.

The Station is prepared to analyze and test fertilizers, cattle-food, seeds, soils, waters, and other agricultural materials and products, to identify grasses, weeds, and useful or injurious insects, and to give information on the various subjects of Agricultural Science, for the use and advantage of the citzens of Connecticut.

All chemical analyses, seed examinations, etc., proper to an Experiment Station, that can be used for the public benefit, will be made without charge. Work done for individuals, that is not of any general interest, will be charged for at moderate rates, to be learned on application. The Station will undertake no work, the results of which are not at its disposal to use or publish, if deemed advisable for the public good.

Samples of Commercial Fertilizers, Seeds, etc., will be examined in the order of their coming; but when many samples of one brand of fertilizer are sent in, the Station will make a selection for analysis. In taking samples of Commercial Fertilizers and Seeds for examination, the Station's "Instructions for Sampling" must be strictly followed, and its blank "Forms for Description of Samples" must be filled out and sent with the samples. Instructions and Forms will be furnished on application.

The results of each analysis or examination will be promptly communicated to the party sending the sample. Results that are of general interest will be sent to all the newspapers of the State for publication, and will be furnished to all who apply for them by letter or otherwise.

The Officers of the Station will take every pains to obtain for analysis, samples of all the commercial fertilizers sold in Connecticut; but the organized coöperation of farmers is essential for the timely and full protection of their interests. Farmers' Clubs and like Associations can most efficiently work with the Station for this purpose, and are requested to send in samples early during each season of trade.

It is the wish of the Board of Control to make the Station as widely useful as its resources will admit. Every Connecticut citizen who is concerned in agriculture, whether farmer, manufacturer, or dealer, has the right to apply to the Station for any assistance that comes within its province to render, and the Station will respond to all applications as far as lies in its power.

☞ Instructions and forms for taking samples, and Terms for testing Fertilizers, Seeds, &c., for private parties, sent on application.

☞ Parcels by Express, to receive attention, should be prepaid, and all communications should be directed to

Agricultural Experiment Station, New Haven, Conn.

Laboratory and Office, in East Wing of Sheffield Hall, Grove St., head of College St.

CONTENTS.

REPORT OF THE BOARD OF CONTROL.

To the General Assembly of the State of Connecticut:

The Board of Control of the Connecticut Agricultural Experiment Station have the honor to submit the following Report.

In presenting an account of this Station for the year just concluded, it is not necessary to review at length the history of the inception and development in Connecticut of an enterprise which in all the foremost countries of Europe has come to be regarded as indispensable to the welfare of Agriculture and the State. This history is largely to be found in the Reports of the State Board of Agriculture for the years 1873, 1874, 1875, and 1876.

The Legislature in 1875 secured to Connecticut the honor of establishing the first Agricultural Experiment Station in America, by the passage of the following resolution:

"To Promote Agricultural Interests.

"*Whereas*, The Trustees of the University at Middletown, tender the free use of ample laboratories and other facilities for establishing and carrying on an Experiment Station, for the general benefit and improvement of Agriculture and kindred interests of the State of Connecticut: be it

"*Resolved by this Assembly:* Section 1. That the sum of seven hundred dollars per quarter for two years, is hereby appropriated to the University located at Middletown, Middlesex County, to be used in employing competent scientific men to carry on the appropriate work of an Agricultural Experiment Station; and the Comptroller is hereby directed to draw his order in favor of the Treasurer of the Board of Trustees of said University, for seven hundred dollars per quarter, for two years, beginning October 1, 1875; *provided*, the said Treasurer shall satisfy the Comptroller that such money is expended in the employment of scientific men for making the experiments and investigations contemplated in this resolution; and that the said University shall superintend such experiments, and shall provide ample laboratories and buildings therefor, free of all charge.

"Sec. 2. This resolution shall take effect from its passage."

An account of the organization and very useful operations of the Station at Middletown, is to be found in the able Report of Dr. Atwater, its Director, which is printed in the Report of the State Board of Agriculture for 1876. The above resolution practically limited the existence of that Station to a term of two years, and its operations accordingly ceased July 1st, 1877.

Meanwhile the General Assembly had provided for the continuance of experimental work, by the passage of the following Act:

"An Act establishing the Connecticut Agricultural Experiment Station.

"*Be it enacted by the Senate and House of Representatives in General Assembly convened:*

"Section 1. That for the purpose of promoting agriculture by scientific investigation and experiments, an institution is hereby established, to be called and known as The Connecticut Agricultural Experiment Station.

"Sec. 2. The management of this institution shall be committed to a Board of Control, to consist of eight members, one member to be selected by the State Board of Agriculture, one member by the State Agricultural Society, one member by the Governing Board of the Sheffield Scientific School at New Haven, and one member by the Board of Trustees of the Wesleyan University at Middletown, and two members to be appointed by the Governor of this State, with the advice and consent of the Senate. The Governor of the State, and the person appointed as hereinafter provided to be the Director of the Station, shall also be *ex officio* members of the Board of Control.

"Sec. 3. After the appointment of the members of the Board of Control as aforesaid, said members shall meet and organize by the choice from among their number of a President, a Secretary, and a Treasurer, who shall be elected annually, and shall hold their respective offices one year, and until the choice of their successors. Five members of said Board shall constitute a quorum thereof for the transaction of business.

"Sec. 4. Said Board shall meet annually after the first meeting thereof, on the third Tuesday in January in each year, at such place in the city of Hartford as may be designated by the President of said Board, and at such other times and places, upon the call of the President, as may be deemed necessary, and may fill vacancies which may occur in the officers of said Board.

"Sec. 5. Said Board of Control shall locate and have the general management of the institution hereby established, and shall appoint a Director who shall have the general management and oversight of the experiments and investigations which shall be necessary to accomplish the objects of said institution, and shall employ competent and suitable chemists and other persons necessary to the carrying on of the work of the Station. It shall have power to own such real and personal estate as may be necessary for carrying on its work, and to receive title to the same by deed, devise, or bequest. It shall expend all moneys appropriated by the State in the prosecution of the work for which said institution is established, and shall use for the same purpose the income from all funds and endowments which it may hereafter receive from other sources, and may sue and be sued, plead and be impleaded, in all courts, by the name of The Connecticut Agricultural Experiment Station. It shall make an annual report to the Legislature which shall not exceed two hundred printed pages, of which not exceeding three thousand copies shall be printed.

"Sec. 6. The sum of five thousand dollars annually is hereby appropriated to said Connecticut Agricultural Experiment Station, which shall be paid in equal quarterly installments to the Treasurer of said Board of Control, upon the order of the Comptroller, who is hereby directed to draw his order for the same; and the Treasurer of said Board of Control shall be required, before entering upon the duties of his office, to give bond with surety to the Treasurer of the State of Connecticut in the sum of ten thousand dollars, for the faithful discharge of his duties as such Treasurer.

"Sec. 7. Upon the death or resignation of any of the members of the Board of Control, the authority or institution by which such deceased member was originally appointed shall fill the vacancy so occasioned.

"Sec. 8. Professor Samuel W. Johnson, of New Haven, is hereby empowered to appoint and call the first meeting of said Board of Control as soon as may be practicable after the appointment of the members thereof, and he shall notify all said members of the time and place of said meeting. Two of said members shall hold office for one year, two of them for two years, and two of them for three years; and at said first meeting they shall determine by lot which of said members shall hold office for one year, which for two years, and which for three years. All members of said Board thereafter chosen or appointed, except such as are appointed or chosen to fill vacancies in said Board, shall continue in office for the term of three years from the first day of July next succeeding such appointment.

"SEC. 9. This act shall take effect from its passage.

Approved March 21, 1877."

Shortly after the enactment of this law, the Board of Control was constituted by the appointment of the following persons, viz: Messrs. James J. Webb of Hamden and Edwin Hoyt of New Canaan, appointed by the Governor with approval of the Senate, Hon. E. H. Hyde of Stafford by the State Agricultural Society, T. S. Gold, Esq., of West Cornwall by the State Board of Agriculture, Mr. Orange Judd of Middletown by the Trustees of the Wesleyan University, and Prof. W. H Brewer of New Haven by the Governing Board of the Sheffield Scientific School. The first meeting was called at the city of Hartford, April 11th, 1877, and the Board of Control organized by choosing Gov. R. D. Hubbard, President, Hon. E. H. Hyde, Vice-President, and W. H. Brewer, Secretary and Treasurer.

Prof. S. W. Johnson was chosen Director of the Station and eighth member of the Board. The Board adjourned to meet at New Haven, April, 20th, and again adjourned to May 4th, when the Station was located in rooms set apart for its exclusive use by the authorities of the Sheffield Scientific School. An Executive Committee was chosen at this meeting consisting of Messrs. Webb, Brewer and Johnson. This committee proceeded to organize and equip the Station for actual work. The experienced services of Messrs. Edward H. Jenkins and Henry P. Armsby as chemists were secured. The rooms tendered to the Station for use, comprising the entire main floor of the east wing of Sheffield Hall, and consisting of two rooms each 16×32 feet, a smaller one 8×10 feet with separate entrance and vestibule, were prepared for Station work by making suitable changes and repairs and putting in additional fixtures. One of the large rooms was made

into a chemical laboratory, the other into an office. The expense of these alterations and fixtures, including laying in of water and gas and making sewer connections, rendered necessary by these changes, and amounting to about $550 for carpenter, plumber and gas fitter's bills was entirely assumed by the authorities of the Sheffield School.

Another meeting of the Board of Control was held at the Station, December 11th, 1877. For the expenses and operations of the Station we refer your honorable body to the following reports of the Treasurer and Director, presented to this Board at its Annual Meeting, held in Hartford, January 15th, 1878.

By order of the Board.

Signed, R. D. HUBBARD, *President.*
W. H. BREWER, *Secretary.*

REPORT OF THE TREASURER.

Wm. H. Brewer, *in account with The Connecticut Agricultural Experiment Station.*

Received.

From State Treasurer, to date,	$2,500.00	
For Chemical Analyses,	131.65	
Cash gift for purchase of seeds,	10.00	

Paid.

E. H. Jenkins, salary six months,	$700.00	
H. P. Armsby, " "	600.00	
S. W. Johnson, " "	500.00	
		$1,800.00
Stationery, postage and printing,		240.67
Laboratory expenses,		141.50
Furniture,		94.12
Miscellaneous,		63.95
		$2,340.24
Cash on hand,		301.41
	$2,641.65	$2,641.65

There is now due the Station, eighty (80) dollars for chemical analyses made, and the bills outstanding against the Station amount to about three hundred and fifty (350) dollars.

WM. H. BREWER,
Treasurer.

New Haven, Conn., January 14th, 1878.

REPORT OF THE DIRECTOR.

In accordance with the decision of the Executive Committee of the Experiment Station, Messrs. Jenkins and Armsby were engaged to enter upon their work July 1st, 1877. The apartments placed at the disposal of the Station by the authorities of the Sheffield Scientific School, could not be put under repair until the same date, and therefore, with permission, the chemical work was begun in one of the laboratories of the Sheffield School, which then became vacant by the closing of the college year, and the work was carried on there for six weeks. About August 15th the Station Laboratory was ready for occupancy, and since that date all our operations have been conducted in it.

Some weeks were consumed in the needful preparations for chemical work, and the first analysis of a swamp muck (peat) was reported August 6th.

During July, the announcement, which stands upon a previous page of this volume, was printed and distributed as widely as possible through the newspapers, the Agricultural Societies and the Farmers' Clubs of the State, as well as by the mail.

At the same time the Director prepared a sheet of printed "Instructions for Sampling Commercial Fertilizers" and another "Form for Description of Samples," to issue to parties sending in fertilizers for analysis. These, like the similar instructions and blanks that were found useful at the Middletown Station, were based upon a circular prepared by the writer and printed March, 1875, by the Secretary of the Board of Agriculture, for use in the work of fertilizer analysis, undertaken for the Board at that time by the undersigned, with the aid of Mr. Jenkins. The circular, as well as the results of that work, were not published except in the newspapers of the State.

The "Instructions for Sampling" now issued by the Station are the following, and explain themselves.

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION, NEW HAVEN, CONN.

Instructions for Sampling Commercial Fertilizers.

The *Commercial Value* of a high priced Fertilizer can be estimated, if the percentages of its principal fertilizing elements are known. Chemical analysis of a small sample, so taken as to fairly represent a large lot, will show the composition of the lot. The subjoined instructions, if faithfully followed, will isnure a fair sample. Especial care should be observed that the sample neither gains nor loses *moisture* during the sampling or sending, as may easily happen in extremes of weather, or from even a short exposure to sun and wind, or from keeping in a poorly closed vessel.

1. Provide a tea cup, some large papers, and for each sample a glass fruit can or tin box, holding about one quart, that can be tightly closed, all to be clean and dry.
2. Weigh separately at least three (3) average packages (barrels or bags) of the fertilizer, and enter these *actual weights* in the "Form for Description of Sample."
3. Open the packages that have been weighed, and mix well together the contents of each, down to one-half its depth, emptying out upon a clean floor if needful, and crushing any soft, moist lumps in order to facilitate mixture, but leaving hard, dry lumps unbroken, so that the sample shall exhibit the texture and mechanical condition of the fertilizer.
4. Take out five (5) equal cupfuls from different parts of the mixed portions of each package. Pour them (15 in all) one over another upon a paper, intermix again thoroughly but quickly to avoid loss or gain of moisture., fill a can or box from this mixture, close tightly, *label plainly*, and send, charges prepaid, to

THE CONN. AGRICULTURAL EXPERIMENT STATION,
New Haven, Conn.

Here is subjoined the Form for Description of Sample, now used.

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION, NEW HAVEN, CONN.

Form for Description of Sample.

Station No. Rec'd at Station, 18

Each sample of Fertilizer sent for analysis must be accompanied by one of these Forms, with the blanks *below* filled out fully and legibly.

The filled out Form, if wrapped up with the sample, will serve as a label.

Send with each sample a specimen of any printed circular, pamphlet, analysis, or statement that accompanies the fertilizer or is used in its sale.

Brand of Fertilizer,
Name and address of Manufacturer,
Name and address of Dealer from whose stock this sample is taken,
Date of taking this Sample,
Selling price per ton or hundred, bag or barrel,
Selling weight claimed for each package weighed,
Actual weights of packages opened.

Here write a copy of any analysis or guaranteed composition that is fixed to the packages.

Signature and P. O. address of person taking and sending the sample.

On receipt of any sample of fertilizer from the open market, the filled out "Form for Description," which accompanies it, is filed in the Station's Record of Analyses and remains there as a voucher for the authenticity of the sample and for the fact that it has been fairly taken. It is thus sought to insure that manufacturers and dealers shall not suffer from the publication of analyses made on material that does not correctly represent what they have put upon the market.

The "Form for Description" also contains all the data of cost, weight, &c., of a fertilizer necessary for estimating, with help of the analysis, the commercial value of its fertilizing elements, and the fairness of its selling price.

When a sample of fertilizer has been analyzed the results are recorded on a printed form, as in the subjoined specimen, which is filed in the Records of Analyses facing the "Description of Sample" that was received with the fertilizer to which it pertains, and there remains for future reference.

RECORD OF ANALYSES.

Sample No. 14.

Received *Aug.* 23*d*, 1877.

Analysis reported *September* 6*th*, 1877. References*
Brand, *Pure Ground Bone.*
Manufacturer, *G. M. Dean, Springfield, Mass.*
Dealer, *G. M. Dean, Springfield, Mass.*
Sampled and sent *Aug.* 17, by *Andrews Bros., Southington, Ct.*
Wt. of packages, Wt. claimed, Cost, $30 *per* 2,000 *lbs. at the Manufactory.*

* To Chemist's note book.

Condition, *dry, but rather coarse.*

Mechanical Analysis: Passed holes $\frac{1}{50}$ inch 28 per cent.

Passed holes $\frac{1}{50}$ inch	28	per cent.
" " $\frac{1}{25}$ "	8	" "
" " $\frac{1}{12}$ "	12	" "
" " $\frac{1}{6}$ "	17	" "
Coarser than $\frac{1}{6}$ "	35	" "

Chemical Analysis and Valuation.

	Pounds per Hundred.	Pounds per Ton (2,000 lbs.)	Estimated Value per Pound	Estimated Value per Ton.
Moisture,	7.78			
Organic Matter,*	35.98			
Ash,†	56.24			
	100.00			
* With Nitrogen,	3.80	76	15 cts.	$11.40
† With Phosphoric Acid,	19.94	400	5 cts.	20.00

Total estimated value, ...$31.40

Cost,..$30.00

A copy of the analysis is also immediately reported to the party that furnished the sample, the report being entered on one page of another printed form and facing a second printed page of "Explanations" intended to embody the principles and data upon which the valuation of Fertilizers is based.

The following is a copy of such a Report of Analysis with the Explanations.

Report of Analysis.

CONNECTICUT AGRICULTURAL EXPERIMENT STATION.

New Haven, Conn., *Oct. 5th*, 1877.

Analysis of "*Fine Bone Manure.*"

Sample No. 28, rec'd *Sept.* 29, 1877 from *Smith Terrill, Seymour, Conn.*

Condition, *quite dry and fine.*

Mechanical Analysis:

Passed holes $\frac{1}{50}$ inch	62.4	per cent.
" " $\frac{1}{25}$ "	3.8	" "
" " $\frac{1}{12}$ "	5.6	" "
" " $\frac{1}{6}$ "	3.5	" "
Coarser than $\frac{1}{6}$ "	24.7	" "

Chemical Analysis and Valuation.

	Pounds per Hundred.	Pounds per Ton (2,000 lbs.)	Estimated Value per Pound.	Estimated Value per Ton.
Phosphoric Acid,	19.04	380.8	7 cts.	$26.66
Nitrogen,	1.91	38.2	18 cts.	6.88

Total estimated value, ...$33.54

Cost, ...$30.00

S. W. JOHNSON, *Director.*

EXPLANATIONS.

Nitrogen is commercially the most valuable fertilizing element. It occurs in various forms or states. *Organic nitrogen* is the nitrogen of animal and vegetable matters generally, existing in the albumin and fibrin of meat and blood, in the uric acid of bird dung, in the urea and hippuric acid of urine, and in a number of other substances. Some forms of organic nitrogen, as that of blood and meat, are highly active as fertilizers; others, as that of hair and leather, are comparatively slow in their effect on vegetation, unless these matters are reduced to a fine powder or chemically disintegrated. *Ammonia* and *nitric acid* are results of the decay of *organic nitrogen* in the soil and manure heap, and are the most active forms of Nitrogen. They occur in commerce —the former in sulphate of ammonia, the latter in nitrate of soda. 17 parts of ammonia contain 14 parts of nitrogen.

Soluble Phosphoric acid implies phosphoric acid or phosphates that are freely soluble in water. It is the characteristic ingredient of Superphosphates, in which it is produced by acting on "insoluble" or "reverted" phosphates with oil of vitriol. It is not only readily taken up by plants, but is distributed through the soil by rains. Once well incorporated with soil it shortly becomes reverted phosphoric acid.

Reverted (*reduced or precipitated*) *Phosphoric acid*, means strictly, phosphoric acid that was once freely soluble in water, but from chemical change has become insoluble in that liquid. It is freely taken up by a strong solution of ammonium citrate, which is therefore used in analysis to determine its quantity. "Reverted phosphoric acid" implies phosphates that are readily assimilated by crops, but have less value than soluble phosphoric acid, because they do not distribute freely by rain.

Insoluble Phosphoric acid implies various phosphates not freely soluble in water or ammonium citrate. In some cases the phosphoric acid is too insoluble to be readily available as plant food. This is true of the South Carolina rock phosphate, of Navassa phosphate, and especially of Canada apatite. The phosphate of raw bones is nearly insoluble in this sense, because of the animal matter of the bone which envelopes it, but when the latter decays in the soil, the phosphate remains in essentially the "reverted" form.

Potash signifies the substance known in chemistry as potassium oxide, which is the valuable fertilizing ingredient of "potashes" and "potash salts." It is most costly in the form of sulphate, and less so in the shape of muriate or chloride.

The Valuation of a Fertilizer signifies ascertaining its worth in money, or its trade-value, a value which it should be remembered is not *necessarily* proportional to its fertilizing effects in any special case.

Plaster, lime, stable manure and nearly all of the less expensive fertilizers have quite variable prices, which bear no close relation to their chemical composition, but guanos, superphosphates and other fertilizers, for which $30 to $80 per ton are paid, depend chiefly for their trade-value on the three substances, *nitrogen*, *phosphoric acid* and *potash*, which are comparatively costly and quite steady in price. The money-value per pound of these ingredients is easily estimated from the market prices of the standard articles which furnish them to commerce.

The following are the trade-values or cost in market, per pound, of the ordinarily occurring forms of nitrogen, phosphoric acid and potash, as recently found in the New York and New England markets:

	Cents per Pound.
Nitrogen in ammonia and nitrates,	24
" in Peruvian Guano, fine steamed bone, dried and fine ground blood, meat and fish,	20
" in fine ground bone, horn and wool dust,	18
" in coarse bone, horn shavings and fish scrap,	15
Phosphoric acid soluble in water,	12½
" " "reverted" and in Peruvian Guano,	9
" " insoluble, in fine bone and fish guano,	7
" " " in coarse bone, bone ash and bone black,	5
" " " in fine ground rock phosphate,	3½
Potash in high grade sulphate,	9
" in kainite, as sulphate,	7½
" in muriate, or potassium chloride,	6

These "estimated values" are not fixed, but vary with the state of the market and are from time to time subject to revision. They are not exact to the cent or its fractions, because the same article sells cheaper at commercial or manufacturing centers than in country towns, cheaper in large lots than in small, cheaper for cash than on time. These values are high enough to do no injustice to the dealer, and accurate enough to serve the object of the consumer.

By multiplying the per cent. of Nitrogen, &c., by the trade-value per pound, and then by 20, we get the value per ton of the several ingredients, and adding the latter together we obtain the total estimated value per ton.

The uses of the "Valuation" are, 1st, to show whether a given lot or brand of fertilizer is worth as a commodity of trade what it costs. If the selling price is no higher than the estimated value, the purchaser may be quite sure that the price is reasonable. If the selling price is but $2 to $3 per ton more than the estimated value it may still be a fair price, but if the cost per ton is $5 or more over the estimated value, it would be well to look further. 2d, Comparisons of the estimated values, and selling prices of a number of fertilizers will generally indicate fairly which is the best for the money. But the "estimated value" is not to be too literally construed, for analysis cannot always decide accurately what is the *form* of nitrogen, &c., while the mechanical condition of a fertilizer is an item whose influence cannot always be rightly expressed or appreciated.

The *Agricultural value* of a fertilizer is measured by the benefit received from its use, and depends upon its fertilizing effect, or crop-producing power. As a broad general rule it is true that Peruvian guano, superphosphates, fish scraps, dried blood, potash salts, plaster, &c., have a high agricultural value which is related to their trade value, and to a degree determines the latter value. But the rule has many exceptions, and in particular instances the trade-value cannot always be expected to fix or even to indicate the agricultural value. Fertilizing effect depends largely upon soil, crop and weather, and as these vary from place to place and from year to year, it cannot be foretold or estimated except by the results of past experience, and then only in a general and probable manner.

The "estimated values per pound" in the above schedule are those employed by Dr. Goessmann and Prof. Atwater in their recent Reports.

The Best Sources of Fertilizer Samples are Farmers' Clubs.

As a measure towards securing samples of fertilizers for analysis, the following circular letter was addressed to the Secretaries of the twenty-seven Agricultural Societies and eighteen Farmers' Clubs known or supposed to be in existence in this State.

Circular.

THE CONN. AGRICULTURAL EXPERIMENT STATION,
New Haven, Aug. 14th, 1877.

Sec'y *Agricultural Society.*

DEAR SIR—Doubtless the most effectual way of maintaining the fertilizer business in a state satisfactory both to buyers and sellers is to make and publish from time to time, and especially during each season of active trade, several analyses of every brand of fertilizer found in our markets. Such analyses are obviously most satisfactory when made on samples taken by actual consumers from their purchased stock or from lots offered to them for purchase. Analyses of samples authenticated by an association like yours will naturally carry more weight than any other. The publication of analyses will tend to hold dealers and manufacturers up to their guarantees, and will promptly expose anything of a fraudulent or doubtful character.

There are in this State some forty-five county and other local societies and Farmers' Clubs. Their concerted action will easily supply the Station with the requisite samples. Will you bring this matter before the members of your association and take measures to coöperate at once with the Station. It will be best to advise with me before sending samples, in order to learn what fertilizers have already been received in sufficient number.

If desired by your association I will forward to you a copy of each commercial fertilizer analysis made at the Station, to be put on file for the use of your members.

Very truly yours,
S. W. JOHNSON, *Director.*

Responses by letter or in person were received from a goodly number of these organizations, although during the summer months they hold no meetings, and in every case their hearty coöperation and desire to profit by the work of the Station was cordially expressed.

There are, however, some of the societies and clubs that remain to be heard from, and it is hoped that they will come speedily to the front and work energetically with the Station for their own and for the general good.

"Fertilizer Control."—The above circular expresses the views of the officers of the Station as to the best mode of exercising a "Fertilizer Control." It is not deemed expedient for the Station to attempt any formal and systematic inspection of manufactories or store-houses of fertilizers, with the idea that such inspection can in any sense be made a guarantee of the genuineness and good quality of whatever is sent out therefrom. It is held that the liability of any brand of fertilizer, if exposed for sale anywhere in the State, to be subjected to the scrutiny of the Station at the hands of consumers, and in the very condition in which it is offered to them, will be the most easy, the most healthy, and in the long run the most certain and effectual method of "control." It has the great advantages over any other system that it is entirely fair; that it so distributes responsibility that the Station and its officers cannot enter into the temptation or incur the suspicion of favoritism or partiality; it keeps the producer and dealer constantly alert to hold their wares up to a high standard of excellence; and it exercises the caution and the intelligence of the consumer in a manner that must react favorably on every branch of his business.

The Station, therefore, does not assume any direct or positive "control" over the fertilizers that are placed in our markets. It does not send its agents to take samples from the stock of all makers and sellers of fertilizers, with the intent to guarantee to all buyers a good bargain.

It is manifestly impossible by any practicable amount of "inspection" under existing laws and customs to exclude inferior articles from the markets of this State. Nothing short of a special police on duty day and night at every place where fertilizers are prepared or stored can prevent a dishonest maker or dealer from diluting and falsifying the articles he offers, between the time when the Station takes its samples and the time the farmer may buy on the Station's analysis and guarantee.

The system adopted by the Station is that which for twenty years has worked well in Connecticut, under the auspices of the State Agricultural Society and of the Board of Agriculture,—which has worked well although applied very imperfectly and at considerable intervals of time.

It is believed by the officers of the Station that when it is fully understood that there is in each town of the State one Farmers' Club, or at least one farmer who will take the trouble to communicate with the Station in respect to the fertilizers which are offered for sale, and when it is known that *the work of analysis will inevitably go on from year to year*, adulterations and frauds will be unheard of, and, what is equally important, the good articles will be sold at equitable rates.

It is believed also that a comparatively small number of analyses will accomplish this result, leaving the energies of the Station available, in good degree, for other and higher classes of work.

Publication of Results.—The fourth and fifth samples of fertilizers, brought to the Station for analysis August 11th, were a "Composition for Grass" and a "Composition for Vegetables," prepared and sold by Pollard Bros., 3 Custom House Square, New Haven. The results of the analyses of these articles were so worthy of immediate publication that the following Bulletins were prepared and copies* were dispatched to the editors of each newspaper in the State, so far as known to the Station, and to the Secretary of each Agricultural Society and Farmers' Club.

The matter of these Bulletins was widely copied by the press throughout the country, and stands as conclusive evidence that the Experiment Station was needed in this State this year.

Bulletin.

CONN. AGRICULTURAL EXPERIMENT STATION,
New Haven, Conn., Aug. 18th, 1877.

Analysis of "Composition for Grass," sold by Pollard Bros., Manufacturers and Dealers in Improved Fertilizers, 3 Custom House Square, New Haven, Ct.

Analysis on Barrels.

Organic and soluble plant food	86 per cent.
Inorganic matter	54 per cent.

Station Analysis and Valuation.

	Pounds per 100.	Pounds per ton.	Value per lb.	Value per ton.
Water	16.72	637.5		
Vegetable Matter	13.92	227.7		
(Nitrogen of Vegetable Mat.)	(.19)	(3.1)	18 cts.	56 cts.
Sand and Earth	65.27	1067.8		
Potash	.15	2.5	6 cts.	32 cts.
Soda	.23	2.8		
Lime	1.38	22.6		
Magnesia	.96	15.7		
Phosphoric Acid	.37	6.1	5 cts.	15 cts.
Carbonic Acid and Chlorine	1.00	16.4		

* Made by aid of Edison's Electrical Pen and Duplicating Press.

Value per ton, estimated	$ 1.03
Cost per ton	32.00

As analyzed, the sample contains but 4 *per cent.* of plant food. 96 per cent. is water, vegetable matter and earth, not worth barreling. The lime, magnesia and soda have indeed a small trade value, but since they accompany nitrogen, phosphoric acid and potash in all good high-priced fertilizers, their value is included in that of the last-named substances.

The "*pounds per ton*" statement includes, as water, the difference between the selling weight of 250 lbs. per bbl. and the actual weight, 204½ lbs.

S. W. JOHNSON, *Director.*

Bulletin.

CONN. AGRICULTURAL EXPERIMENT STATION,
New Haven, Conn., August 28, 1877.

Analysis of "Composition for Vegetables," sold by Pollard Brothers, 3 Custom House Square, New Haven, Conn.

Analysis on Barrels.

Organic and soluble plant food	73 per cent.
Inorganic matter	27 per cent.

Station Analysis and Valuation.

	Pounds in 100 dry.	Pounds in ton fresh.	Value per pound.	Value per ton.
Water	15.41	677.1		
Vegetable Matter	12.04	188.3		
(Nitrogen of Vegetable M.)	(.09)	(1.4)	18 cts.	25 cts.
Sand and Earth	68.12	1065.3		
Potash	.46	7.2	6 cts.	43 cts.
Soda	1.24	19.4		
Lime	1.41	22.0		
Magnesia	.88	13.8		
Phosphoric Acid	.39	6.1	5 cts.	31 cts.
Carbonic Acid and Chlorine,	.05	.8		

Value per ton, estimated	$ 0.99
Cost per ton	32.00

Since the barrel, stated to contain 250 lbs., weighed but 195½ lbs. owing presumably to loss of water, 1,564 lbs. of this "composition" as analyzed represent one ton of it fresh from the factory. In the fresh state it contains 2½ *per cent.* of plant food, or less than a good compost. This "Composition for Vegetables" strikingly resembles the "Composition for Grass," reported August 18, and contains in the ton of fresh substance the same amounts of sand and earth, of lime, magnesia, and phosphoric acid, with a little more water, potash and soda, and less vegetable matter.

S. W. JOHNSON, *Director.*

To call the attention of the press particularly to the character and significance of the Station's labors, the following circular letter was addressed to the editors of all the newspapers of the State, thirty seven in number, whose address was obtainable.

Circular Letter.

THE CONN. AGRICULTURAL EXPERIMENT STATION,
New Haven, Conn., August 28, 1877.

MR. EDITOR,—The analyses and investigations made at this Station, at the State expense, are items of news, of interest and importance to every farmer who uses Commercial Fertilizers or endeavors to apply science to his practice. The analyses are of especial interest because they give exact knowledge of the composition and trade-value of a class of articles of which little can be judged by appearance, and in which the gravest frauds are practised. The analysis of Pollard's "Composition for Grass," issued from this Station Aug. 18, and the accompanying analysis of a similar worthless article, illustrate the impositions to which our agriculture is exposed. The Station sends out its Bulletins simultaneously to every newspaper in the State. Their prompt publication, especially in the weekly papers, will insure the farmers getting this information in season to be of use.

May not the Station rely on your assistance in making the subject matter of its Bulletins accessible to every farmer in the State by immediate publication in your columns? Should you do so, please send a copy of your paper with the printed Bulletin, to the undersigned, so that the Station may possess the evidence of your coöperation, and be able to judge how extensively its investigations are appreciated. Yours very truly,

S. W. JOHNSON, *Director*.

The response to this letter was very prompt and encouraging in a number of cases, but not so in others, and the Station is unable to declare how large a proportion of Connecticut newspapers regard its Bulletins as entitled to immediate and complete reproduction in their columns.

The Station cannot with its present resources reach nearly all the farmers of the State, in any way except by this help of the local newspapers. If subscribers call for prompt publication of the Station Bulletins, there is no doubt that their wishes will be carefully attended to, and it rests therefore largely with the farmers themselves whether or no they receive the information which is designed for their benefit.

Another widely-known fertilizer was made the subject of a third Bulletin, which is as follows:

Bulletin.

CONNECTICUT AGRICULTURAL EXPERIMENT STATION,
New Haven, September 8, 1877.

A sample of Soluble Pacific guano lately obtained at Mount Carmel, Conn., has the following composition and valuation, according to the Station analysis:

	Pounds per hund.	Pounds per ton.	Value per pound.	Value per ton.
Nitrogen	2.43	48.6	20 cts.	$ 9.72
Soluble Phosphoric Acid	5.18	103.6	12½ cts.	12.95
Reverted "	.96	19.2	9 cts.	1.73
Insoluble "	6.12	122.4	5 cts.	6.12
Potash	1.63	32.6	7½ cts.	2.44
Moisture	19.88	397.6		

Total estimated value $32.96
Cost $45.00

This fertilizer comes in 200 pound packages. Five packages from which this sample was drawn weighed 1,006 pounds. The soluble Pacific guano is represented or guaranteed to contain:

Soluble Phosphoric Acid	4½ –8	per cent.
Reverted Phosphoric Acid	2 –5	"
Insoluble Phosphoric Acid	4 –6½	"
Potash-Soda	3 –5	"
Available Ammonia	2½ –3½	"
Nitrogen	2 1/10–2 9/10	"

With the highest per cents the value would be $54.60; with the lowest $31.75 per ton. This wide range of per cents corresponds to a difference in trade-value of $22.88 per ton. The mean per cents would make a value of $43.17 per ton.

S. W. JOHNSON, *Director*.

It may be mentioned that a second sample of soluble Pacific guano brought to the Station by Mr. Dickerman, the Agent, was analyzed without charge, and the analysis was found to agree substantially with that given above. The details of this second analysis are given on a subsequent page.

Early in October analyses had accumulated to the number of thirty, many of which were of sufficient interest to the agricultural public to justify their publication. It was difficult, however, to put them in suitable form for comparison on single page bulletins like those previously issued, and it was also desirable to circulate a larger number of copies than could be obtained without help of the printer. The Executive Committee therefore ordered to be prepared and struck off 1,500 copies of a "Bulletin for October, 1877." It will not be advantageous to reproduce this Bulletin literally in the Annual Report, because the matter of it will necessarily appear with additions on subsequent pages. It scarcely need be added that the October Bulletin was soon distributed, and that a much larger edition might have been printed to the advantage of the public, and would have been, had the Station's funds permitted the outlay.

These details as to the efforts made to secure publication of the Station work are entered into because it is as important to put valuable information promptly at the service of the people as it is to prosecute the labors which yield useful knowledge.

An Organ for the Experiment Station needed.—It is greatly to be regretted that Connecticut has not an agricultural paper of its own which might serve as the organ of the Experiment Station, and the means of weekly communication between it and the farmers who are to be benefited by its investigations, and it is to be earnestly hoped that some enterprise of the kind may soon be undertaken among us. A good practical journal would greatly support and aid the Station and promote the agriculture of the State. It can not be doubted also that the Station might largely contribute to give character and circulation to an agricultural paper conducted on sound and liberal principles. There is certainly a field for journalism quite unoccupied as yet in this country, viz: making accessible to American readers the fruits of the practical agricultural science that has been flourishing so vigorously abroad during the last five and twenty years, and the lack of knowledge of which, daily occasions immense loss and waste of labor and capital among us. In Germany no pains have been spared to facilitate intercourse between the Experiment Stations and the people. Not only have all the various agricultural papers and magazines been eager to serve as channels of publication but special journals have been established for the purpose. Since 1859 a bi-monthly journal entitled *Die Versuchs-Stationen* (The Experiment Stations) has been issued without interruption as the special organ of the Saxon Stations, and for a number of years the Prussian Board of Agriculture has annually published a large volume in bi-monthly parts, to embody the results of the investigations made in the Prussian Experiment Stations and agricultural schools. In Italy also a similar organ of the sixteen Experiment Stations of that country is issued at Turin.

While the Annual Report serves to publish the detailed results of the work of this Station, and while by means of bulletins and communications to the newspapers the more important results of investigation may be diffused, yet the Connecticut Experiment Station cannot reach its full efficiency until every farmer in the State is able to find in some one publication a ready means of learning promptly what is doing in the way of testing fertilizers, seeds, etc., and of asking and having answered in its columns questions which would not be appropriate nor timely in an annual volume.

Summary of Station Work.—The nature of the experiments and investigations undertaken at the Station is briefly specified in the following paragraphs:

Naturally, the Analysis of Fertilizers has been our chief occupation, because the advantages of that kind of work are widely appreciated by the citizens of the State, and the necessity for continued vigilance in respect to fraudulent or worthless articles, is liable to be illustrated anew every season.

Fifty-one samples of fertilizers have been analyzed and reported during the five months that have elapsed since preparations for this kind of work were completed. For details, see subsequent pages.

Mr. Jenkins has devoted some time to Seed-Testings and has examined thirty-two samples, most of them coming from the Department of Agriculture at Washington.

Of Feeding-Stuffs, nine samples have been analyzed.

Mr. Armsby has worked upon some of the Relations of Soils to Water.

The Methods of Fertilizer Analysis have been the subject of numerous experiments with a view to simplifying them and saving for other purposes a part of the labor and time now required in their execution. Already some decided improvements have been made in preparing the reagents required for the Estimation of Nitrogen. In respect to Phosphoric acid we are testing a process greatly simpler than those in use, and have in most cases obtained highly satisfactory results, but further investigation is needed to make it entirely trustworthy in general application, and its publication is therefore withheld for the present.

In addition to this experimental work, a not inconsiderable Correspondence has necessarily been attended to. This has consisted not only in the exchange of letters on current business, but also in responses to inquiries respecting the organization and work of the Station that have come from Boards of Agriculture, Official Committees and interested individuals in eight other States, and in answers to a great variety of questions on the value or use of fertilizers and kindred topics from practical farmers in this State not only, but in many others, from Maine to Texas.

Fertilizer Analyses.

During the six months of its existence, fifty-one analyses have been performed in the Station Laboratory, on fertilizers or substances used as such, viz. :

2 Pollard's compositions for grass and vegetables,
2 peat and bog ashes,
3 peats or swamp mucks,
1 pond mud,
3 native phosphates from South America,
7 bone manures,
2 tankings,
1 hair manure,
1 horn shavings,
2 blood fertilizers,
4 guanos or substances so-called,
4 superphosphates,
15 dried fish scraps or fish guano,
4 potash salts.

Of these fifty-one fertilizer analyses, twenty-five have been made for manufacturers, importers and dealers, and twenty-six have been made in the interest of consumers. The analyses that have any general interest are given below, and those that represent articles in the market are accompanied with a valuation.

The Pollard Fertilizers.—These are so-called fertilizers that were sold by, or on the representations of one H. M. Pollard, styling himself Agricultural Chemist, who during the Spring of 1877, established his head-quarters at New Haven and made a business of visiting farmers and proposing to inform them what applications were necessary to make their fields productive. He professed to analyze soils by smell and taste as well as by "chemicals" that he carried in his pockets, and thereby pretended to discover what was lacking in their composition or what needed to be supplied in order to remedy their deficiencies. This done, he wrote on the spot the prescriptions suited to each field or crop,

or undertook to compound a fertilizer suited to the case. He produced testimonials purporting to be from well known citizens of Rhode Island whose endorsement served to secure him an attentive hearing. The following are specimens of the applications he recommended upon a farm near New Haven. Each formula was for one acre.

For one lot:
100 pounds soda ash.
150 pounds stone lime.
60 pounds carbonate of potash.*
20 pounds copperas.
1 bushel salt.

For a second lot:
100 pounds lime-chalk.
100 pounds ground niter cake.
25 pounds copperas.
1½ bushel salt.

For a third lot:
The above and 200 pounds cotton seed meal.

For a fourth lot:
50 pounds soda ash.
100 pounds carbonate of lime.
50 pounds German salts.
30 pounds copperas.

For garden:
The last named and ten pounds dry soda.

Ability to make such nice distinctions between contiguous fields argues either wonderful wisdom or vast effrontery, and the appearance of wisdom was very well maintained for a while.

H. M. Pollard having visited Naugatuck and vicinity and excited the interest of the farmers there, Mr. M. S. Baldwin, Secretary of the Naugatuck Farmers' Club, inspected the "works" of "Pollard Bros." in New Haven, who were prepared to furnish a considerable quantity of fertilizer, adapted to the farms of Naugatuck and at a low price. Mr. Baldwin informed the Station by letter under date of August 22d, that on reaching the "purported manufactory at 3 Custom House Square, he found an unoccupied building, but nought to indicate any business except a bright new-looking sign over the door of 'Pollard Bros. Improved Fertilizers.'

* See Carbonate of Potash, p. 44.

On inquiry found they were operating on ground formerly overflowed by tide water between the New Depot and Meadow Street. On reaching their place early in the day, found no one about but saw where the surface of the ground had been removed and under a shed close by were heaps of sand and mud that appeared to be mixed from this surface soil and to be the basis of the fertilizer; consequently none of the fertilizer was ordered."

The "Composition for Grass" and "Composition for Vegetables," whose analyses are subjoined, were taken from barrels in the hands of a purchaser at Mt. Carmel. The samples were drawn August 10th, by Mr. Webb, Chairman of the Executive Committee of the Station. See also pp. 22, 23.

	Composition for Vegetables.	Composition for Grass.	HARBOR MUD.
	POLLARD BROS., 3 Custom House Sq., New Haven.		L. Wharf, N. Haven, 1860.
Station No.	**4**	**5**	**H. M.**
Moisture	15.41	16.72	Dried at 212°
Organic and Volatile Matters	12.04	13.92	10.56
Nitrogen	(.09)	(.19)	(.52)
Sand and Insoluble	} 68.12	} 65.27	77.21*
Soluble Silica			.42
Oxides of Iron and Alumina			7.36
Lime	1.41	1.38	.73
Magnesia	.88	.96	.73
Potash	.46	.15	.77
Soda	1.24	.23	.80
Sulphuric Acid	*trace*	*trace*	.96
Phosphoric Acid	.39	.37	.03
Chlorine and Carbonic Acid	.05*	1.00*	.43
	100.00	100.00	100.00
Estimated Value	$ .99	$ 1.03	
Cost	$32.00	$32.00	

The analysis **H. M.** which is given above represents the composition of a sample of New Haven harbor mud dredged up off Long Wharf in 1860. The analysis was made on the fresh mud by W. H. Bergen, Esq., then studying Analytical Chemistry under the writer's tuition. On comparing the analyses 4 and 5 with **H. M.**, making allowance for the water in Pollard's Composition, it is seen that the harbor mud, if mixed with one per cent. of bone-ashes and one per cent. of oyster shell lime would equal or surpass these "improved fertilizers" in every respect.

* By difference.

It is scarcely needful to mention that on the publication of these analyses, H. M. Pollard ceased his operations in this State. The newspapers that had advertised his fertilizers without payment, advertised his character gratuitously, and the last intelligence of his operations came from the Springfield, Mass., jail.

Ashes of Bogs and Peat.

21 from P. M. Augur, Esq., Secretary of the Middlefield Farmers' Club, is the residue after burning the "bogs" or hummocks of coarse grass or sedge that grow in swamps.

44 is the ashes of peat (muck) from Mr. John Davis, of North Stonington. The swamp of 100 acres, more or less, has several small streams running through it and one outlet. It is flooded in wet times and is frequently dry in summer.

The other analyses—from my Report to the Conn. State Agricultural Society in 1858, and from "Peat and its Uses as Fuel and Fertilizer"—serve for comparison.

	BOG ASHES.	PEAT OR SWAMP MUCK ASHES.			
	Middlefield.	Nor. Stonington.	Poquonock, '57.	Colebro'k, '57.	Guilford.
Station No.	**21**	**44**			
Moisture	4.10	6.29	----	----	----
Sand and Insoluble	} 77.50	90.11	20.34	16.44	64.85
Soluble Silica					
Oxides of Iron and Alumina	12.59	3.46	5.17	9.08	15.59
Lime	2.06	trace	40.52	35.59	6.60
Magnesia	1.11	.13	6.06	4.92	1.05
Potash	.51	none	.69	.80	3.46
Soda	.29	"	.58	----	trace
Sulphuric Acid	.72	trace	5.52	10.41	4.04
Phosphoric Acid	.55	.22	.50	.77	1.55
Chlorine	} .57*	trace	.15	.43	.70*
Carbonic Acid			19.60	22.28	2.16
	100.00	100.21	100.13	100.72	100.00

The Bog Ashes, **21**, consist chiefly of sand and soil (90 per cent.) but, with 2 per cent. of lime, 1 of magnesia, and one-half per cent. or more each of potash, of phosphoric acid and of sulphuric acid, have considerable fertilizing value.

The Peat Ashes, **44**, are almost completely destitute of plant-food; they contain but one-third per cent. of lime and phosphoric acid, and are practically worthless.

* By difference.

The other analyses show that some peat-ashes are rich in carbonates of lime and magnesia, and sulphate of lime. Generally, however, such richness in plant-food belongs only to the ashes obtained from the burning of small undrained peat-basins, where much leaf mold has accumulated, or else to the result of firing the surface of swamps that have carried a copious shrubby vegetation. The Guilford sample, with 3½ per cent. of potash, was of the kind last named.

Swamp Muck or Peat.

Three samples of this material, so abundant in Connecticut, have been sent in for examination.

	Station No.	Water.	Organic and Volatile.	Ash and Soil.	Nitrogen.	Locality.
Swamp Muck, air-dried	1	11.57	55.95	32.48	1.65	Westbrook.
The same, water-free			63.27	36.73	1.87	
Peat, newly dug, wet	10	85.00	13.17	1.83	.30	Ashford.
The same, water-free			87.80	12.20	2.00	
Peat, dug one year ago, very moist	11	71.17	26.66	2.17	.41	Ashford.
The same, water-free			92.47	7.53	1.43	

1 from the farm of H. P. Hoadley, Esq., at Westbrook, lies close by the cattle yard and barns, and is easy to raise. It is confidently recommended as an excellent material for litter in the stables, as well as to compost with white-fish and sea-weed. Notwithstanding its large admixture with sand and soil (34 per cent.) it is rich in nitrogen. The organic matter itself contains 2.95 per cent. of this element.

10 and **11** were sent by Mr. J. D. Gaylord, of Ashford, as of interest to a number of farmers of that place. **10**, just taken out of the swamp, was fully saturated with water. **11** had been lying in a heap for a year. The water had diminished by this long exposure but 14 per cent., and while both samples contain a good proportion of nitrogen in the dry substance, they are heavily ballasted with water, and therefore will not bear expensive handling or long transportation. Farmers who are considering the use of swamp-muck would do well to figure the cost of its application against that of plowing in green crops, such as buckwheat and rye. The latter, under many circumstances, may prove the cheaper amendment.

Pond and Harbor Mud and Soil.

A sample of Pond Mud was sent by Mr. G. A. Penniman, of North Woodstock, with regard to which the question was asked, would its transportation to a neighboring farm to use as a fertilizer and absorbent prove remunerative? A very full analysis was undertaken with a view of obtaining data that might assist to answer this question, and that would also contribute something towards a knowledge of the composition of Connecticut soils. The mud is simply the finer surface soil of the country whose wash enters the pond, and its composition has a certain bearing upon the value of the adjacent lands. For purposes of comparison the analysis of this fresh water deposit is stated by the side of that of harbor mud already quoted. The composition of a sample of soil from the farm of Smith Terrill, Esq., of Seymour, is also given. This soil is stated to represent a considerable area of land in its vicinity.

Lastly, the composition of a highly fertile and durable wheat soil of Illinois is appended, made by Mr. M. A. Scovell, Chief Chemical Assistant in the Illinois Industrial University, and communicated to me by Professors Morrow and Weber.

	Pond Mud. North Woodstock.	Harbor Mud. L. Wharf, N. Haven, 1860.	Soil. Seymour.	Best Wheat Soil. Illinois.
Station No.	8	H. M.	38	W. S.
Moisture	7.000	Dried at 212°	4.240	Dried.
Organic and Volatile Matters	10.000	10.56	9.390	5.688
Nitrogen	(.260)	(.52)	(.089)	undet
Sand and Insoluble	77.024*	77.21	80.591*	89.471
Soluble Silica	.088	.42	.094	.063
Oxides of Iron and Alumina	4.470	7.36	4.830	3.575
Lime	.248	.73	.522	.505
Magnesia	.821	.73	.189	.042
Potash	.242	.77	.028	.043
Soda	.041	.80	.017	.012
Sulphuric Acid	trace	.96	.053	.134
Phosphoric Acid	.066	.03	.046	.232
Chlorine and Carbonic Acid	trace	.43	----	.235
	100.00	100.00	100.000	100.000

The Pond mud is seen to have in most respects the composition of a fertile soil. It contains considerable mica, evident to the eye

* By difference.

in the form of glistening scales. To this mineral it probably owes its large proportion of magnesia (0.821 per cent.), and of potash (0.242). To the leaf mold and decayed wood found in it, or perhaps to animal matters, is due its large content of nitrogen (0.260). It is not deficient in lime nor in phosphoric acid, but is almost destitute of sulphates. It would, so far as can be judged from the analysis, make an excellent top-dressing to most of the lighter or coarser-textured soils of this State, but it would not repay much handling or cartage to any considerable distance.

The Harbor mud is noticeable as having an amount of nitrogen (0.59), equal to that of ordinary yard or stable manure. This is in part due to the various minute animals with which this material usually teems. With exception of phosphoric acid, the Harbor mud is uniformly rich in plant-food, and it forms an efficient means of fertilizing shore lands, although it will not bear great expense in application. The soil-analyses are given here solely for the purpose of comparison. The Seymour soil contains but one-third as much nitrogen as the pond deposite, and but one-sixth as much as the harbor mud; of lime it contains a good supply, more than the prairie soil, but less than the harbor mud; its magnesia is abundant, but less than that of either of the muds; in potash it falls behind the mud; and yet the wheat soil contains but one-third more of this element.

These analyses do not probably convey a just idea of the availability to crops of the plant-food present, however well they exhibit the comparative amounts. In considering the soil-analyses it must be remembered that the Seymour soil is coarse in texture and is underlaid at a little depth by a compact yellow hard-pan, while the wheat soil has a texture as excellent and a depth as great as its productiveness is extraordinary. Drainage and deep tillage would probably do more for 38 than any quantity of manures.*

Bone Manures.

Eight samples of bone dust or ground bone have been examined. The subjoined table gives the results of their chemical and mechanical analysis.

* Since the above was written, Mr. Terrill informs me that the land is moist or wet on account of its situation. In 1872 seven acres of it were top-dressed with 1,100 bushels of screenings of oyster shell lime. The land responds well to stable manure. Recent crops, rye and timothy, have not done well, but the ox-eye daisy (*Leucanthemum vulgare*) has taken possession. Plainly, then, so far as these facts represent the case, the soil needs drying and deepening. Further studies as to the amount of clay, etc. in this soil are in progress.

Brand.	Station Number.	Phos. Acid.	Nitrogen.	Finer than				Coarser than	Estimated Value.	Cost.
				$\frac{1}{50}$ in.	$\frac{1}{25}$ in.	$\frac{1}{12}$ in.	$\frac{1}{6}$ in.	$\frac{1}{6}$ in.		
Dean's Pure Ground Bone --	**14**	19.94	3.80	28	8	12	17	35	$31.40	$30.00
Lister's Ground Bone --	**24**	24.10	3.49	76	18	6	--	--	46.30	38.00
Bird's Ground Bone --	**25**	22.60	3.48	17	4	6	7	66	33.04	35.00
Peter Cooper's Coarse Bone---	**27**	29.51	0.95	59	6	9	10	16	44.73	25.00
Peter Cooper's Fine Bone-----	**28**	19.04	1.91	62	4	6	3	25	33.54	30.00
Peter Cooper's Ground Bone --	**33**	28.91	1.65	67	6	8	6	13	46.41	30.00
Struble's Bone Dust-----	**34**	11.76	6.22	37	11	18	16	18	38.85	35.00
Tankings -------	**29**	13.79	4.32	--	--	-	--	--	34.86	?
Tankings -------	**53**	13.68	6.06	42	9	17	14	18	40.97	22.00

The estimated values (see p. 18) in every case except **25**, are higher than the cost. Accordingly, the rates at which the nitrogen and phosphoric acid of this class of fertilizers have been valued may be lowered. The rates used in these valuations are as follows for the above articles. The sources whence the bone manures were obtained are also specified below:

Name.	Station No.	Estimated value per lb. of		Dealer.	Sent by
		Phos. Acid.	Nitrogen		
Dean's ----	**14**	5 cents.	15 cents.	G. M. Dean, Springfield, Ms.	Andrews' Brothers, Southington,
Lister's ---	**24**	7 "	18 "	John S. Wells, Hebron.	S. F. West, Columbia.
Bird's ----	**25**	5 "	15 "	James Bird, Naugatuck.	Sec'y Farmers' Club, Naugatuck.
P. Cooper's	**27**	7 "	18 "	Pet'r Cooper, N. Y. City.	Smith Terrill, Seymour.
P. Cooper's	**28**	7 "	18	Pet'r Cooper, N. Y. City.	Smith Terrill, Seymour.
P. Cooper's	**33**	7 "	18 "	Pet'r Cooper, N. Y. City.	Dennis Fenn, Milford.
Struble's*	**34**	7 "	18 "	Wm. A. Carson, New York City.	Dennis Fenn, Milford.
Tankings--	**29**	7 "	18 "	Not in market.	Russell Coe, Meriden.
Tankings--	**53**	7 "	18 "	Toby & Booth, Chicago.	Burritt Eaton, Kent.

The estimated value of the fertilizing elements is proportioned to the mechanical fineness of the article containing them. Bird's

* Made by O'Neil & Co., Jersey City.

ground bone is pure but very coarse; for that reason its value is relatively less than that of the better ground brands. There is reason to suppose that the designations "coarse" and "fine" applied to **27** and **28**, as well as the selling prices, have by accident been exchanged. **27** is really finer and better than **28**, and should have the better price in market.

The "Tankings" are a mixture of bone and other animal matters and connect bone manures with the blood and meat fertilizers, which often contain some bone.

Taking together Lister's and Cooper's bone manures, we find that their average cost is $30.75, their average content of nitrogen is 2.00 per cent., of phosphoric acid 25.4 per cent. Multiplying these percentages respectively by 15 and 5 cents and the sum of the products by 20, we have the final product $31.40. Accordingly, the prices of 15 cents per pound for their nitrogen and 5 cents for their phosphoric acid, cover their cost in market. But these brands are quite variable in composition, and for that reason should sell lower than an article whose content of fertilizing elements is steady and can presumably be judged of without an analysis of every lot.

The Tankings, **29**, were analyzed for a private party, and the Station has no information as to source or cost.

Sample **53** is stated to be procurable in Chicago for $13 per ton, and to cost some $9 for freight to this State. At that price the cost of the nitrogen would be about 10½ cents and phosphoric acid 3½ cents per pound. The sample **53** contained but 5 per cent. of moisture. Most probably the material sent to fill an order would not be so dry, and might be so wet as to largely diminish the valuation.

Blood, Hair and Horn Manures.

Four fertilizers of this class have been analyzed, viz:

	Station No.	Moisture.	Nitrogen.	Phosphoric Acid.	Estimated Value.	Cost.	Dealer.
Blood Fertilizer	**30**	26.37	6.22	6.36	$33.78	$30.00	Sperry & Barnes, New Haven.
Blood Fertilizer	**31**	8.13	9.09	3.36	41.06	30.00	Strong, Barnes, Hart & Co., New Haven.
Hair Manure	**26**	24.61	7.90	2.23	25.93	12.00	Peter Cooper, New York.
Horn Shavings	**42**	22.33	12.32	----	36.96	20.00	Staples & Davis, Monroe.

The blood fertilizers, brought in by J. J. Webb, Esq., even when containing one-fourth their weight of water, are ahead of valuation, with phosphoric acid rated at 7 cents and nitrogen at 20 cents per pound. The average content of nitrogen in them is 7.65 per cent., the average of phosphoric acid is 4.86 per cent. These quantities multiplied by 15 cents and 5 cents, and then by 20, give a product of $32.40, so that the market prices of nitrogen and phosphoric acid in blood may be reduced to 15 cents and 5 cents respectively.

In hair manure, sent by Mr. Smith Terrill of Seymour, and horn shavings, sent by Mr. James Burr of Monroe, we have articles which, though containing much moisture, give a valuation nearly double the cost when nitrogen is rated at 15 cents and phosphoric acid at 5 cents per pound. Their average valuation is $31.45 and average cost $16.00. In these two articles, therefore, we have nitrogen purchasable at nearly half the received rates, viz: in hair at 10 cents, and in horn shavings at 7½ cents per pound.

Guanos.

Four samples of fertilizers bearing this trade title have been examined.

	Station No.	Soluble Phos. Acid.	Reverted Phos. Acid.	Insoluble Phos. Acid.	Potash.	Nitrogen	Estimated Value.	Cost.	Dealer.
"Soluble Pacific Guano"	**9**	5.18	0.96	6.12	1.63	2.43	$32.96	$45.00	J. H. Dickerman, Mt. Carmel.
"Soluble Pacific Guano"	**40**	6.05	1.41	5.35	0.89	2.39	33.92	45.00	J. H. Dickerman, Mt. Carmel.
Peruv. Guano, Standard	**13**	5.47	5.20	4.99	4.21	8.62	58.22	53.50	C. L. Willard, Hartford.
Phœnix Guano	**51**	----	----	20.71	----	0.69	23.47	35.00	Haven, Williams & Co., New London.

9 was sampled by J. J. Webb, and **40** by J. H. Dickerman. **13** was sent by Andrews' Brothers, Southington, and **51** by N. S. Platt, Cheshire.

The analysis of **40** confirms the correctness of the analysis of **9**, which was the subject of a Station Bulletin issued Sept. 8th, 1877. In that Bulletin (see p. 25) it was shown that while the Pacific Guano Co. guarantee the composition of the Pacific Guano, which they manufacture, the guarantee is so made that the estimated value of the Pacific Guano may be as high as $54.69, or as low as $31.75 per ton. The mean value would be $43.17. They charge the mean value, or $45.00 for their fertilizer, but they furnish little more than the minimum guaranteed value, so that the purchasers of the lot represented by these samples have paid $11.00 or $12.00 per ton for it more than the same fertilizing elements in the same forms and condition can be bought for in market.

The Phœnix Guano, **51**, has been analyzed more completely than appears from the above tabular statement. Its detailed composition is as follows:

Phosphate of lime (tricalcic phosphate)	45.21
Carbonate of lime	17.70
Sulphate of lime (gypsum)	7.80
Water expelled at 100°	14.47
Organic matters and combined water	11.30
Undetermined matters by difference	3.52
	100.00

In the valuation its phosphoric acid has been reckoned at 5 cents and its nitrogen at 20 cents per lb.

The "Standard Peruvian Guano" maintains its character in the sample **13**.

Fish Manures.

It is well known that large quantities of Menhaden (*Clupea menhaden*), also called by the names bony fish, pogie, moss bunker, hard head and white fish, are taken during the warm season in the waters of Long Island Sound and along the sea coast from Maine to the Carolinas. From early times these fish have been used by Indians and farmers on the coast as a fertilizer, applied fresh to maize in or rather near the hill and also for making composts.

Thirty years ago the Menhaden were also caught for the extraction of the oil, of which they yield, by the process now commonly employed, from one-half gallon to fifteen gallons per 1,000 fish. From Virginia to Rhode Island the average is four gallons, for the Maine coast it is seven gallons per 1,000. The process formerly used for extraction was simply to throw the fish into large tanks and allow them to decompose. The oil rose to the surface of the putrid mass. The first attempts that I am aware of to dry the fish and convert them into a portable and inoffensive

fertilizer were made in East Haven, Conn., as early as 1848. The record books of Professor John P. Norton, show that in that year, samples of dried fish were examined in his laboratory. In 1850 a sample of "white fish dried for manure by Mr. Lewis," was found by W. H. Brewer to contain 8.53 per cent. water and 10.23 per cent. nitrogen.

Mr. W. D. Hall of Wallingford, achieved the first practical success in this direction in 1853. He discovered how the oil might be extracted from the fresh fish in a few hours' treatment, leaving the "pomace" or "scrap" in such a condition of half-dryness that it could be stored or barreled and transported at once, or could be further dried by exposure to the sun and converted by grinding into "fish guano." From that time the manufacture of Menhaden oil and fish scrap or fish guano has gone on increasing until now the business is an important item in the industry of the country. In 1873, 88,200,000 Menhaden were taken on the Connecticut shores, and 82,700,000 on the shores of Long Island. These yielded 17,090 tons of scrap and 601,100 gallons of oil, valued at $543,935.

The published reports of the U. S. Menhaden Oil and Guano Association give the following statistics for the Menhaden fisheries of the entire Atlantic coast.

	1874.	1875.	1876.	1877.
No. of factories in operation,	64	60	64	56
No. of men employed,	2,438	2,633	2,758	2,631
No. of sailing vessels employed,	283	304	320	270
No. of steam vessels employed,	25	39	46	63
No. of fish caught,	492,878,000	563,327,000	512,450.000	587,624,125
No of barrels caught,	1,642,927	1.877,767	1,535,885	1,958.747
No. of gallons of oil made,	3,372,847	2,681,487	2,992,000	2,426,589
No. of tons of crude guano or green scrap made,	50.976	53,625	51,215	55,444
Am't of capital invested,	$2,500,000	$2,650,000	$2,750,000	$2,047,612

During the season of 1877, eight factories have not been in operation, and their capital is not included in the statistics for that year.

The measurements and estimates in use among the Menhaden manufacturers are the following:

1 ton (2,000 lbs.) is reckoned the weight of 3,000 fish.

2½ tons of fish yield 1 ton (40 per cent.) of green scrap, pomace, chum or crude guano.

3 tons of fish yield 1 ton (33 per cent.) of half-dry scrap.

5 tons of fish yield 1 ton (20 per cent.) of dry scrap or guano.

The green scrap or crude guano contains 55 to 60 per cent. of water.

The half-dry scrap contains 40 to 50 per cent. of water.

The dry guano contains 10 to 20 per cent. of water.

The coarse "half-dry scrap" and the "dry fish," "dry ground fish" or "fish guano," are considerably used by farmers, but by far the larger quantity of the scrap is made up into various superphosphates, soluble Pacific guano and the like, by admixture with ground Carolina rock phosphate, or bone black and oil of vitriol, and often with potash salts. While the fertilizers thus prepared are—the best of them—excellent as regards solubility and promptness of action, as well as fineness of pulverization and convenience in use, there can be no doubt that the half-dry fish scrap itself or the dry ground fish guano, is in many cases a cheaper fertilizer than the superphosphates.

The amount of dry guano made in 1877 was 6,010 tons. The quantity of guano held by the manufacturers, Jan. 9th, 1878, was but 2,340 tons. At present writing (Jan. 1878), the prices of fish are, for half-dry scrap (very scarce) $15 to $20 per ton, for dry ground guano, delivered at railroad stations in bags, per single ton $40, in lots of ten or more tons $35. Cargo lots bring $30 per ton at works in bulk, unground.

Analyses of Fish Guano.

The following fifteen analyses of dry ground fish were chiefly made for wholesale dealers, and mostly on samples representing cargoes of considerable amount. The large transactions in this material are based on the percentage of nitrogen it contains without regard to the phosphoric acid. The analyses show the range of variation in the moisture and nitrogen to which the "fish guano" or "dry ground fish" is subject. The phosphoric acid in the dry fish averages about 7 per cent.

The average amount of nitrogen obtained in fourteen samples of Dry Fish at the Middletown Station, in 1875 and 1876, was 7.80 per cent., the average moisture 11.78 per cent. The fish of 1877 appear to have yielded a richer scrap than in the previous years; they were also poorer in oil, according to the reports of the manufacturers.

	Station No.	Moisture.	Nitrogen.	Nitrogen in water-free fish.	Oil.
Dry Ground Fish Scrap	2	10.75	8.52	9.54	
" " " "	12	----	8.21		
" " " " old, 1876	15	16.59	7.35	8.81	
" " " " new, 1877	16	23.95	7.30	9.59	
" " " "	17	----	9.26		
" " " "	18	----	8.77		
" " " "	22	19.57	7.98	9.92	
" " " "	43	9.03	8.04	8.83	
" " " "	45	11.38	8.51	9.60	
" " " "	46	10.74	8.43	9.44	
" " " "	50	9.76	7.77	8.61	8.94
" " " "	52	11.19	8.78	9.88	7.30
Average		13.66	8.24	9.36	8.12
Fish by Adamson's Process	36	4.91	10.78	11.32	2.07
" " " "	39	3.67	10.74	11.15	
" " Goodale's "	41	11.45	10.24	11.56	4.64

The extraction of the oil by the usual process of steaming and submitting the cooked fish to hydraulic pressure is by no means complete. The Dry Fish Scrap still contains 7 to 15 per cent. of oil. Two patented processes may be applied to effect a more perfect separation of the oil from the scrap. One of these, the Adamson process, depends upon the use of hot petroleum naphtha or benzine, to dissolve the oil. The vapor of the boiling naphtha is directed upon the unbroken fresh fish. The operation is said to be very simple and effectual. The oil may be very completely extracted and is of very superior quality. The residual scrap is left in a state admitting of easy drying. The drawback to this process consists in the necessity for a costly new apparatus and the abandonment of a good share of the appliances now used. The analyses 36 and 39 of Fish prepared by this method show in the scrap a gain of 2½ per cent. of nitrogen and a diminution of 10 per cent. water over the old process; at the same time the drier residue contains but 2 per cent. of oil. The other improved plan of working is the invention of Hon. S. L. Goodale, of Saco, Me., formerly Secretary of the Board of Agriculture of that State. It is described as a simple modification of the usual treatment and as seen by the analysis 41 gives a scrap which when equally dry is no less rich in nitrogen than that yielded by Adamson's process, and contains but 4.6 per cent. of oil.

Potash Salts.

Three analyses of commercial potash salts have been executed.

	Station No.	Potash.	Muriate of Potash.	Sulphate of Potash.	Bisulphate of Potash.	Estimated Value.	Cost.	Dealer.
Muriate of Potash...	**19**	51.97	82.31	....	....	$62.00	$55.00	Southmayd & Gardiner, Middletown.
"Sulphate of Potash"	**20**	42.31	21.87	30.16	35.27	63.46	65.00	Southmayd & Gardiner, Middletown.
Kainite	**48**	11 54	....	....	....			Not in market.

19 and **20** were sent by Hon. P. M. Augur, Secretary of the Middlefield Farmers' Club. **19** is a high grade (82 per cent.) muriate of potash. **20** if judged simply by its content of potash would pass for a high grade (78 per cent.) sulphate of potash. It is in fact chiefly sulphate of potash, but is not what that name commonly implies. There are two sulphates of potash, one of these is the *neutral sulphate*, which is produced when sulphuric acid and potash combine chemically in such proportions as to neutralize the highly caustic and corrosive qualities which they separately possess. This is sulphate of potash, properly speaking, and is the salt which the farmer should expect to obtain when he buys a fertilizer of this name. It has no acid or alkaline qualities, and when properly used is harmless to vegetation. The other compound is the *acid sulphate* or *bisulphate of potash*. It is in fact a compound of neutral sulphate of potash with sulphuric acid, and in it the acid properties of sulphuric acid are strongly manifest. It has a *sharp*, *sour*, as well as *bitter* taste, is corrosive and positively blighting and destructive to young vegetation with which it comes in contact. The sample **20** yields to water 35 per cent. of bisulphate, and this explains the fact that where it was used, as a fertilizer, it acted as a poison to the crops, retarding their growth and greatly diminishing the produce. Mr. Augur writes as follows, regarding its action in his fields:

"The sulphate of potash was used last May on land naturally moist, for potatoes principally, at the rate of nearly 200 lbs. per acre, mixed with 250 lbs. dried blood, 250 lbs. finely-ground bone dust, and 200 lbs. of gypsum. The mixture was applied in drills opened with a broad sward plow, and was scattered very thinly in the drills and somewhat over the general surface so that when the application was made the whole ground looked white. The potatoes were dropped by hand and covered with a harrow. Where the potash was used the potatoes were a long time in coming up so as to show the rows, and for equal areas the crop was not more than one-third as much as from five rows on the side of the field where the potash was left out."

Mr. Augur's planting of two kinds of squashes and six varieties of melons resulted in total failure where the sulphate was used. This acid sulphate is furthermore objectionable because it is very imperfectly pulverized and therefore does not admit of rapid and uniform distribution. It contains a large proportion of hard lumps which dissolve slowly in water, and would require weeks for their solution and diffusion in the soil. If the substance had been reduced to the fineness of flour the ill-effects would have been much less noticeable, and might have been altogether obviated by applying the salt a week or two before planting, so as to get the distributing effect of rain, or by mixture with an equal bulk of leached ashes or other carbonate of lime and wetting the mass, whereby the acid sulphate is converted into neutral sulphate, with formation of sulphate of lime.

Great pains should always be taken in the use of saline fertilizers that are freely soluble in water, to insure their perfect distribution in the soil, because even the harmless and nutritious salts, which are essential to growth, have a retarding effect on vegetation unless presented to the plant in a state of great dilution. This acid sulphate of potash has been used to sprinkle on stable floors and compost heaps for retaining ammonia. Its sale as a fertilizer, without caution as to its corrosive qualities is a proceeding that will as certainly injure dealers as it does consumers. The valuation given in the Station's October Bulletin was $67.68, and was based on the estimated value of 9 cents per pound for potash in the form of high grade sulphate. The potash is equivalent to 78 per cent. of sulphate, but in fact only 30 per cent. of sulphate is present, the remainder being muriate and bisulphate, and it would be more correct to call its potash worth 7½ cents, as in kainite. This would make its valuation $63.46, as above given. Sold as sulphate, however, without notice of its real nature, it plainly is a subject not for valuation but for damages.

A few words as to the valuation of Potash in the Potash Salts. In **19** the valuation is based upon the estimate of 6 cts. per lb. for potash in the form of high grade muriate. In fact, however, the cost of potash in it is but 5¼ cts. per lb.

The 28th of September last the Treasurer of the New Haven Chemical Co., who has for years imported large quantities of potash salts for manufacturing purposes, informed me that muriate of potash containing 50 per cent. potash, costs to import in quantities of 50 to 100 tons, $1.50 to $1.55 gold, per 100 lbs. He wrote, "we sell it for 2¼ to 2½ cts. per pound in small quantities." This retail price equals 4½ to 5 cts. per lb. for potash, at New Haven.

In 20, considered as a high grade (78 per cent.) sulphate of potash,—a more costly salt to produce than the muriate—potash costs $7\frac{7}{10}$ cts. per lb. The New Haven Chemical Company offered September 28th a lower grade (56 per cent.) sulphate of potash containing 30 per cent. potash at $2.00 per 100 lbs., which furnishes potash partly in the form of sulphate, probably also to some extent as muriate, at $6\frac{6}{10}$ cts. per lb.

Pollard's Carbonate of Potash.

One other Potash Fertilizer has been submitted to the Station for analysis, by Hiram Camp, Esq., of New Haven. It was supplied by H. M. Pollard, as Carbonate of Potash, to help make up one of the formulae given on page 29, and was offered "at cost." This cost was $4.00 per 100 lbs. The sample on analysis gave the subjoined composition:

Potash,	1.76
Soda,	29.04
Sulphuric acid (SO_3),	47.25
Carbonic acid,	none
Sand,	7.28
Water, with a little iron, lime, magnesia and chlorine,	14.67
	100.00

The above results of analysis justify the following statement of the mode of combination of the elements:

Carbonate of potash,	none
Sulphate of potash,	3.25
Sulphate of soda,	51.77
Bisulphate of soda,	24.90
Sand,	7.28
Water, with a little iron, magnesium, and calcium chlorides,	12.80
	100.00

This "Carbonate of Potash" is thus seen to contain no carbonate of any kind and but 1.76 per cent. of potash. It is probably a mixture of kainite (with 12 per cent. of potash) and "niter cake," a cheap chemical, in the proportion of 15 of the former to 85 of the latter. It yields to water 25 per cent. of corrosive bisulphate of soda. Ground niter cake can be bought at 80 cts., and kainite at 90 cts. per 100 lbs. The real commercial value of the article is therefore not more than 85 cts. per hundred, instead of $4.00, the price paid for it.

Examination of Seeds.

The Station's Instructions for sampling seeds, are as follows:

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION, NEW HAVEN, CONN.

Instructions for Sampling Seeds.

The Agricultural value of seeds intended for Farm and Garden use is learned by examining a small average sample. A weighed amount of seed is taken, the pure seeds are culled out and weighed, foreign matters and especially noxious seeds are identified, the vitality of the pure seeds is tested by careful sprouting trials and a report is drawn up of the results.

As the test of germinating power requires some time for its completion, a report on samples sent in cannot be ordinarily expected in less than two weeks.

The examination of *grass-mixtures* can only be undertaken in special cases. It requires a large outlay of time and labor which is not often justified by the results.

In selecting a sample for examination the greatest care should be used to have it represent accurately the whole amount from which it was taken.

1. Mix well together with the hand and arm the contents of the package (bag or barrel) or packages of seed.

2. Take out five or six small handfuls or cupfuls* from various parts of the package, mix these together and take a part of this mixture for the sample.

3. Send of the smaller seeds—red top, white clover, timothy, etc., two (2) ounces; of beets, turnips, red clover, etc., four (4) ounces; of wheat and cereals, and of peas and other legumes, eight (8) ounces.

4. Samples may be sent by mail, or otherwise, prepaid, and should be *plainly labeled* and addressed to

CONN. AGRICULTURAL EXPERIMENT STATION,
New Haven, Conn.

* (A small cup may be closed with the palm of the hand, forced down to the desired place, then filled and withdrawn.)

Seeds sent in for Examination must be described on the subjoined Form.

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION, NEW HAVEN, CONN.

Form for Description of Sample.

STATION NO. REC'D AT STATION, 18

Each sample of Seed sent for examination must be accompanied by one of these forms, with the blanks *below* filled out fully and legibly.

The filled out Form, if sent with the sample, will serve as a label; but it must be returned in good order for filing in the Station Records.

Send with each sample a specimen of any printed circular, or statement that accompanies the seed or is used in its sale.

Name or label of seed,
Name and address of Dealer from whose stock this sample is taken,
Date of taking this Sample,
Selling price per pound or bushel,
Known or reputed age of seed,
Number of packages from which sample is taken,
Quantity of stock which the sample represents,
Was sample taken according to Station Instructions, or how?
Signature and P. O. address of person taking and sending the sample.

The results of the examinations are entered in a suitable record book, and are also reported to the parties sending, on forms of which the following is an example.

Report of Seed Test.

CONNECTICUT AGRICULTURAL EXPERIMENT STATION,

New Haven, Conn., Jan. 9, 1878.

Examination of Kentucky Blue Grass (*Poa pratensis*, L.).
Sample No. 31. Received Nov. 28, 1878. From
Impurities, 7.59 per cent. by weight.
The foreign matter consists chiefly of chaff. A few seeds of a sedge (*Carex rosea*, Schk.) are present.

	This sample contains	Av. of previous examinations.
Pure Seed, per cent. by weight,	92.41	51.67
Pure Seed, capable of germination, per cent. by number,	5.	11.
Time of germination, days,	13.	8.
Per cent. value,	4.62	5.68
1000 Seeds weigh (in grams)	0.174	0.148

S. W. JOHNSON, *Director.*

Explanations and Remarks.

Seeds used in agriculture and horticulture suffer more or less rapid deterioration by keeping. It is written in agricultural books that the seeds of rye, oats, barley, maize, clover, timothy and rye grass, remain good but two years, wheat and cole-seed three years, hemp and flax four years; and if these statements are not exact, they still express the fact that new seed is good and old seed is poor. Commercial seeds are often impure. They may contain matters like chaff and dirt, which are harmless except as they are paid for at the same rate as pure seed. They may also contain an admixture of old seeds, which have no vitality, or what is worse, yield weak plants. They may contain seeds of inferior varieties, as yellow clover (killed by heat to escape detection) mixed with red clover. They may contain seeds of other plants, or of weeds, in great variety and poisonous plants at that. They may contain artificial imitations of seeds made of sand or ground rock,* or finally they may contain no seeds at all, but, as has happened in case of some grasses, consist simply of flowers, not to be distinguished in appearance from seed. In some parts of Connecticut the seed of one and the same grass, *Agrostis vulgaris*, is said to have been gathered at an early stage of ripening and sold as "Blue top" at $2.00, while at a later stage it yielded "Red top," that could be had for $1.00 per bushel.

To aid in identifying the foreign seeds that may be found in samples tested, the Station is in possession of a seed collection containing 500 authenticated specimens of the seeds of the agricultural plants and weeds of Central Europe, prepared by P. Hennings, of the Botanical Institute at the University of Kiel in Holstein. The Station is making additional collections of American seeds, and will thankfully receive any contributions of this kind. Seeds of weeds should be accompanied by the plant, in flower if possible, to make their identification free from doubt.

The germinating power of seeds is tested in the following simple manner, which farmers can apply for themselves with means everywhere obtainable. Count out two hundred seeds, or if large, one hundred. Soak in water for twelve to twenty-four hours, or until they cease to swell. The seeds are then spread

* The Station is in possession of samples of five imitations of clover seed made from quartz rock and dyed various colors, that were found in the German market. They were manufactured at Prague and Hamburg, and offered "to the trade" for from $1.10 to $3.50 per cwt.

out on a common porous flower-pot saucer, three or four inches in diameter, which has been just previously boiled in water to destroy mould. Place this saucer in another saucer, porous or glazed, two inches wider. Pour water into the outer saucer, but not as high as the level of the seeds. and cover the whole either by a second large saucer inverted or by an inverted flower-pot. Place in a situation where the temperature varies but little from 60° to 70° Fahrenheit. Examine from time to time to maintain a constant supply of water in the lower saucer and to observe when sprouting begins. Every twenty-four hours remove and count the seedlings, until no more seeds show signs of life, recording the dates and the number of seeds that germinate each day. The points to be especially observed are to hold the seeds uniformly within the limits of temperature above named, and to keep them always moist and surrounded by moist air, but never wet with visible liquid.

The sprouting of squash, pumpkin and melon seeds does not succeed in the arrangement just described. They should be placed in a large saucer and covered with clean sand moistened with water, over which another saucer may be inverted.

The trials last ten to fifteen, or more days. When terminated, one-third of the number of seeds which have not sprouted, but remain sound and healthy in aspect, is added to the number of those which have grown, and that sum, if one hundred seeds were used, or half that sum when two hundred are taken, is the per cent. of pure seed capable of germination.

At the Station, two sprouting trials are always carried on together, one in the earthen saucers, as above described, and another in moist unsized paper. The average of the two trials, which should not commonly differ more than five per cent. is the result reported.

The time of germination is the time required for *the larger part* of the seeds to sprout. Experience has shown that while in many cases a few seeds sprout over a period of one week, or even of two weeks, the large majority usually germinate within a space of three or four days.

The "per cent. value" of a sample of seed is obtained by multiplying its per cent. (by weight) of pure seed into the per cent. (by number) capable of germination, and dividing by 100. It refers the number of seeds capable of germinating, from "pure seed" back upon the sample itself, in terms of per cent.

In many cases the report of a sprouting trial may convey a wrong impression as to the quality of seed, unless due regard is had to the average per cent. value of the genuine seeds of commerce. Some kinds of seeds, like wheat and the other common cereal grains, have usually a high degree of purity and vitality. Other seeds, especially those of certain grasses, are only found in commerce largely admixed with foreign matters, chaff and dirt and the pure seeds have but moderate vitality. Some data on this important point are given in the last columns of the tabular statement of results of seed examinations, p. 50. These data, as well as the mode of testing seeds in most of its details, are due to the labors of Dr. Friedrich Nobbe, Professor in the Royal Saxon Academy of Agriculture and Forestry and Director of the Experiment Station at Tharand, whose admirable book on seeds (*Handbuch der Samenkunde*) is full of most valuable information, both new and old, upon every branch of this subject.

The weight of 1,000 seeds is given (in grams for sake of comparison with the weighings recorded in other countries) because as a rule the heavier seeds are the better.

Dr. Nobbe has invented a special earthenware apparatus for sprouting trials. The funds of the Station being insufficient to meet even the very moderate outlay for a few dozens of this apparatus, the arrangement of flower-pot saucers, before described, was adopted, and although less convenient, has served the purpose perfectly well. This is shown by the following comparison of results obtained by use of the two kinds of instruments.

In 33 trials made with the common field and garden seeds, both in Nobbe's apparatus and in unsized paper—

4,668 seeds sprouted in the apparatus.
4,604 " " " paper.
493 " remained sound without sprouting in the apparatus.
470 " " " " " " paper.

Or for every 100 seeds which sprouted in paper, 101 sprouted in the apparatus.

10 seeds out of 104.7 remained sound in the apparatus.
10 " " 108.0 " " " paper.

In 22 trials made with similar kinds of seeds both in the saucer arrangement, above described, and in paper—

2,659 seeds sprouted in the saucers.
2,693 " " " paper.
286 " remained sound without sprouting in saucers.
258 " " " " " paper.

Or for every 100 seeds which sprouted in paper, 99 sprouted in saucers.

10 seeds out of 103 remained sound in the saucers.
10 " " 114 " " paper.

This comparison shows that the results obtained with the apparatus in use here are perfectly satisfactory and comparable with those obtained by using Nobbe's apparatus.

Results of Examinations of Seeds.

Name.	Source.	Per cent. by weight of pure Seed.	Of 100 pure Seed, sprouted (vitality).	Per Cent. Value.	Time of Germination. Half sprouted.	Time of Germination. All sprouted.	As determined by Dr. Nobbe. Average per cent. of pure Seed.	As determined by Dr. Nobbe. Average vitality of pure Seed.
Lettuce, old,	Prof. Johnson,	100	40.8	40.8	5 days.	13 days.	96.7	77
Turnip, "	"	100	56.5	56.5	2 "	12 "	----	----
Radish, "	"	100	78.8	78.8	5 "	12 "	98.6	91.0
"	Dep't Agriculture,	100	98.3	98.3	2 "	6 "	----	----
..	"	100	67.0	67.0	5 "	13 "	----	----
Wheat,	"	100	99.3	99.3	2 "	9 "	98.5	95.0
Barley,	"	100	98.0	98.0	2 "	9 "	99.2	88.0
Oats,	"	100	98.3	98.3	4 "	10 "	99.0	74.0
Watermelon,	"	100	74.4	74.4	7 "	19 "	0.0	----
Melon,	"	100	75.0	75.0	7 "	19 "	----	----
Carrot,	"	96.2	34.5	33.2	7 "	13 "	86.7	59.0
"	"	87.6	57.5	50.4	7 "	17 "	----	----
Parsnip,	"	100.0	29.0	29.0	10 "	17 "	95.2	17.0
Onion,	"	100	63.0	63.0	6 "	13 "	99.5	50.0
Tomato,	"	100	98.3	98.3	5 "	10 "	96.7	77.0
Celery,	"	100	24.7	24.7	14 "	33 "	97.9	32.0
Broccoli,	"	100	88.0	88.0	4 "	17 "	----	----
Cabbage,	"	100	70.2	70.2	5 "	14 "	99.0	79.0
Cauliflower,	"	100	65.0	65.0	3 "	14 "	99.8	87.0
Rhubarb,	"	100	16.5	16 5	5 "	12 "	----	----
Okra,	"	100	62.0	62.0	2 "	11 "	----	----
Beet,	"	98.5	81.6	80.4	----	----	98.4	----
"	"	98.2	62.4	61.3	----	----	----	----
"	"	99.24	89.0	88.3	----	----	----	----
Lucerne,	F. S. Platt,* New Haven,	100 0	68.0	68.0	2 "	4 "	95.6	76.0
Orchard Grass,	" *	81.0	48.5	39.3	7 "	17 "	47.6	22.0
Red Top,	R. Veitch & Son,* New Haven,	55.5	42.0	23.3	8 "	17 "	25.1	21.0
Timothy,	F. S. Platt,* New Haven,	98.9	95.0	93.9	5 "	9 "	94.9	82.0
Eng. Rye Grass,	" *	94.1	66.7	62.7	6 "	14 "	95.4	73.0
Red Clover,	" *	94.1	77.8	73.2	4 "	----	95.5	82.0
"	Crop of 1872, Prof. Brewer,	----	35.5	----	3 "	9 "	----	----
"	"	----	29.0	----	3 "	9 "	----	----
Ky. Blue Grass,	F. S. Platt,* New Haven,	92.5	5.0	4.6	12 "	23 "	51.7	11.0

* Sold as old Seed, last year's stock.

Investigation of Feeding Stuffs.

During the months of winter there is little call for fertilizer-analyses, but the attention of farmers is naturally directed with great interest to the various substances employed as cattle food. The Station has, therefore, provided for its winter work from the abundant materials of this kind to be found on our farms and in our markets. Thanks to the laborious investigations carried on of late years in the Experiment Stations and University Laboratories of Europe, and especially of Germany, the simple analysis of an article of cattle food may be usefully employed in fixing its place and nutritive value in the feeding-ration, and also in deciding how much the farmer can afford to pay for it, or at what price, and to what extent he can substitute it for other materials customarily used. I am glad to be able to say that Mr. Armsby, Chemist to the Station, is engaged in preparing for publication a small volume, in which the latest results of European investigation will be made available to the agriculturists of this country. It is needful, however, in order to use these results to advantage, that we have analyses of our own grasses, hay, grains, and in fact of all our fodder materials, because, under considerable differences of climate and cultivation, it is to be anticipated that the products of this State, or those consumed here, may differ more or less widely in composition from those of corresponding name used abroad.

The 37 feeding stuffs of which samples have been obtained for analysis are as follows:

7 samples of maize meal.
4 " " cob.
6 " maize fodder.
5 " bran and middlings.
1 sample of malt sprouts.
10 samples of hay.
4 " roots.

Of these, nine have been completely analyzed and are reported in subsequent pages.

In selecting samples care has been taken to obtain representation of the various qualities of hay, raised in the State, to make comparisons between maize fodder in different stages of growth, to examine side by side maize meal from the west and that of home production, for the purpose of aiding to answer the oftrepeated question—Which is the best and cheapest? The value of maize cob has occasioned much discussion, and is a matter which a few new analyses may probably put at rest. We already have results indicating that the value attributed to maize-cob by the German writers, based upon a single analysis, is much too great.

Among the articles of fodder which it is hoped to examine soon are Hungarian grass and Kohl rabi. The former has become rather largely cultivated in the New England and Middle States. The latter promises very favorably in some trials made near New Haven by Mr. Webb.

So little authentic information exists among most of our farmers regarding the less common fodder plants, that Mr. Jenkins has undertaken to render into English and adapt to our circumstances a small volume upon the subject of Fodder Plants and Grasses, with the details of cultivation, curing and use, which I am certain will prove a valuable addition to our agricultural literature.

In order to make our analyses of cattle feed directly useful, it is needful to adduce some of the results of the prolonged study of this subject made in other countries.

The following Table of the Composition, Content of Digestible Nutritive Ingredients and Money Value, of a few of the most important Feeding Stuffs, is taken from the German of Dr. Emil Wolff, of the Agricultural Academy at Hohenheim, and represents the most recent and most trustworthy knowledge on these subjects.*

The composition of feeding stuffs, as here stated, is the average result of the numerous analyses that have been made within twenty-five years, mostly in the German Experiment Stations.

The quantities of digestible ingredients are partly derived from actual feeding experiments and are partly the result of calculation and comparison.

The percentages of the three classes of digestible matters, viz: albuminoids, carbhydrates and fat, form the basis for calculating the money-value of feeding stuffs. The values attached to them by Dr. Wolff are the following, the German mark being considered as equal to 24 cents, and the kilogram equal to 2.2 lb. av.

1 lb. of digestible	albuminoids	is worth	4½ cents.
1 " "	fat	"	4⅓ "
1 " "	carbhydrates	"	$\frac{9}{10}$ "

* From "*Mentzel u. Lengerke's Kalender*," for 1878.

These figures express the present relative money-values of the respective food elements in the German markets. Whether or not these values are absolutely those of our markets, they represent presumably the *relative* values of these elements approximately, and we may provisionally employ them for the purpose of comparing together our feeding stuffs in respect to money value. These money or market values are to a degree independent of the feeding values. That is, if of two kinds of food, for example Hungarian hay and malt sprouts, the one sums up a value of $0.66 and the other a value of $1.31 per hundred, it does not follow that the latter is worth for all purposes of feeding twice as much as the former, but it is meant that when both are properly used, one is worth twice as much money as the other. In fertilizers we estimate the nitrogen of ammonia salts at 24 cents per pound and soluble phosphoric acid at 12½ cents, but this means simply that these are equitable market prices for these articles, not that nitrogen is worth twice as much as soluble phosphoric acid for making crops. In the future more exact valuations may be obtained from an extensive review of the resources of our markets, in connection with the results of analyses of the feed and fodder consumed on our farms.

The column headed "nutritive ratio" in the table gives the proportion of digestible albuminoids to digestible carbhydrates inclusive of fat.* The albuminoids, which are represented in animal food by the casein or curd of milk, the white of egg and lean meat, and in vegetable food by the gluten of wheat (wheat gum), and other substances quite similar to milk-casein and egg-albumin, have a different physiological significance from the carbhydrates, which are starch, the sugars and similarly constituted matters. The albuminoids may easily be made over by the animal into its own substance, i. e., into muscles, tendons and the various working tissues and membranes which are necessary parts of the animal machine, because they are the same kind of materials, are, chemically speaking, of the same composition. The carbhydrates, on the other hand, probably cannot serve at all for building up the muscles and other parts of the growing animal, and cannot restore the waste and wear of those parts of mature animals, because they are of a very different nature. They contain no nitrogen, an element which enters into all the animal

* Fat and carbhydrates have, it is believed, the same nutritive function, and it is assumed that 1 part of fat equals 2·4 of carbhydrates.

tissues (albuminoids) to the extent of some 15 per cent. of their dry matter.

The carbhydrates cannot restore the worn out muscles or membranes of the animal any more than coal can be made to renew the used up packing, bolts, valves, flues and gearing, of a steam-engine. The albuminoids are to the ox or the man what brass and iron are to the machine, the materials of construction and repair.

The carbhydrates are, furthermore, exactly to the animal what coal and fuel are to the steam-engine. Their consumption generates the power which runs the mechanism. Their burning (oxidation) in the blood of animals produces the results of life just as the combustion of coal in the fire-place of the steam-engine produces the motion and power of that machine.

There is, however, this difference between the engine and the animal. The former may be stopped for repairs, the latter may run at a lower rate, but if it be stopped it cannot resume work. Hence the repairs of the animal must go on simultaneously with its waste. Therefore, the materials of which it is built must admit of constant replacement, and the dust and shreds of its wear and tear must admit of escape without impeding action. The animal body is as if an engine were fed with coal and water not only, but with iron, brass and all the materials for its repair, and also is as if the engine consumed its own worn out parts, voiding them as ashes or as gas and smoke. The albuminoids, or blood- and tissue-formers, are thus consumed in the animal, as well as the carbhydrates, or fuel proper. The fact that the albuminoids admit of consumption implies that when the carbhydrates or proper fuel are insufficient, they, the albuminoids, may themselves serve as fuel. Such is the case, in fact. But, nevertheless, the two classes of substances have distinct offices in animal nutrition, and experience has demonstrated what science predicted, viz: that for each special case of animal nutrition a special ratio of digestible albuminoids to digestible carbhydrates is the best and most economical, and, within certain limits, is necessary. This proportion we designate as the *nutritive ratio*, and these explanations make its significance evident.

To allow of directly comparing the money-value of feeding stuffs with some universally accepted standard, the last column gives a comparison with good average meadow hay taken as 1.

Average Composition, Digestibility and Money Value of Feeding Stuffs as given by Dr. Wolff for Germany for* 1878.

	Water.	Ash.	Albuminoids.	Fiber.	Carbhydrates.	Fat.	Digestible matters.			Nutritive Ratio.	Money value.	
							Albuminoids	Carbhydrates.	Fat.		Dollars per 100 lbs.	Comparison with meadow hay = 1
Meadow hay, inferior,	14.3	5.0	7.5	33.5	38.2	1.5	3.4	34.9	0.5	10.6	0.48	0.74
" " better,	14.3	5.4	9.2	29.2	39.7	2.0	4.6	36.4	0.6	8.3	0.55	0.86
" " average,	14.3	6.2	9.7	26.3	41.4	2.5	5.4	41.0	1.0	8.0	0.64	1.00
" " very good,	15.0	7.0	11.7	21.9	41.6	2.8	7.4	41.7	1.3	6.1	0.74	1.17
" " extra,	16.0	7.7	13.5	19.3	40.4	3.0	9.2	42.8	1.5	5.1	0.84	1.32
Clover hay, average,	16.0	5.3	12.3	26.0	38.2	2.2	7.0	38.1	1.2	5.9	0.69	1.08
" best,	16.5	7.0	15.3	22.2	35.8	3.2	10.7	37.6	2.1	4.0	0 88	1.39
Timothy hay,	14.3	4.5	9.7	22.7	45.8	3.0	5.8	43.4	1.4	8.1	0.69	1.09
Hungarian hay,	13.4	5.7	10.8	29.4	38.5	2.2	6.1	41.0	0.9	7.1	0.66	1.04
Rye straw,	14.3	4.1	3.0	44.0	33.3	1.3	0.8	36.5	0.4	46.9	0.35	0.55
Oat "	14.3	4.0	4.0	39.5	36.2	2.0	1.4	40.1	0.7	29.9	0.44	0.69
Rich pasture grass,	78.2	2.2	4.5	4.0	10.1	1.0	3.4	10.9	0.6	3.6	0.27	0.42
Average meadow grass, fresh,	70.0	2.1	3.4	10.1	13.4	1.0	1.9	14.2	0.5	8.1	0.22	.36
Green maize, German,	85.0	1.0	1.2	4.7	7.6	0.5	0.7	7.4	0.2	11.3	.10	.16
" *Mr. Webb*, 1874,	86.0	0.8	0.8	4.8	7.3	0.3	0.6	8.3	0.2	14.4	.11	.17
Cured Maize fodder, Mr. Webb,	27.3	4.2	4.4	25.0	37.9	1.3	3.2	43.4	1.0	14.4	.57	.91
Potatoes,	75.0	0.9	2 1	1.1	20.7	0.2	2.1	21.8	0.2	10.6	.29	.46
Mangolds,	88.0	0.8	1.1	0.9	9.1	0.1	1.1	10.0	0.1	9.3	.14	.22
Rutabagas,	87.0	1.0	1.3	1.1	9.5	0.1	1.3	10.6	0.1	8.3	.15	.24
Sugar beets,	81.5	0.7	1.0	1.3	15.4	0.1	1.0	16.7	0.1	17.0	.19	.30
Maize, German,	14.4	1.5	10.0	5.5	62.1	6.5	8.4	60.6	4.8	8.6	1.10	1.73
" *meal, American II*,	12.9	1.2	8.7	1.8	71.9	3.5	7.3	68.3	2.6	10.2	1.04	1.69
Oats,	14 3	2.7	12.0	9.3	55.7	6.0	9.0	13.3	4.7	6.1	.97	1.53
Malt sprouts,	10.1	7.2	24.3	14.3	42.1	2.1	19.4	45.0	1.7	2 5	1.31	2.06
Wheat bran, coarse,	12.9	6.6	15.0	10.1	52.2	3.2	12.6	42.6	2.6	3.9	1.04	1.63
" fine,	13.1	5.4	14.0	8.7	55.0	3.8	11.8	44.3	3.0	4.4	1.03	1.62
Middlings,	11.5	3.0	13.9	4.8	63.5	3.3	10.8	54.0	2.9	5.7	1.07	1.68
Cotton seed cake decorticated.	11.2	7.6	38.8	9.2	19.5	13.7	31.0	18.3	12.3	1.6	2.05	3.22
Fish scrap, by *Goodale's process*,	11.5	----	64.0	----	----	4.6	57.6	----	4.1	0.2	2.67	4.17
Fish scrap, dry ground,	11.7	----	51.5	----	----	8.1	46.4	----	6.2	0.3	2.28	3.56
Dried blood,	12.0	4.1	80.8	----	2.6	0.5	54.1	2.6	0.5	----	2.39	3.76
Whey,	92.6	0.7	1.0	----	5.1	0.6	1.0	5.1	0.6	6.6	.11	.18
Milk,	87.5	0.7	3.2	----	5.0	3.6	3.2	5.0	3.6	4.4	.34	.53

* Except those in italics.

Analyses of Feeding Stuffs.

The analyses that follow were made by the methods and are stated in the manner adopted in the European experiment stations. In stating the analyses the average composition of the same article as given by Dr. Wolff, is quoted for comparison, headed W.

Malt Sprouts.

Station No. I. From Wm. Hull & Sons, New Haven, cost $12.00 per ton, Oct. 31st, 1877. Price variable, from 9 to 25 cents per bushel of 15 pounds. Sampled by James J. Webb.

			Nutritive Matters (digestible substance.)	
	I.	W.	I.	W.
Water	11.55	10.1	----	----
Ash	6.68	7.2	----	----
Albuminoids	25.91	24.3	20.8	19.4
Fiber	9.30	14.3	43.7	45.0
Carbhydrates	45.47	42.1		
Fat	1.09	2.1	0.9	1.7
Nutritive ratio			1:2.2	1:2.5
Selling price			$0.60	
Calculated value *			$1.33	$1.31

Maize Meal.

	II.	III.	IV.	W.
Water	12.91	20.67	21.67	14.4
Ash	1.17	1.17	1.16	1.5
Albuminoids	8.69	7.81	7.38	10.0
Fiber	1.79	0.93	1.41	5.5
Carbhydrates	71.93	66.35	65.88	62.1
Fat	3.51	3.07	2.50	6.5
	100.00	100.00	100.00	100.0
Selling price per 100 lbs.	$1.30	$1.40	$1.40	
Calculated value, according to Wolff	$1.04	$0.93	$0.91	$1.10

The experiments hitherto made on the digestibility of maize show that 84 per cent. of its albuminoids, 37 per cent. of its fiber, 76 per cent. of its fat, and 94 per cent. of its carbhydrates are digested. Calculated on this basis, the *nutritive matters* and *nutritive ratio* of the several samples analyzed are as follows, per cent.

	II.	III.	IV.	W.
Albuminoids	7.3	6.5	6.2	8.4
Fiber	0.7	0.4	0.5	60.6
Carbhydrates	67.6	62.4	61.9	
Fat	2.6	2.3	1.9	4.8
Nutritive ratio	1:10.2	1:10.5	1:10.8	1:8.6

* Value in money, according to Dr. Wolff's estimates for the average German market for the autumn of 1867, here adduced for purposes of comparison. See p. 52.

II, sampled by J. J. Webb, from store of D. B. Crittenden, New Haven, Oct. 31st.

III and IV, sent by T. S. Gold, West Cornwall, Nov. 27th; III, from new home-grown yellow flint, IV, from old (?) western corn.

The samples III and IV contain some 8 per cent. more water than II. Their greater cost is probably due to difference of freight.

Entire Maize.

For comparison the composition of four kinds of New England maize as found by Dr. Atwater,* and of a variety raised near Raleigh, North Carolina, is here given: A, *Early Dutton*, 12-rowed, kernels rather small. B, *Common Yellow*, or *Canada Corn*, 8-rowed, large ears and kernels. C, *King Phillip*, or *Rhode Island Corn*, brown-red, 8-rowed, large. D, *Stowell's Evergreen Sweet Corn*, 12 and 16-rowed, short, thick ears. E, *Southern White*, large, 16-rowed.

	A.	B.	C.	D.	E.
Water	8.08	10.52	9.79	10.86	11.56
Ash	1.52	1.31	1.60	1.89	1.47
Albuminoids	9.62	9.72	11.87	11.10	10.58
Fiber	2.52	2.40	2.21	2.63	2.67
Carbhydrates	72.62	71.63	70.08	65.86	69.63
Fat	5.64	4.42	4.45	7.66	4.09
	100.00	100.00	100.00	100.00	100.00

The calculated digestibility, etc., is as follows:

	A.	B.	C.	D.	E.
Albuminoids	8.08	8.16	9.97	9.32	8.88
Carbhydrates	69.19	68.22	66.69	62.87	66.44
Fat	4.29	3.31	3.36	5.82	3.11
Nutritive ratio	1:9.9	1:9.4	1:7.5	1:8.3	1:8.3
Calculated value	$1.16	$1.11	$1.18	$1.22	1.12

The above figures show that our maize is quite variable in composition. Its nutritive ratio ranges from 1:9.9 to 1:7.5. King Phillip, Sweet Corn and Southern White yield the most albuminoids, Sweet Corn the most fat and the least carbhydrates. The different amounts of water of the several samples must be considered in comparing their estimated values. The nutritive ratios are independent of their state of moisture.

* *American Journal of Science*, Nov., 1869.

Commercial Corn Meal inferior to Entire Corn.

For a strict comparison of the composition of meal and corn the analyses must be calculated upon water-free substance. This reduction gives the subjoined percentages.

	Maize Meal.			Entire Maize.				
	II.	III.	IV.	A.	B.	C.	D.	E.
Ash	1.34	1.48	1.48	1.66	1.46	1.77	2.12	1.66
Albuminoids	9.97	9.85	9.42	10.46	10.86	13.16	12.45	11.96
Fiber	2.06	1.17	1.80	2.74	2.68	2.45	2.95	3.02
Carbhydrates	82.60	83.63	84.11	78.98	80.06	77.69	73.89	78.72
Fat	4.03	3.87	3.19	6.16	4.94	4.93	8.59	4.64
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

It is probable that analyses III. and B. represent the same variety of corn. The difference that is observed between them is also found between all the samples of meal on the one hand and all those of entire corn on the other. The meal contains, on the average, one per cent. less fiber, two per cent. less albuminoids, and nearly two and a half per cent. less fat than the unground maize. This would suggest that the meal has possibly undergone a sifting process that would remove the hulls, which are relatively rich in fiber and albuminoids, and the chits which contain most of the oil, and are also rich in albuminoids.

In no other way is it probable that these differences can arise. The methods of analysis were the same in all cases, and it is quite unlikely that differences of variety or of season should give such diversity of composition. The result is a "sifted meal" (?) whose nutritive ratio is 1 : 10½, whereas the entire corn has, on the average, the narrower and richer ratio 1:8.7, and is worth as cattle food an average of twenty cents per hundred more than the meal.

Wheat Bran and Middlings.

	V.	VI.	VII.	W.	W.	VIII.	IX.	W.
	Coarse Bran.	Coarse Bran.	Coarse Bran.	Coarse Bran.	Fine Bran.	Fine Bran.	Middlings.	Middlings.
Water	10.87	11.14	12.12	12.9	13.1	10.47	10.56	11.5
Ash	5.75	5.99	6.33	6.6	5.4	5.56	3.45	3.0
Albuminoids	13.63	12.13	13.50	15.0	14.0	13.88	14 22	13.9
Fiber	7.56	9.31	8.79	10.1	8.7	7.98	5.35	4.8
Carbhydrates	58.92	58.36	55.90	52.2	55.0	58.88	62.90	63.5
Fat	3.27	3.07	3.36	3.2	3.8	3.23	3.52	3.3
Selling price, per 100 lbs.	$1.05	$ 1.00	$ 1.00			$1.20	$1.60	
Calul ated	1.02	0.96	1.01	$1.04	$1.04	1.03	1.07	$1.07

Calculating the actual nutritive matters on the basis furnished by experiments, according to which 84 per cent. of the albuminoids, 29 per cent. of the fiber, 70 per cent. of the fat, and 76 per cent. of the carbhydrates are digested, we have the following per cent. statement:

	V.	VI.	VII.	W.	W.	VIII.	IX.	W.
	Coarse Bran.	Coarse Bran.	Coarse Bran.	Coarse Bran.	Fine Bran.	Fine Bran.	Middlings.	Middlings.
Albuminoids	11.45	10.19	11.34	12.60	11.76	11.66	11.94	11.68
Fiber	2.19	2.70	2.55	2.93	2.52	2.31	1.55	1.39
Carbhydrates	44.78	44.35	42.48	39.68	41.8	44.75	47.80	48.26
Fat	2.29	2.15	2.35	2.24	2.66	2.26	2.46	2.31
Nutritive ratio	1:4.6	1:5	1:4.5	1:3.9	1:4.4	1:4.5	1:4.6	1:4.7

V, "Coarse Wheat Feed," from white wheat, D. B. Crittenden, New Haven.

VI, "Coarse Wheat Feed," from red wheat, D. B. Crittenden, New Haven.

VII, Western Wheat Bran, sent by T. S. Gold, West Cornwall.

VIII, "Fine Feed," ground bran, D. B. Crittenden.

XIX, Wheat Middlings, D. B. Crittenden.

V, VI, VII, VIII and IX, were brought in by J. J. Webb.

The analyses of three samples of Western bran (shorts) and two of middlings by Prof. Storer (Bussey Bulletin, p. 27, 1874,) give the following averages, to which are prefixed an average of the foregoing analyses of bran.

	Ct. Exp. Station.	Bussey Institution.	
	Bran.	Bran.	Middlings.
Water,	11.15	11.65	12.69
Ash,	5.91	4.28	2.14
Albuminoids,	13.28	11.98	10.60
Fiber,	8.41	8.29	4.46
Carbhydrates,	58.01	58.56	67.00
Fat,	3.24	4.24	3.11
	100.00	100.00	100.00

The fine bran, VIII, and middlings, IX, are worth but slightly more than the coarse brans. It is not probable that their fineness renders them sensibly more digestible in the extensive alimentary apparatus of ruminating animals, than is the coarse bran, as they are not appreciably more soluble in the acids and alkalies used for separating their fiber.

Feeding Standards.

A.—Per Day and per 1,000 lbs. Live Weight.

	Total organic substance.	Nutritive (digestible) substances. Albuminoids.	Carbhydrates.	Fat.	Total nutritive substance.	Nutritive ratio.
	lbs.	lbs.	lbs.	lbs.	lbs.	
1. Oxen at rest in stall,	17.5	0.7	8.0	0.15	8.85	1 : 12.
2. Wool sheep, coarser breeds,	20.0	1.2	10.3	0.20	11.70	1 : 9.
" " finer breeds,	22.5	1.5	11.4	0.25	13.15	1 : 8.
3. Oxen moderately worked,	24.0	1.6	11.3	0.30	13.20	1 : 7.5
" heavily worked,	26.0	2.4	13.2	0.50	16.10	1 : 6.
4. Horses moderately worked,	22.5	1.8	11.2	0.60	13.60	1 : 7.
" heavily worked,	25.5	2.8	13.4	0.80	17.00	1 : 5.5
5. Milk cows,	24.0	2.5	12.5	0.40	15.40	1 : 5.4
6. Fattening oxen, 1st period,	27.0	2.5	15.0	0.50	18.00	1 : 6.5
" " 2d "	26.0	3.0	14.8	0.70	18.50	1 : 5.5
" " 3d "	25.0	2.7	14.8	0.60	18.10	1 : 6.0
7. Fattening sheep, 1st period,	26.0	3.0	15.2	0.50	18.70	1 : 5.5
" " 2d "	25.0	3.5	14.4	0.60	18.50	1 : 4.5
8. Fattening swine, 1st period,	36.0	5.0	27.5		32.50	1 : 5.5
" " 2d "	31.0	4.0	24.0		28.00	1 : 6.0
" " 3d "	23.5	2.7	17.5		20.20	1 : 6.5
9. Growing cattle: Age, months. Average live weight per head.						
2—3 150 lbs.*	22.0	4.0	13.8	2.0	19.8	1 : 4.7
3—6 300 "	23.4	3.2	13.5	1.0	17.7	1 : 5.0
6—12 500 "	24.0	2.5	13.5	0.6	16.6	1 : 6.0
12—18 700 "	24.0	2.0	13.0	0.4	15.4	1 : 7.0
18—24 850 "	24.0	1.6	12.0	0.3	13.9	1 : 8.0
10. Growing sheep:						
5—6 56 lbs.	28.0	3.2	15.6	0.8	19.6	1 : 5.5
6—8 67 "	25.0	2.7	13.3	0.6	16.6	1 : 5.5
8—11 75 "	23.0	2.1	11.4	0.5	14.0	1 : 6.0
11—15 82 "	22.5	1.7	10.9	0.4	13.0	1 : 7.0
15—20 85 "	22.0	1.4	10.4	0.3	12.1	1 : 8.0
11. Growing fat pigs:						
2–3 50 lbs.	42.0	7.5	30.0		37.5	1 : 4.0
3—5 100 "	34.0	5.0	25.0		30.0	1 : 5.0
5—6 125 "	31.5	4.3	23.7		28.0	1 : 5.5
6—8 170 "	27.0	3.4	20.4		23.8	1 : 6.0
8—12 250 "	21.0	2.5	16.2		18.7	1 : 6.5

In the accompanying tables from Dr. Wolff are stated the quantities and proportions of the digestible food elements which, according to the extensive experience of the German Experiment Stations, are to be given in the daily rations of farm animals, in order to secure the best results of feeding. By "total organic substance"

* The German pound is equal to $1\frac{1}{10}$ lb. avoirdupois. The above weights are therefore to be increased $\frac{1}{10}$ to represent our weights. For practical purposes, however, this reduction will be in most cases unnecessary as the weights are relative and approximate.

is meant the organic matter of feed considered free from water and ash. The difference between total organic substance and "total nutritive substance" expresses the quantity of indigestible or undigested matters of the ration. We are told that animals will indeed often do well with a ration less rich in albuminoids, the total amount of nutritive matters being kept up to the figures given below; but when by the use of the more highly nitrogenous feeding stuffs, such as brewer's grains, beans, peas, cotton seed cake, and meat or fish scrap, the nutritive ratio can be brought up to the subjoined standards, the results will be the most satisfactory.

(*Feeding Standards, continued from page* 60.)

B.—Per Day and per Head.

Growing cattle: Age, Months.	Average live weight per head.	Total organic substance.	Nutritive (digestible) substances. Albuminoids.	Carbhydrates.	Fat.	Total nutritive substance.	Nutritive ratio.
		lbs.	lbs.	lbs.	lbs.	lbs.	
2—3	150 lbs.	3.3	0.6	2.1	0.30	3.00	1 : 4.7
3—6	300 "	7.0	1.0	4.1	0.30	5.40	1 : 5.0
6—12	500 "	12.0	1.3	6.8	0.30	8.40	1 : 6.0
12—18	700 "	16.8	1.4	9.1	0.28	10.78	1 : 7.0
18—24	850 "	20.4	1.4	10.3	0.26	11.96	1 : 8.0
Growing sheep:							
5—6	56 lbs.	1.6	0.18	0.87	0.045	1.095	1 : 5.5
6—8	67 "	1.7	0.17	0.85	0.040	1.060	1 : 5.5
8—11	75 "	1.7	0.16	0.85	0.037	1.047	1 : 6.0
11—15	82 "	1.8	0.14	0.89	0.032	1.062	1 : 7.0
15—20	85 "	1.9	0.12	0.88	0.025	1.047	1 : 8.0
Growing fat swine:							
2—3	50 lbs.	2.1	0.38	1.50		1.88	1 : 4.0
3—5	100 "	3.4	0.50	2.50		3.00	1 : 5.0
5—6	125 "	3.9	0.54	2.96		3.50	1 : 5.5
6—8	170 "	4.6	0.58	3.47		4.05	1 : 6.0
8—12	250 "	5.2	0.62	4.05		4.67	1 : 6.5

The practical significance of these Feeding Standards, is explained by the following paragraphs which I have freely translated, from Dr. Wolff.

A milk cow is kept in good condition and with a full flow of milk on rich pasturage, or young clover, of which 30 lbs. are on an average daily consumed per 1,000 lbs. of live weight of improved breeds. 30 lbs. of young clover or best clover hay contain

Organic Substance.	Digestible. Albuminoids.	Carbhydrates.	Fat.
23 lbs.	3.21	11.28	0.63

Experiment in the stall shows that the same result can be had with the best meadow hay, obtained from rich ground and cut young, in which 30 lbs. contain

		Digestible.		
	Organic Substance.	Albuminoids.	Carbhydrates.	Fat.
	23.2	2.49	12.75	0.42
Feeding Standard,	24	2.5	12.5	0.4

or almost exactly the quantities of the feeding standard, and 0.7 lb. less of albuminoids than in the clover.

In the winter keep of cows the hay at disposal is usually of only average or even of inferior quality and not capable alone of suitably nourishing milk cows. It is therefore necessary to add something to it in order to get a proper feed. Where hay commands a high cash price, it is often cheaper to use straw, chaff or maize fodder in combination with richer maize meal, bran, brewer's grains, cotton seed meal, etc., than to feed hay alone. By help of the tables we can calculate the kind and quantities of these various feeding stuffs which may compose a ration that shall take the place of clover hay and correspond to the feeding standard. Suppose there is on hand and at the daily disposal of the cows, for each 1,000 lbs. of live weight, 12 lbs. of meadow hay of average quality, 6 lbs. of oat straw and 20 lbs. mangolds, while 25 lbs. brewer's grains daily can be cheaply got. By use of the tables it is easy to calculate that all these materials together will give a ration coming short of the standard by half a pound of albuminoids, while by adding to it 2 lbs. of cotton seed meal, the requirements of the ration are fully met, as shown by the following figures.

Ration for Milk Cows.

	Dry Organic Matter.	Digestible.		
		Albuminoids.	Carbhydrates.	Fat.
12 lbs. average meadow hay,	9.5	0.65	4.92	0.12
6 lbs. oat straw,	4.9	0.08	2.40	0.04
20 lbs. mangolds,	2.2	0.22	2.00	0.02
25 lbs. brewer's grains,	5.6	0.98	2.70	0.20
2 lbs. cotton seed meal,	1.6	0.62	0.36	0.24
	23.8	2.55	12.38	0.62
Standard,	24	2.5	12.5	0.4

I have calculated the following rations as examples of such combinations as may be made from materials in our markets. In

the first ration, bulky corn fodder such as raised by Mr. Webb in Hamden, in 1874, and analyzed by Mr. Jenkins (*Country Gentleman*, 1877 p. 711), is a large ingredient. In the others ordinary corn stalks or "stover" enters or may enter interchangeably with rye straw, since according to Wolff their nutritive value is the same pound for pound. The use of these rations must of course finally depend upon whether the animals can be got to relish and digest them, as well as upon their cost. I have not made any computations as to the latter point, but it is easy to do so with a knowledge of the cost of the several materials used. Actual experience alone can determine whether cattle will eat these mixtures. The fish scrap is not recommended for milk cows unless trial should show that it communicates no ill flavor to the milk.

Rations for Milk Cows.

	Dry Organic Substance.	Digestible.		
		Albuminoids.	Carbhydrates.	Fat.
20 lbs. cured corn fodder,	13.7	0.64	8.68	0.20
5 lbs. rye straw, or stover,	4.1	0.04	1.82	0.02
6 lbs. malt sprouts, I,	5.0	1.16	2.70	0.10
2 lbs. cotton seed meal,	1.6	0.62	0.36	0.24
	24.4	2.46	13.56	0.56
Standard,	24	2.5	12.5	0.4

Or again,

	Dry Organic Substance.	Digestible.		
		Albuminoids.	Carbhydrates.	Fat.
15 lbs. rye straw,	12.2	0.12	5.47	0.06
6 lbs. maize meal, II,	5.2	0.43	4.10	0.15
25 lbs. brewer's grains,	5.6	0.98	2.70	0.20
2 lbs. Goodale's fish scrap,	1.4	1.15		0.08
	24.4	2.68	12.27	0.49

Or,

	Dry Organic Substance.	Digestible.		
		Albuminoids.	Carbhydrates.	Fat.
15 lbs. stover,	12.1	0.16	5.55	0.04
5 lbs. bran,	4.1	0.59	2.21	0.15
5 lbs. malt sprouts, I,	4.1	0.97	2.25	0.08
3 lbs. maize meal, II,	2.5	0.22	2.05	0.07
2 lbs. cotton seed meal,	1.6	0.62	0.36	0.24
	24.4	2.56	12.42	0.58

In giving the foregoing tables of the composition and digestibility of cattle foods, &c., the writer does not ignore the fact that other systems of feeding are followed, and that many good farmers are content with a practice which apparently cannot be reconciled with these standards. The German experimenters do not themselves imagine that they have by any means overcome the difficulties of the subject. Their results are simply the best they can offer after twenty-five years of arduous labor, after making thousands of analyses and hundreds of laborious feeding trials. They believe that they are using the right methods, but admit that many further experiments must be undertaken before the investigation can be closed. In fact they are experimenting to-day more industriously than ever, with the object to test and sift the theories which their past experience has led them to adopt, and to gain a nearer approach to the true science and best practice of cattle feeding. It is to be anticipated that their views will materially change as further knowledge is gained.

The German system is based upon the idea that underlies the general practice of all Europe and of this country, viz: that coarse and bulky fodder is the natural and to a great extent the necessary food of ruminating animals, but that certain proportions of concentrated food may be advantageously used to remedy the defects of exclusive coarse fodder.

Exclusive Corn Meal feeding.

The plan of winter feeding adopted by Mr. Linus W. Miller, of Stockton, N. Y., stands in great contrast to the usual system. Mr. Miller states that for six different seasons he has fed maize meal exclusively to his dairy herd of dry mature animals for a greater or less length of time, and he says that three quarts of yellow maize meal, ground *fine* and fed in accordance with his rules,* is fully the equivalent of twenty pounds of the best hay as ordinarily fed, and that, if necessary, hay may be entirely dispensed with in wintering dry-stock or sheep. He states that one bushel of Indian corn ground aud tolled and yielding thirty-six quarts of meal weighing about fifty pounds, will last an ordinary sized cow of 900 pounds weight twelve days, and is equal to 240 pounds of hay. Corn at sixty cents per bushel is the equivalent of hay at $5 per ton of 2,000 pounds, and when it can be had at that rate,

* Given in his pamphlet on "Meal Feeding and Animal Digestion."

the cost of wintering an animal weighing 900 pounds will range from $7 to $10, according to the coldness and length of the foddering season. The system of Mr. Miller has been the subject of much skepticism and ridicule, but several cattle keepers report success with his method, and as nobody has given details of adverse experiments, his statements deserve to be carefully considered.

The ration of three quarts of maize meal weighs not more than four and one-fifth pounds, *and assuming a perfect digestion*, yields about the quantities of food elements given below, and compared with the requirements of Wolff's standard ration, for a store animal of 900 pounds live weight.

	Standard.	$4\frac{1}{5}$ lbs. Yellow Dutton Corn.
Dry organic substance	15.75	3.86
Undigested matters	7.78	----
Digestible albuminoids	0.63	0.40
" carbhydrates	7.20	3.15
" fat	0.14	0.24

The contrast is extraordinary. We have: 1st, the entire or almost entire absence of undigested matters, which in case of coarse fodder are held to consist largely of fiber and vegetable cuticular substance. The bulkiness of the ordinary winter ration of farm stock has been held to be needful because natural, and has been regarded as essential to digestion and rumination. Mr. Miller and a committee of the Western New York Dairymen's Association, that was appointed in 1875 to report upon his system, assert that the animals which were fed for seven weeks on corn meal alone, each animal receiving three quarts daily, did not suffer in health or lose flesh, or evince unsatisfied hunger, although rumination was suspended.

We notice, 2d, that the digestible substance of Miller's ration is in round numbers but one-half that of Wolff's standard. The former is 3.9, the latter eight pounds. The digestible albuminoids in Miller's ration are but two-thirds that of Wolff's, the carbhydrates less than half and the oil nearly twice as much. Accounting the 0.10 excess of oil as equal to 0.25 carbhydrates does not bring the latter up to one-half the demands of Wolff's standard. As Mr. Miller and those who have tested his method distinctly state that the animals have had no access to other food of any kind whatever, save limited supplies of water, we must restrict the validity of Wolff's standards to rations largely composed of bulky and indigestible food and adapted for rumination, and deny their universal applicability. This involves no incompatibility of the two systems. They are each adapted to a very different state of things. So far as I can find, no trials have been made in the European Experiment Stations on ruminating animals, except with hay or coarse fodder as the basis of the ration.

The reports of trials on Mr. Miller's system that have come under my observation do not record any weighings of the animals before and after the exclusive meal feeding, and the maintenance of undiminished live weight seems to be inferred from the appearance of the animals rather than demonstrated by actual test. But even if the live weight remained essentially unchanged, on three quarts of meal, that fails to prove that the cows were not really consuming their own substance. It is a fact that the internal make up of an animal may change considerably without any corresponding alteration in live weight.

The following figures show the composition per cent. of a lean and of a fat ox, both with and exclusive of the contents of the stomach and intestines.

	Entire Ox.			Dressed Ox.		
	Fat.	Lean.	Difference.	Fat.	Lean.	Difference.
Fat	26.8	7.1	−19.7	30.5	8.7	−21.8
Albuminoids (flesh, &c.)	13.7	15.8	+ 2.1	15.6	19.2	+ 3.6
Ash (earth of bones, &c.)	3.9	4.8	+ 0.9	4.4	5.9	+ 1.5
Water	43.6	54.3	+10.7	49.2	66.2	+17.2
Contents of stomach and intestines	12.0	18.0	+ 6.0			
	100.0	100.0		100.0	100.0	

These figures mean that when a fat animal is put on an insufficient ration, the loss of fat which immediately begins is largely compensated by a gain of water; or for twenty pounds of fat lost, there is an increase of seventeen pounds of water alone in dressed carcase, or of nearly that amount of water and contents of alimentary canal in entire animal.

These well authenticated facts make evident that both the external appearance of an animal and its live weight are entirely unsafe criteria from which to judge of its real condition or of the effect of its rations. It is only by actual analysis of the slaughtered animal, or by measuring the amount of carbon exhaled from its lungs and skin in a respiration apparatus, that we can ascertain how well it has been nourished in any case where the ration has been unusual in kind or quantity. If Mr. Miller should claim

that under his system the diminished quantity of food is sufficient because the animal is relieved from the labor needful to extract four pounds of real nutriment from sixteen pounds of indigestible or needless material, the facts would appear to justify that claim to some extent at least; but the whole subject requires to be worked up carefully, as it only can be with the methods and appliances of a fully equipped Experiment Station.

Potato Scab and Skin Crack.

In a letter bearing date of Sept. 27th, Hon. Levi S. Wells, of New Britain, called the attention of the Station to an affection of the potato, a disease of the surface of the tuber, resulting in a discolored and scabby appearance, and to some extent in deep cavities like worm-holes. Mr. Wells mentioned that for a number of years this disease has caused great loss to the farmers of this State, a large portion of the crop being in many instances rendered unmarketable. He sent three tubers which well represented the various stages of the malady.

The following reply was made to Mr. Wells' communication:

The potatoes exhibit two kinds of disease, which have been studied by competent investigators in Germany, and what can be said here in regard to them is mainly derived from Dr. Hermann Schacht's "*Report on the Potato Plant and its Diseases*," made to the Prussian Board of Agriculture in 1854, and from Dr. Paul Sorauer's "*Treatise on the Diseases of Plants*," published in 1874.

The fairest of the three potatoes sent would ordinarily pass for a sound tuber, being diseased in but a few places. On its surface, however, are seen a multitude of *skin cracks*, or scars of skin cracks, mostly running lengthwise of the tuber. The larger number of these cracks have healed up by formation of new skin, leaving the tuber quite sound underneath. Some of the wider cracks, however, while externally healed, or dry at least, cover a discolored moist mass of decayed tissue nearly half an inch deep. The rotten places are not due to the attacks of insects, so it has been decided from careful microscopic observation, but result from the skin-cracks and the decay of the tissues and juices thereby exposed. Very probably insects or worms, getting lodgment in the cracks, hinder or prevent healing, while dampness of the soil and presence of decaying organic matters obviously would favor decay.

The cracks are attributed to a period of quick growth succeeding a time when the tuber was at a stand-still and had begun to ripen off. When the tuber is young and is supplied with material for growth from the foliage and roots (the tuber is itself a part of the stem), it gradually expands, and the cuticle enlarges by development of new tissue to accommodate the interior growth. If growth be checked after the tuber has advanced towards maturity, the skin shortly becomes firm in texture and less capable of yielding. Should rapid growth then recommence, the inner expansion must burst the skin. The cause of the cracks is thought to lie in the weather, or in the supplies of water and plant food as influenced by the weather. Drought checks the growth and tends to ripen. After drought a moist growing time brings on the enlargement of the tuber and the cracking of its skin, and, at the same time, usually causes some of the eyes to grow—the sprouts either run a little way and then set to small potatoes, or more rarely reach the surface of the ground and throw out leaves and branches.

The second best potato sent shows evidence of another disease, called Scab or Pock.

This malady, though beginning differently from skin crack, affects the skin and results very similarly to that disease. On this tuber are seen but few skin cracks, but a great many little warts or pimply points of darker tint than the rest of the skin. These come from an abnormal growth of the cuticle. The skin, which when healthy is a layer of cork-cells of uniform thickness, at these points has begun to grow into the substance of the tuber, at the expense of the starch and starchy tissue underneath, very much as a corn on the foot appears to grow at the expense of the flesh. As the cork growth continues the outer parts of the affected spot decay, and the decay follows down into the substance of the tuber. When these scabby tubers are dug and dried the decay ceases and the pock remains, a black or brown cavity separated by a rough layer of corky matter from the starchy tissue. This potato scab is thought to be connected with wetness of soil. The writer has seen it years ago in northern New York, but never, to the best of his recollection, on mellow up-land or well-drained soil.

If the causes of these affections are truly stated, the remedy must consist in improving the texture of the soil, so that it shall duly regulate the water-supply, and thereby the food-supply, to the crops.

How do the facts as to the water-supply and circumstances of your crop the past season accord or disagree with the views herein expressed?

To this Mr. Wells answered: "The drainage of the soil on which grew the potatoes I sent you cannot be improved. The soil is a gravelly loam with a very clean gravel for a subsoil to the depth of twenty feet to water. The season has been very good, and every condition apparently favorable for the growth of the crop until maturity."

"I planted another plot of ground where the disease occasioned more loss. This was on high and dry ground, the soil sandy loam, the subsoil sand (good plastering sand). On this field the rotation had been tobacco, corn and potatoes. It had been well served each time with yard- or stable-manure."

"At harvest the potato-rot as well as scab was quite prevalent."

"The cooking quality of the potatoes this season has been excellent."

Mr. Wells also says: "I have observed that potatoes grown in northern New England very rarely show these defects, and when we fertilize with tobacco stalks the crop is freer from them."

It should be noticed that while the soils of Mr. Wells' potato-fields have "perfect drainage" in a certain sense, they are in fact not circumstanced most favorably for a well regulated water supply to the crops they bear. A gravelly loam with 20 feet of clean gravel intervening between it and bottom water is liable to suffer from extremes of drought and wet. When heavy rains fall on such a soil, the surface loam becomes fully saturated with water, and this state of saturation continues for a considerable time. The porous gravel permits indeed the surplus of *flowing water* to run away in the depths, but the finely porous loam remains fully saturated with *capillary water* like a suspended lamp-wick, upon which oil is poured from above, until it is completely drenched. If the bottom of such a wick be put in contact with a mass of cotton, the oil will be sucked into the latter, and the wick will be left with its pores lined with oil, but not full. So a loam resting on loam, i. e., finely porous to the bottom water, will not remain saturated at the surface, but the rain that falls upon it will soak down to uniformly coat the particles and line the pores of the entire mass of soil.

The loam underlaid by gravel remains overcharged with water after copious rains to an extent and for a time that checks growth, it being proved by experiment that too much water is as injurious to vegetation as too little, a certain moderate supply being best for most cultivated plants. After heavy rains have saturated the soil, continued dry weather gradually removes the excess, the sun and wind evaporating it from the surface, as a flame takes up the oil of a lamp, and the water from below rises in the porous earth as the oil ascends in the porous wick. In time the proportion of water becomes favorable to growth, but as dry weather continues, the stock of water in the soil underlaid with gravel may soon be reduced below the quantity best for crops, and drought may ensue because the gravel cannot raise the bottom water rapidly enough, whereas if the loam extended to bottom water, the latter would ascend and maintain the surface soil moist and supply the crop.

Perfect drainage implies a certain freedom of motion of the soil-water in all directions, that of flowing water through channels, that of capillary water through pores. Bottom water should drain upwards, through a sufficiently extensive and connected system of fine pores, to maintain the surface soil moist in drought, and surface water should drain downwards rapidly enough to prevent any prolonged capillary saturation of the surface soil.

It is a matter of experience among florists and gardeners that slight surface wettings of the soil, whether that of pots, beds or lawns, is of little or no use compared to an occasional thorough drench. During a long period of hot weather with frequent light rains, but no heavy rain, the soil at the depth where the roots of a crop are mainly situated may easily become so dry as to check growth, when the surface soil and the sub-soil are both sufficiently moist. The evaporation of water from the vegetation of a cultivated field is much greater than that from the naked soil, and this larger evaporation must be supplied from the earth which the roots penetrate. It is plain that a soil separated from bottom water by a gravel bed may suffer greatly from want of moisture during a period of summer weather, when no heavy rains fall, although many light showers wet the surface to a little depth.

I call attention to these details in order to show that the state of the water supply may be really unfavorable to vegetation when no such condition of things is suspected, but must leave to further observation to decide whether the potato scab is in fact attributable to these vicissitudes.

On some of the Properties of Clay.

The properties of a clay soil are very unlike those of a sand. Clay is very retentive of water, neither allowing this liquid to flow through a mass of it readily nor permitting rapid evaporation of the moisture which may be contained in its pores. Clay is also plastic, i. e., when suitably moist it may be moulded into any shape and retains that shape on drying and burning. This quality makes trouble in the tillage of clay lands, for if plowed before reaching a certain stage of dryness, the soil forms clods which harden on further drying and require much labor to break them down.

The cohesion of wet clay into plastic masses is mainly no doubt a property of the special kind of matter which composes it, but it also appears to be to some extent dependent on the fineness and perhaps the shape of the particles.

The essential ingredient of some of the finest porcelain clays is a mineral species, known as *Kaolinite* which is composed in 100 parts of

Silica,	46.4
Alumina,	39.7
Water,	13.9
	100.0

This substance is found occasionally in the form of a gritty powder not at all coherent which, under a low magnifier is seen to consist of transparent angular (six-sided) plates or scales. It is more frequently met with as a much finer white powder having a soapy feel and forming a plastic mass with water.

The gritty kaolinite, when pulverized very finely, developes to some degree the adhesive plastic quality which belongs to the naturally fine porcelain clay.

It is highly probable that all clays contain the same kaolinite as the chief chemical ingredient of their clayey portion, but more or less in admixture with other hydrous aluminous silicates, and with silicates of iron as well as with alumina and iron hydrates. Under the microscope the fine matter of many clays, even of the common blue and brown clays used for pottery, reveals a transparent or translucent substance like pulverized kaolinite, with here and there angular fragments of six-sided crystal plates. In agricultural clays the chemical nature of the adhesive material is not fully understood, but the studies of Prof. E. W. Hilgard upon the soils of Mississippi, and of Prof. Schlösing of the French Agricultural Institute, have given valuable information with regard to its properties.

If a clay soil be briskly boiled with water for twenty-four hours or more, the particles that compose it are very perfectly detached from each other. On then stirring up the whole with a considerable volume of pure water and letting stand for twenty-four hours, the grains of sand, silt and rock-dust, down to a scarcely measurable degree of fineness gradually settle out, and there remains an opake milky liquid that requires weeks or months of rest before the suspended particles will be deposited.

The matter diffused in this water is clay in the common and agricultural sense of that word, or rather it is that which gives to clay soils their peculiar properties. Much of it is matter so fine that the microscope with its highest powers cannot define or discover it. If to the turbid clay-water a little common salt or strong brine is added the clay will separate from the water in visible flocky aggregations, and within a few hours will settle to the bottom of the vessel as a bulky gelatinous deposit. If this clay be separated from the liquid and exposed to the air it shrinks away on drying to a small fraction of its original bulk, if dried on paper or cloth it crimps the latter as would drying glue. "After drying it constitutes a hard, often horny mass, difficult to break, and at times somewhat resonant. Since the iron-oxide with which the soil or clay may have been colored is mainly accumulated in this portion, it usually possesses a dark brown or chocolate tint. When a large amount of iron is present, water acts rather slowly on the dried mass which gradually swells like glue, the fragments retaining their shape. Not so when the substance is comparatively free from iron. It then swells up instantly on contact with water, horny scales of it quickly lose their shape, bulge like a piece of lime in process of slaking," and fall to pieces.

This clay "when dry adheres to the tongue so tenaciously as to render its separation painful. When moistened and worked into the plastic condition it is exceedingly tenacious and 'sticky,' adhering to everything it touches."—Hilgard (*American Journal of Science and Arts*, Oct., 1873.)

In 1867, the writer, in conjunction with Mr. J. M. Blake of New Haven, showed that kaolinite in a transparent and crystalline form is a common and often an abundant ingredient of clays, most abundant in the mealy white porcelain clay, and less abundant or scarce in fire and common clays.

Schloesing (*Comptes Rendus*, t. 78, 1874,) has confirmed this observation, and has shown that some porcelain clays consist almost entirely of kaolinite, which in some cases is crystalline, in others is not. Schloesing finds, however, that the finest and smallest part of these clays is not kaolinite, but has a different chemical composition and is more glue-like in its properties, corresponding to Dr. Hilgard's description of the "clay" obtained from clayey soils. The analysis of one specimen of the latter shows again very different composition from those examined by Schloesing. It appears in fact that we cannot chemically define the "clay" which pure water takes up from clayey soils and holds so long in suspension. It is a mixture of all the very finest kinds of matter which the earth may contain, and its properties vary according to the kinds and states of that matter.

This "clay," however, is or largely contains a something which imbibes water with great energy and swells with it to many times the bulk it has when dry. It belongs to the class of bodies designated by Graham as *Colloids* (glue-like), and confers on the soil peculiar and valuable properties.

According to Hilgard the heaviest agricultural clays contain but 40 to 47 per cent., and ordinary loams but 10 to 20 per cent. of this true clay, the rest being sand and silt. Schloesing states that the strongest clay he examined contained but 35 per cent., while very strong clays contain but 16 to 20 per cent. Schloesing's "clay" was freed from lime and organic matter by chemical treatment, which Hilgard has not employed. Schloesing's object was simply to ascertain the total quantity of clay in the substances he experimented on, and Hilgard's to make a mechanical separation of the various grades of sand, silt and finer matters, for the purpose of estimating their influence on the physical qualities of soils.

After thus briefly stating the main facts known with regard to the nature of this colloid clay, I will call attention to its influence on the soil. When a dry clay soil is copiously rained upon or exposed to the abundant pure water of melting snow its "clay" swells, assumes a gummy or gluey consistency, and by enveloping the sand and silt grains confers upon the whole mass its own sticky qualities. When soluble salts of the surface soil are completely washed out of it, then the clay enters into suspension and is carried down in the pores of the soil and clogs them up, as it does the pores of a paper filter or of a cloth strainer in the experiments of the laboratory. Thus it comes that clay lands are so muddy and impervious to rain in spring and autumn, and that the water they contain dries out slowly, as it does from dissolved glue, gum, or jelly. The sprinkling of the wet and sticky clay with a weak brine or with a much weaker solution of a lime-salt, either sulphate of lime (gypsum or plaster) or with a solution of lime in carbonated water, or the sprinkling of these salts dry on the wet surface, where they speedily dissolve, coagulates the clay as rennet curdles the casein of milk, i. e., the lime-salts separate the clay atoms from the water in which they were suspended, and shrinks them together into distinct curd-like masses. Thus the clogged pores between the sand-grains are opened and channels formed which permit the clear water to run off.

Schloesing found by experiment, both in pottery clays and heavy clay soils, that the matter held in suspension in pure water was coagulated and thrown down quickly by adding to the water a few ten-thousandths of a soluble lime or magnesian salt, as well as by about five times that quantity of a potash-salt, and by a still larger proportion of a soda-salt.

The coagulation of clay by soluble saline matters assists in explaining some facts long if not widely known in agriculture. It has been found in some regions of Germany that the application of lime to clay lands is an effectual means of loosening the texture of even the stiffest soils. It is doubtless the bicarbonate of lime which acts in this case. The effect lasts for only a term of years, because the lime gradually dissolves away, and as it disappears from the surface the clay recovers its original impervious quality. Mr. D. G. Mitchell, of Edgewood, near New Haven, has found that a soggy and nearly worthless hill-slope has become dry and valuable for pasture, mainly as the result of an application of lime. Mr. Lawes, the veteran English experimenter, informs us that the continued use of nitrate of soda for many years as a fertilizer on clay land has noticeably improved its texture and relieved its heavy quality. The often-observed good effects of spreading out stable manure on the ground during winter in improving the texture of the soil at time of spring tillage may be due in part to the effect of the soluble salts in coagulating the clay and preventing the clogging and puddling of the soil.

In studying recently the question of the transmission of water through soils, it occurred to the writer that since some colloid (glue-like) bodies when diffused in water, such as starch in the

form of thin paste, are coagulated and separated in glutinous clumps by the freezing of the mass, it is likely that the well-known good effects of strong frost on clay thrown up by the plow in autumn are in part due to a coagulation of the clay by the solidification of the water. Advantage was at once taken of a cold night to expose some turbid clay-water, that had been standing for 36 hours, to the action of frost. In the morning the milky water was in fact found to have yielded a cake of transparent ice, within or beneath which was seen the clay in distinct flocky aggregations. As the ice melted, it yielded clear water, while the clay remained at the bottom of the vessel. On examination with the microscope it was seen to consist largely of a translucent, nearly white, material with a granular or cellular appearance, while a portion of the unfrozen and turbid clay-water contained nothing discoverable by the same magnifying power of some 500 diameters. The result of this experiment brought to mind a fact often noticed years ago when living in a region of clayey and loamy soils, viz: that during late autumn and early spring weather, water stood turbid during the warm day in low places where the ground was poached by the feet of cattle, but in early morning was covered by clear ice, beneath which the same gelatinous or flocky clay sediment seen in the experiment was plainly to be noticed.

Frost acts on wet sandy soils to force apart the particles by the simple expansion of the intervening water, which increases in bulk one-twelfth in the act of congelation. On wet clay lands the act of freezing condenses and agglutinates the clay, deprives it of its sticky cementing quality, and thus opens the pores to the flow of water, and for a time converts, so far as texture and consistence are concerned, a clay into a loam.

It is probable that light loamy lands with a deficiency of clay, and therefore tending towards undue porosity and want of retentiveness, may be rather damaged in respect to their texture by the agencies which coagulate clay and improve heavy clay lands. On such lands the uncoagulated clay fully charged and swollen with water is needed to give body and loamy quality to the soil. On such lands accordingly deep fall-plowing and thorough freezing, as well as fall or early spring application of soluble saline fertilizers are, other things being equal, to be avoided, and applications which furnish the only colloid substitute for clay at the farmer's disposal, viz: soluble humus, should be made. Soluble humus, the humic acid of the chemist, is abundant in well rotted stable manure, leaf mold, swamp muck, peat and decayed vegetable matter generally. The considerations that have been adduced in regard to the nature and uses of clay promise valuable practical results when applied to the investigation of humus, and this is a point to which the Station will give attention in future as it finds opportunity.

Studies on the Relations of Soils to Water.

The paramount importance of water to crops is sufficiently demonstrated both by practical observation and by accurate experiment. The farmer cannot increase or lessen the supplies of water to his soil except by irrigation, but he can largely influence the distribution and storage of water in the soil by tillage and drainage. He can dry out the soil by one mode of working it, and can diminish the loss of its moisture by another. In a lecture on "Some Reasons for Tillage," printed in the Report of the Connecticut Board of Agriculture for the current year, the writer has discussed some branches of this subject at length, and the reader is referred to that volume for details. The practical importance of the matter has led to undertaking its extended investigation in the Station Laboratory. Already several series of experiments have been put in progress and no little labor expended upon them. The work is not however sufficiently advanced to require a detailed record in this Report of the results as yet obtained; and from the complex nature of the subject, prolonged study will be needful to explore it with tolerable completeness. The first step in such an inquiry is to collate and put in accessible form what has been done already by others. I requested Mr. Armsby to undertake this collation, and he has carefully gone through the literature of the subject so far as it is accessible to us, and has drawn up a valuable paper which exhibits in systematic form the present condition of experimental knowledge and of scientific opinion regarding the Relations of the Soil to Water. The perusal of Mr. Armsby's paper (see p. 81), will I think serve a useful purpose in directing the attention of thinking farmers to the important points involved in this inquiry. They will see that the matter has been the subject of much thought and experimental work, that in some directions it appears to be fairly understood, but in others it is yet obscure. It will not escape notice that the investigations hitherto made do not adequately touch the relations of

clay soils to water. Something is inferred as *probable* regarding these soils, by application of the facts made out from experiments on sands of various grades of fineness, as well as from general knowledge, but the experiments on clay soils or soils approaching clay in character, have often given contradictory results, obviously because the elements of the problem have not been sufficiently understood, or because proper modes of experiment have not been found. In fact, the nature of clay has not been adequately studied by those who have worked on this subject. Now that the researches of Hilgard and Schlœsing have opened the plain way to be followed in this part of the inquiry, it may be anticipated that new investigations will prove highly fruitful.

The second step in this inquiry next to learning what has been done, is to subject the old experimental methods to critical investigation, beginning with the easier problems and testing the results now received, by new experiments made under varied conditions. Subsequently, when firm ground is reached in respect to the simpler branches of the subject, the research will move on naturally and certainly to the more difficult points.

Already experiments are in progress for the purpose of learning how to study the simple facts of the transmission of water from below up to the surface of soils, and its loss by evaporation into the atmosphere. After various trials we have devised a simple apparatus by means of which a column of soil fourteen inches deep and two inches in diameter can be maintained for months in contact at its base with water at a practically constant level, and so that no evaporation of this water can take place except through the soil, and so that the soil shall be always supplied with all the water it can transmit upwards. This apparatus can be put upon a powerful and yet delicate balance loaned to the Station and weighed from day to day. The loss it undergoes is an accurate measure of the ability of the soil it contains to transmit water. It has been already applied for two months in various preliminary experiments, upon the evaporation of water from peat, loam and emery. Emery has been the main subject of observation hitherto because its different numbers afford a sand-like material of graded sizes from about $\frac{2}{100}$ of an inch down, and since the extreme and average dimensions of the particles of each sort can be ascertained under the microscope, the influence of size of particles may be fixed by its use, and a standard of measure established for comparative trials of evaporation from soils and mixed materials whose particles defy attempts at measurement. It is necessary to carry on a considerable number of experiments simultaneously, under the same conditions of temperature and exposure in order to get comparable results, and these trials should obviously embrace many different kinds of well-defined soils or soil-like materials in different conditions of fineness, compactness and depth. They ought to be in some cases conducted on a larger scale than the balance at our service can accommodate, and it need scarcely be hinted that the preparation of suitable materials, the fitting up and mounting several dozens of the apparatus, and weighing them all daily for many weeks, will require a long time and occasion much labor. Some of the results already obtained are worth stating here, although they are merely confirmatory of what has been already known in a general sense before.

The clay-loam in these experiments was taken in the air-dry state, and was divided by sifting through round holes into three grades of fineness, one consisting of lumps between $\frac{3}{16}$ and $\frac{1}{16}$ of an inch in diameter, another of smaller lumps from $\frac{1}{16}$ to $\frac{1}{50}$ inch diameter, and a third comprising all the finer parts from $\frac{1}{50}$ inch down to dust. This clay-loam in all these grades consists of highly and finely *porous* lumps or grains. The peat, also a highly but differently porous material, was taken in a state of moisture nearly approaching saturation. It was employed both loose and packed.

The emery was chosen in the extremes of commercial fineness, "No. 46" and "flour," and also a medium grade, "No. 80." Microscopic measurements of the emery showed that the angular particles of the flour range widely in diameter from 0.00016 to 0.00066-inch, but are for the most part comprised between 0.0016 and 0.0033-inch. Their average dimensions may roughly be given as about 0.002-inch. The grains of No. 80 are more uniform in size, ranging between 0.0075 and 0.0125-inch, most of them being very nearly 0.01-inch in diameter. In No. 46 the dimensions mostly vary from 0.0175 to 0.02.

The table on page 80 gives the quantities of water evaporated through 14 inches of the materials named and from an area of one square inch,* under the same conditions of temperature and exposure, and during the times specified.

* In case of peat and loose flour of emery the surface area of the column changed considerably by the shrinkage of the material, as it dried out at the top of the column.

It is gathered from the figures of this table that in many cases the total evaporation is the greater the finer the materials experimented with. The fine loam loses water more than twice as rapidly and twice as much as the coarse. The closely packed peat and the packed flour of emery transmit and lose water more rapidly than the same materials with a looser texture, but the results with them are not entirely satisfactory on account of their shrinkage.

In case of emery of different grades we notice that the total evaporation is not greatest from the flour, but from No. 80. In fact, at the beginning of the experiment No. 80 took the lead, and for two weeks evaporated the most. Then the flour went ahead for a period. The experiment was, however, vitiated by the accumulation at the surface of the flour, and especially of No. 80 of a crust of saline matter, mostly sulphate of alumina. The weighings had to be interrupted in order to wash the emery and remove this source of disturbance, and at this writing have not been resumed sufficiently long to give results suitable for discussion here.*

* Since the above was written and before going to press, a second series of trials, on washed emery of five numbers, has proceeded far enough to show that the results of the table on page 80 were essentially vitiated by the saline incrustation. In this new series, thus far, No. 80 has decidedly surpassed the flour. Nos. 80 and 100 have kept, on the whole, very even pace, each alternating in the lead. With Nos. 80 and 100, the evaporation appears to have reached its maximum. Flour and No. 54 stand quite equally separated from and below Nos. 80 and 100. No. 54 is but just behind flour.

The results are tabulated below, in three periods, and refer to one square inch of surface and fourteen inches of depth.

Evaporation Experiments.—New Series.

	Emery.				
	No. 46.	No. 54.	No. 80.	No. 100.	Flour.
	grms.	*grms.*	*grms.*	*grms.*	*grms.*
17 days, Jan. 2–19	12.19	33.90	35.68	35.38	33.99
11 days, Jan. 19–30	6.08	18.51	20.02	20.06	18.65
13 days, Jan. 30–Feb. 12	6.10	20.21	22.10	22.04	20.70
Total, 41 days	24.37	72.62	77.80	77.48	73.34

Evaporation Experiments—1st Series.

Average dimensions of masses or particles.	Clay Loam. Coarse. $\frac{1}{8}$ inch.	Clay Loam. Medium. $\frac{1}{25}$ inch.	Clay Loam. Fine. less than $\frac{1}{100}$ inch.	Peat. Loose.	Peat. Packed.	Emery. No. 46. $\frac{1}{50}$ inch.	Emery. No. 80. $\frac{1}{100}$ inch.	Emery. Flour. less than $\frac{1}{500}$ inch.	Emery. Flour loose.	Emery. Flour packed.
Evaporation per sq. in. in periods from one minimum rate to another:	*grms.*	*grms.*	*grms.*	*grms.*	*grms.*	*grms.*	*grms.*	*grms.*	*grms.*	*grms.*
Nov. 6–10, ...	2.16	2.69	4.81	4.89	4.97	2.89	5.36	5.01	----	----
Nov. 10–19, ...	4.01	5.28	11.25	9.92	11.21	6.54	13.02	11.82	----	----
Nov. 19–28, ...	3.29	4.80	11.85	9.37	11.52	6.87	12.88	12.98	----	----
Nov. 28–Dec. 7, ...	2.71	4.25	11.31	7.18	9.74	6.56	10.79	12.26	9.89	17.42
Total Evaporation during 30 days from Nov. 6–Dec. 7, ..	12.17	17.02	39.22	31.36	37.44	22.86	42.05	42.07	----	----
	Oct. 26 to Dec. 7.			Nov. 3 to Dec. 7.		Oct. 27 to Dec. 7.			Nov. 28 to Dec. 7.	
Total Evaporation during entire time of experiment, ...	22.36	28.89	55.88	37.87	44.66	31.43	56.15	55.38	9.89	17 42

The following paper on the Relations of the Soil to Water was prepared at the Directors' request for the use of the Station.

Present State of Knowledge Regarding the Relations of the Soil to Water. By H. P. Armsby, Ph.B., Chemist to the Station.

There are three points in regard to the relations of the soil to water, which are of agricultural importance:

1st. Permeability.—The rapidity with which the water that falls upon the surface of the soil in the form of rain, etc., soaks downward through it.

2d. Water-holding Power.—The amount of water which is held in the various layers of the soil, where it may serve to nourish vegetation.

3d. Evaporation.—The rapidity with which water evaporates from the surface under different conditions.*

I. Permeability.

In a general way we may define the permeability of a soil as the rate at which water falling upon its surface passes downward through it.

Permeability in a uniform soil.

1. Suppose all the interstices of the soil to be full of water and water standing on the surface, and that then the rain-fall ceases. The water will flow downward through the interstices, which will remain filled only to a certain height above bottom water, this height being greater the finer the interstices, and the water being held in them by "capillary attraction."

This adjustment will in many cases be nearly reached pretty rapidly, though some water would cling to the surface of the particles and flow downward slowly. This would be the case especially with sandy and loamy soils. In a clay soil, owing to the peculiar nature of the materials comprising it, the flow would

* To which might be added—
4th. Hygroscopicity.—The amount of water which the soil can condense from the atmosphere. Recent investigations render it doubtful whether this hygroscopic quality of the soil has any significance as a means of supplying crops with water, and therefore this paper is confined to a discussion of the points above named.

probably be modified in some respects. The conditions influencing the rapidity of this downward flow are:

a. *The Fineness of the Soil.*—The larger the interstices between the particles of the soil, the less resistance they offer to the passage of water through them. If they are very small, the flow is governed by the laws of capillary efflux; the rapidity being inversely as the length and directly as the fourth power of the diameter of the tubes or pores.

The more interstices there are in a given area, the more water would flow through in the same time. If the particles of the soil were spherical and of uniform diameter, the total area of the interstices in any cross-section would be the same, whatever the size of the particles; so that the only difference in permeability would be that due to the size of the interstices and the consequent greater or less resistance to the passage of water through them. This would be approximately true for all soils of uniform grain.

If the particles were not of uniform size, we might expect that the smaller would fit in between the larger; and that, the interstices being thus made smaller, the permeability would be less than the mean of the several sizes separately.

In a fine soil the interstices would remain filled to a point nearer the surface than in a coarse one, so that the water would not have so far to sink, thus giving the fine soil an advantage; but it is doubtful if this would be of any practical account, so that we may say *a priori*, that a coarse soil is more permeable than a fine one.

Most experiments on this subject have been made by pouring water on a dry soil, in which case the capillarity of the empty interstices would tend to increase the rapidity of descent.

Von Klenze (*Landw. Jahrbücher*, 6, 113) found that water sank faster into coarse than into fine quartz and marble powders. He kept a constant head of one centimeter of water above the surface.

G. Wilhelm (*Jahresber. ü. Agr. Chem.*, 5, 16,) made similar experiments, using too little water to saturate the soil, and obtained the same result.

b. *Texture of the Soil.*—Whether loose or compact.

The fragments of a soil being ordinarily irregular in shape and size, they may so arrange themselves that, while they are in equilibrium, they can be shaken closer together; that is, the soil may be loose or compact. The effect of packing would be to make the interstices smaller and hence to decrease the permeability.

Von Klenze, in his experiments already mentioned, found that a loose soil was more permeable than a packed. In one case the water descended faster at first in a packed soil, but after an hour that in the loose soil overtook it.

c. *Porosity of the materials of the Soil.*—In this case water is present not only in the interstices of the soil but in the pores of the particles themselves; as e. g., in peat and to a certain extent in clay.

In the case above supposed, viz: motion of water downward through a soil already wet, this would probably have little influence. If the soil were comparatively dry, as in von Klenze's experiments, it might cause the water to descend slower, owing to the soaking up and retention of some of it by the porous particles.

2. If we suppose a little rain to fall on a comparatively dry soil, we have in some respects different conditions.

As the water sinks down through the soil, some is left on the surface of the particles, and finally the whole amount may be thus distributed. After this, the motion will be from the surface (or, in case of porous materials, from the pores) of one particle to another, and in this process the weight of the water would be a small factor. The motion of water downward would be much like the motion of water upward into a dry soil.

Hardly any experiments have been made on this subject.

The effects of varying fineness, texture, etc., are *probably* as follows:

a. *Fineness.*—The finer the soil the greater is the extent of surface in a given volume, and the nearer the surface is the point at which the water ceases to fill the interstices.

Below this point the downward motion would probably be faster in a fine soil, on account of the more numerous points of contact between the particles.

b. *Texture.*—The first stage of the process would probably be longer in a compact than in a loose soil. After that the effect of close texture would probably be like that of increased fineness.

c. *Porosity of Materials.*—Porous materials soak up water and hold it in their pores, and hence the water would fill the interstices of the soil to a shorter distance from the top.

Below this point the transfer of water would be largely from the pores of one particle to those of another, and would be more rapid the finer the particles and the closer they were packed, because in both cases the points of contact would be more numerous.

Permeability in a soil not uniform.

In a soil in which some layers are more permeable than others, owing to greater coarseness, looseness, etc., the permeability would be determined by that of the least permeable portion.

II. Water-holding power.

Not all the water which soaks into the soil from the surface flows through: a considerable portion, as is indicated above, is retained, and it is this mainly which is available to vegetation.

This capability of the soil to hold back a portion of the water which falls upon it has been variously designated as "water-capacity," "water-holding power," "imbibing-power," etc., but all these terms have been used with great looseness.

Ad. Mayer (*Landw. Jahrbücher*, 3, 753) seems to have been the first to distinguish clearly between the various meanings attached to these terms, though his terminology still leaves something to be desired.

Generally the water-holding power of a soil has been measured by the amount of water which a short column of it can hold; though no standard of height has ever been agreed upon. Mayer designates as "total water-capacity" the amount of water which a soil can contain when all its interstices are full of water and as "absolute water-capacity" the amount of water held at some distance above hydrostatic water, without however saying at *what* distance.

What is really of importance, however, is the *distribution of water in the soil.* We care far less about knowing how much water a soil can possibly contain, than about knowing how much water the various layers of it above hydrostatic water contain, how this is affected by fineness, texture, etc., what is the effect of alternating coarse and fine layers, etc.

All results should express the amount of water held in a unit-*volume* and not in a unit-weight of the soil.

Greatest Water-holding Power.

Almost all experiments on water-holding power have been directed towards ascertaining the total amount of water which a soil can hold, and the conditions determining it.

The method has been to weigh a short column of soil, pour excess of water on the top and weigh again after the excess of water has run off. The gain per unit either of the weight or the volume of the original soil, is the water-holding power.

It is possible to get comparable results in this way, or indeed any results of definite meaning, only when we so choose the conditions of experiment that all the interstices of the soil shall be full of water. In this case the water-holding power can be computed from the specific gravity of the materials and the absolute weight of a given volume of soil.

Under these circumstances, the only conditions that can well affect the water-holding power are:—

1st. Fineness of the soil.

2d. Its texture.

3d. Porosity of its materials.

4th. Shape of particles.

5th. Temperature.

All experiments on the effect of varying height of soil column, e. g., are meaningless, since this can only produce an effect by causing the interstices at the top to empty themselves and the soil to thus become half saturated. So also experiments made by allowing water to soak up into the soil from below are of rather doubtful value.

If we suppose a soil composed of uniform spherical particles impermeable to water and in the closest possible contact, then the total volume of the interstices in a given bulk of the soil would be the same, whatever the size of the particles, and consequently the water-holding power would be the same. If the particles are irregular in shape, the law will probably be still approximately true.

If the particles themselves were porous so that they could soak up water, or if they were not in close contact, the water-holding power would be greater.

If they were not all of the same size, the smaller would pass in between the larger, partly fill up the interstices, and diminish the water-holding power.

A priori then we can say:—

1st. Varying fineness has no effect on water-holding power, provided the particles are impermeable to water. If they are porous like lime-sinter or peat, pulverization may destroy the larger pores and decrease the water-holding power, as has been shown by Zenger and Wilhelm.

2d. A loose soil will hold more water in the same volume than a compact one.

3d. The more porous the materials, the greater is the water-holding power.

The following are the principal experimental results as yet obtained.

a. *Effect of Fineness.*—It is difficult to make exact experiments on this point. Most of those accessible show an increase of the water-holding power with the fineness.

Ad. Mayer (*Landw. Jahrbücher*, 3, 759) found the absolute weight of a unit volume of mineral powders to decrease, and the water-holding power to increase with increasing fineness, with the exception of the finest powders.

Von Klenze (*Landw. Jahrbücher*, 6, 124) found the same thing, calculating his results on unit-weight of soil.

Haberlandt (*Wiss. prakt. Untersuchungen*, etc., I, p. 9) found that peat and sand gained in water-holding power by pulverization, but that a garden soil passed a maximum at a certain medium fineness. The water in these experiments was soaked up by a column of soil six to eight centimeters high. The results are on unit volume.

These results seem to contradict the theory, but they may be due, as Mayer thinks his are, to the difficulty of packing the fine materials closely, or in part to the porosity of some of the materials used.

b. *Effect of Texture.*—Von Klenze (*loc. cit.*, p. 124) found that when a short column of soil was used, and the water poured on the top, a loose soil held more water per unit-weight but less per unit-volume than a compact one. If the materials were very coarse, the compact powder held the most per unit-weight as well, probably because the interstices of the loose powder were too large to remain filled to the top. With a long column also the packed soil generally held the more by weight.

Haberlandt (*loc. cit.*) found that loose materials soaked up more water per unit-weight than compact ones.

These results are the reverse of what theoretical considerations would lead us to expect, but the experiments give no guarantee that all the interstices were full of water, and that consequently the results truly give the *greatest* water-capacity.

The increase of water-holding power with the fineness (see above) on the other hand, is explained by Mayer, as probably due to the difficulty of bringing the particles of a fine powder into close contact, i. e., to the greater looseness of texture in these cases.

c. *Effect of Porosity of Materials.*—Ad. Mayer (*loc. cit.* p. 762) found that porous powders held more water than was calculated from their specific gravity and absolute weight. The great amount of water held by peat and similar substances is well known. Peat absorbs water into its microscopic pores and swells.

d. *Effect of varying size and shape of particles.*—Ad. Mayer (*loc. cit.* p. 766) found that the different cleavage of the minerals he used made no appreciable difference in the water-holding power. The fact mentioned above that the water-holding power of his finest powders was less than that of the next to the finest he explains as follows.

While the other powders were tolerably uniform, the finest contained particles ranging from 0.3 millimeter diameter to zero. On shaking, the very fine particles would fill up the interstices between the larger and thus reduce the space left for water. An experiment with a mixture of two other powders of different fineness showed the absolute weight of a given volume of the mixture to be greater than the average of the two, proving that there was less space between the particles.

Treutler (*Jahresber. ü. Agr. Chem.*, 13-15, I, 102) has found that mixtures of different substances, show in most cases, a less water-holding power than the average of the two materials separately.

e. *Effect of Temperature.*—Von Klenze (*loc. cit.*, p. 126) and Haberlandt (*loc. cit.*, p. 14) both agree that less water is held at high than at low temperatures.

"*Absolute water-capacity.*"

The greatest water-capacity, as above defined, is of little practical significance. An arable soil is never saturated with water for any length of time, but the water which falls on it is distributed through the whole mass, and only a portion is held by the upper layers. The questions of interest to every farmer are, what proportion of the total amount which a soil can contain, will it hold under given circumstances of drainage, &c., and how rapidly will a condition of equilibrium be reached.

The *rapidity* with which equilibrium is attained is determined by the permeability of the soil. In considering the distribution finally attained, it will be simplest to take first the case of a soil uniform from the surface down to hydrostatic (bottom) water.

1. *Uniform Soil.*

a. *Effect of Fineness.*—Suppose the soil to be composed of uniform fragments of impermeable materials.

To a certain height above hydrostatic water the interstices will be filled with water and the soil will show its "greatest water-holding power." This height we may call with Nessler (*Jahresberichte ü. Agr. Chem.*, **16** & **17**, I, 50) the "capillary height" of the soil, and perhaps the point to which the water fills the interstices may be called the limit of saturation. Evidently the finer the particles the smaller are the interstices and the greater is the capillary height.

This is shown by numerous experiments, e. g., by those of Nessler (*loc. cit.*) on sands of different fineness, and those of Ad. Mayer (*loc. cit.*) on the greatest water-capacity of coarse as compared with fine powders.

Above the limit of saturation (supposing water to have passed downward through the soil) water will be held on the surface of the particles and in the angles where they touch. The finer the particles the greater is the extent of surface and the more numerous are the points of contact in a unit-volume, and consequently the more water will be held. This is shown by the experiments of Ad. Mayer (*Landw. Jahrbücher*, **3**, 771), and probably by those of Von Klenze (*Landw. Jahrbücher*, **6**, 124).

In Haberlandt's experiments (*Wiss. prakt. Untersuch.*, &c., I, p. 13) fine soils took up more water; but the column of soil was comparatively short, so that the capillary height may not have been exceeded, and in any case the lower end of the column must have been saturated with water, a fact which would influence the result. His results are on unit-weights of soil.

Nessler (*loc. cit.*, p. 51–52) found that, when water rose into a soil from below, the layer moistened above the limit of saturation was higher the finer the soils.

This is the only experimental result on this point except the general one that water rises farther into fine than into coarse soils, even when pretty long columns are used.

As to whether the per cent. of water held at different points of the moist but unsaturated layer is the same, very few experiments have been made. Ad. Mayer (*loc. cit.*, p. 773) says it is the same, but gives no experimental results.

G. Wilhelm (*Jahresber. ü. Agr. Chem.*, **9**, 51, and **10**, 27) found that where hydrostatic water was comparatively near the surface the moisture of the soil increased downward.

Liebenberg (*Jahresber. ü. Agr. Chem*, **16** and **17**, I, 98) found the same in experiments in tubes.

By both Wilhelm and Liebenberg and by Breitlohner (*Jahresber. ü. Agr. Chem.*, **10**, 28) the lower layers of soils bearing plants were found to be drier than the upper.

b. *Effect of Texture.*—The effect of packing would be to make the interstices of the soil smaller and consequently the capillary height greater, though the amount of water held in a unit-volume of the saturated soil would be less. See p. 86.

Ad. Mayer (*loc. cit.*, p. 800) found that water rose farther into packed than into loose powders.

Von Klenze (*Landw. Jahrbücher*, **6**, 102) in experiments on the rise of water into dry soils, found that the water rose farther in some cases in packed, in other cases in loose soil. His experiments were on the rapidity of the rise, however, and he does not state whether the experiments were continued till the water ceased to rise. He also found in experiments on water-holding power that in some cases a long column of packed soil held more water than one of loose soil. This is probably due to the greater height of the limit of saturation.

The same thing was observed with short columns of coarse materials, probably for the same reason.

Haberlandt (*loc. cit.*, p. 17) found that water rose faster into loose soils. It does not follow, however, that it would finally stand at a greater height.

Nessler (*loc. cit.*, p. 52) found that water rose farther into packed than into loose soil.

Above the limit of saturation it seems probable that the packed soil would be moister, there being more small crevices between the particles in which water could be retained.

c. *Effect of Porosity of Materials.*—If some or all the particles of the soil are finely porous or swell up with water, the distribution of water would be greatly modified above the limit of saturation. The fine pores of the particles once filled with water retain it, since they are short and open into the comparatively large interstices of the soil, and in many cases the amount of water thus held would be greater than that held on the surface of the particles.

The effect of fine porosity then would be to equalize the distribution of water above the limit of saturation and to make the amount held greater.

Very likely also the height to which water would rise into a dry soil would be greater in such a case, as Mayer (*loc. cit.*, p. 796) observed in one instance.

An effect somewhat similar to those just mentioned is produced when a soil compacted by rain, &c., is broken up by tillage. The compact mass is broken up into small porous fragments and made to occupy more space. These fragments retain the water they held before, but the large interspaces between them do not fill themselves with water, and so the amount of water held in a unit-volume is less. At the same time the distribution of water is probably more uniform in such a soil than it would be in the same volume of a compact earth, for the reasons already stated.

2. *Soil not uniform.*

Nessler (*Jahresber. ü. Agr. Chem.*, **16 & 17**, I. 49) has worked up this subject. The fundamental consideration which Nessler proceeded from is as follows. "If a narrow tube whose ends are of unequal width be placed with the wide end in water and then inverted after removal from the water, the water which it holds by capillarity will flow down to the narrow end.

If the narrow end is filled and this held uppermost, the water will indeed fall somewhat toward the wide end but will not reach it, if the length and difference in the width are great enough."

a. *Fine soil above coarse.*—If we have a fine or compact soil over a coarse (or loose) sub-soil, water falling on the top will be held in the pores of the fine layer in much the same way as if it were in contact with hydrostatic water at the point where the coarse sub-soil begins, no matter how coarse the latter may be. A soil thus situated is not so well drained as if the sub-soil were as fine as itself. The reason why such a soil is drier than one on a fine sub-soil is that the water held by it soon dries out in fair weather and the sub-soil cannot raise water fast enough to supply the loss. In such a soil the water in the fine and that in the coarse layer would be distributed independently and as in a uniform soil.

The retention of water by a packed layer has been shown experimentally by Nessler (*loc. cit.*, p. 50). When water was poured on a column of soil having the upper one and a half inches packed, most of it was held by this layer and only a little of it reached the lower part of the soil. Nessler remarks that a crust would act in the same way.

b. *Coarse soil above fine.*—If we have a coarse soil over a fine the water will flow down into the latter, merely moistening the upper layers, the interstices of which can remain filled only as long as more water falls than can pass through the fine layers.

c. *Porous materials.*—If the materials of the soil are porous the water-content of the two layers would probably be to a certain extent equalized, since the particles would soak up about the same amount in each. As was noted on p. 90, tillage may produce a condition similar to this, especially in a stiff soil.

3. If evaporation takes place, the upper layers of the soil will dry out to a greater or less extent, depending on the power of the soil to transmit water. See below.

III. Evaporation.

The rapidity of evaporation from the surface of a soil depends, partly upon external and partly upon internal conditions. The former are temperature, exposure, &c., and do not require notice here. The internal conditions are essentially the two following:

1. The amount of moisture in the upper layer; this depending on the rapidity with which water can rise from below to supply the loss by evaporation, it having been shown by Schulze (*Jahresber. ü. Agr. Chem.*, 3, 31), W. Wolf (*Landw. Jahrb.*, 2, 384), Wollny (*same*, 5, 441) and Haberlandt (*Jahresber. ü. Agr. Chem.*, 9, 49) that the drier a layer of soil the less the evaporation. This rise of water from below to supply the loss by evaporation from the surface is due to capillary action, and hence we may properly designate the capillarity of the soil as one of the factors that determine evaporation.

2. The extent of surface exposed to evaporation.

These two conditions, capillarity and extent of evaporating surface, we will consider in their order.

1. *Capillarity.*

By the capillarity of a soil we understand the rapidity with which it permits water to rise in it to supply a deficiency at any point, and *not* the height to which water will fill its interstices, though there is very likely a relation between the two.

Most experiments on this subject have been made by allowing water to rise into a dry soil; but in the first place the adhesion of air to the surface of the particles of a dry soil renders the value of such results doubtful, and in the second place a knowledge of the rapidity with which water will rise into the empty interstices of a dry soil is of little practical value since the conditions in nature are entirely different. There the tendency is simply to preserve the original distribution of water by a motion through the already filled or partly filled interstices toward the point from which water is being abstracted—generally the surface.

In order to get an idea of the capillarity of the soil under natural conditions we need to determine the amount of water evaporated. This will in most cases be a measure of capillarity since it cannot evaporate for any length of time faster than it is supplied from below.

If we have a soil subject to no evaporation and in contact below with hydrostatic water, the water will distribute itself as already explained. If evaporation begins, two cases are possible.

1st. The amount evaporated is less than or equal to what can rise through the soil. In this case the moisture of the upper layers and consequently the evaporation will remain the same.

2d. The evaporation is greater than the amount that can rise through the soil. In this case the upper layers of the soil will dry out and the evaporation will consequently diminish till it and the supply come into equilibrium, and so the evaporation is determined by the supply and becomes a measure of it.

Sometimes the top of the soil may become air-dry and evaporation take place from a point below the surface. In this case the access of air to the evaporating surface would be largely decreased and the evaporation greatly diminished.

The conditions affecting capillarity and hence evaporation are:

a. *In uniform soil.*—(1.) *Fineness of particles.*

Non-porous materials.—It is necessary to distinguish between the motion of water in that part of the soil where the interstices are full of liquid and the motion from the surface of one particle to another above the limit of saturation. The former motion is probably the easier.

If experiments were made on columns of equal height, the effect of increased fineness would be two-fold.

In the first place the capillary height would be greater and there would be a less distance for water to travel on the surface of the particles. This would probably tend to increase the ease of motion. Above the limit of saturation, too, there would be more points of contact between the particles and very likely the motion would be easier on that account.

In the second place, the finer the interstices the greater would be the friction below the limit of saturation, this tending to decrease the ease of ascent.

Possibly there may be a medium fineness which would give the greatest capillarity. Von Klenze (*Landw. Jahrb.*, 6, 104) says there is, but his experiments, like most others on this subject, were made on dry soils, and are hardly conclusive even for those.

Ad. Mayer (*Landw. Jahrb.*, 3, 794) found that water rose faster into fine than into coarse non-porous powders. Von Klenze (*loc. cit.*, p. 96) found the same. Haberlandt (*Wiss. prakt. Unters.*, I, pp. 17-20) obtained in general the same result, but with a few exceptions. He found that water rose fastest into sand of a medium fineness, while it ascended most rapidly after the first few minutes, in the finest peat or garden soil.

Porous Materials.—If the particles of the soil are themselves porous, we have a second system of capillary tubes acting to a certain extent independently of the interstices between the particles. As compared with a soil of non-porous materials of the same grain, the porous would raise water faster because there are more spaces for the liquid to move in. Mayer (*loc. cit.*, p. 796-7) found this to be true of the rise of water into dry materials.

With porous substances, the rise of water, especially at a considerable height, may take place chiefly in the pores of the particles If this be so, making the grain finer (which has no effect on the pores) would not check the rise of water as making non-porous particles finer does, by increasing interstitial friction. Greater fineness of porous particles tends to increase their points of contact and thus far to favor motion of water from grain to grain. This view has been suggested by Haberlandt (*loc. cit.*, p. 20). If it be correct, capillarity in porous-grained soils would increase with the fineness of their particles, instead of being greatest at a medium grain, as is probably the case with non-porous materials. Possibly the results of Haberlandt on sand as compared with peat and garden soil mentioned above indicate this.

(2.) *Texture of the Mass.*

Non-porous materials.—The effect of packing is to make the pores smaller and so to decrease the space for the passage of water. The effect in general would probably be the same as that of increased fineness, and the capillarity may show a maximum in this case also.

Porous materials.—The chief effect of packing would seem to be to bring the particles into closer contact and so to render the passage of water from particle to particle easier, thus increasing capillarity. If, on the other hand, we cultivate a somewhat stiff soil when at a certain stage of dryness, we break it up into small porous fragments, and the mass has less capillarity than before.

Mayer (*loc. cit.*, p. 800) found that water rose fastest into packed mineral powders except in case of the somewhat porous clay-sandstone.

Von Klenze (*loc. cit.*, p. 102) found that in quartz powder and in a "humus lime-sand" water rose faster into the packed than into the loose material. With a loam he found the reverse, but thinks this due to the capillarity having passed a maximum at a certain fineness of the interstices. He made no further experiments on the latter point.

Haberlandt (*loc. cit.*, p. 17) found that water rose slowest into packed soil and fastest into loose.

Nessler (*loc. cit.*, p. 52) found exactly the reverse, both with the soil in contact with water and after it was removed from it.

He also experimented on evaporation by exposing portions of wet soil in glass cylinders with no further water supply. Two series of experiments were made, in one of which the soil was covered with thin filter paper and in the other was exposed freely to the air.

The packed soil evaporated more than the loose, and in one case was found to be moister at the top and drier at the bottom after the experiment than the loose, showing that capillarity was increased by packing.

As long as the loose soil was quite wet it evaporated water faster when covered than the packed. Later, after the upper layers had dried out, the reverse was the case; showing that the loss could not be so easily supplied from below.

The experiments of Wagner (*Jahresber. ü. Agr. Chem.*, **16** & **17**, I, 56), show also a greater capillarity, as indicated by evaporation, in a compact soil, and a drying out of the upper layers similar to that in Nessler's experiments. Equal weights and not equal heights of soil were used.

Schleh (*Biedermann's Central-blatt*, **7**, 84) found that water rose faster into a compact than into a loose soil. In evaporation experiments with a supply of water but not at a constant level, he found that a compact soil evaporated more water than one with a loose layer on top.

The conditions influencing capillarity, and hence, evaporation, are:

b. *In soil not uniform.*—(1.) *A loose layer above.*

As Nessler has shown (*loc. cit.*, p. 53), the general opinion that a loose soil dries faster than a compact one is not always correct. There are two processes to be distinguished; in the first place we have the evaporation from the top of the soil, and in the second place that from layers below the top. Loosening the top of the soil helps the second process by exposing more surface to the air, but it may hinder the first process by decreasing capillarity. With loose materials, like a sandy soil, cultivation, while increasing the surface, might not decrease capillarity very much, and so might increase evaporation.

In the majority of cases, however, loosening the upper layers seems, so far as experiments have been made, to decrease the rate of evaporation by decreasing capillarity. Not only would the water be transmitted less readily by the loose portion, but it would pass with difficulty from the fine interstices below to the large ones above.

Loosening the upper layer would seem likely to affect especially a soil composed of porous materials, or one which like a clay is broken up by tillage into porous fragments, by decreasing the number of points of contact.

Nessler (*loc. cit.*, p. 55) found evaporation to be decreased very much by loosening the upper layer of the soil, and that the soil below remained moister than when the surface was compact. A soil entirely loose lost still less by evaporation.

Wagner and Schleh obtained essentially the same results.

(2.) *A compact layer above.*

The most common case is the formation of a crust when the surface of the soil is "puddled" by the action of rain. No accounts of experiments on this point are accessible. It seems probable that the effect on evaporation would depend largely on the texture of the soil below the crust, whether loose or compact.

In some cases evaporation might be increased, the fine interstices of the crust withdrawing water from the larger ones below to give it up again to the air; while in other cases evaporation might be checked by decreased access of air, or even by a decrease in capillarity, owing to over-fineness of the interstices.

2. *Extent of evaporating surface.*

In all cases the extent of evaporating surface is an important factor in determining the amount of evaporation. By evaporating surface is meant not only the upper surface of the mass of soil but all points from which evaporation takes place. In a loose soil large quantities of water may evaporate at points below the general surface of the mass.

Commonly the coarser and looser a soil is, the more surface it exposes to evaporation. When, after wetting, evaporation begins anew, a soil of coarse or open texture is likely to lose water more rapidly at first than one of a finer or more compact quality, but since the coarse or open soil has usually inferior capillarity it would speedily dry out at the top and then might lose less water than a finer or more compact one. This is shown strikingly in the experiments of Nessler and of Wagner mentioned on p. 94.

The latter found that a loose soil evaporated water rapidly at first, but that it soon fell below a packed soil, and that as the weather grew warmer it evaporated still less, while the evaporation from the compact soil increased; showing that the capillarity of the latter was sufficient to supply the increased evaporation due to a higher temperature, while that of the former was not.

On the Chemical Examination of Drinking Waters for Organic Contamination.

The attention of officers of the Station was called to this subject by the following letter, addressed to the Secretary by Mr. J. M. Hubbard:

"MIDDLETOWN, CONN., Dec. 26th, 1877.

Prof. W. H. BREWER:

Dear Sir—I write to ask if you can render me any assistance in testing a sample of well-water for substances deleterious to health.

The family, neighbors of mine, which have used water from this well the past summer, have been sick with typhoid fever for more than three months, only one person—an infant—out of nine having escaped an attack. None have died, and all but one are considered convalescent and out of danger. The well which has supplied the family with water was originally dug to supply a stock-yard, and is still used for that purpose. It has seemed to me possible that the well may have been contaminated from the yard, and thus have originated the fever."

The Executive Committee of the Station having decided that this was a proper subject for investigation, instructions were sent to Mr. Hubbard for taking a sample of water, which was duly received and examined.

The results of the analysis were communicated to Mr. Hubbard, with essentially the following remarks:

Chemistry has no means of deciding whether a sample of water contains typhoid infection, nor is the nature of that infection certainly known. It is, however, pretty well established that typhoid fever results from a special poison, and is communicated through the intestinal evacuations of typhoid patients. What chemistry can do is this, viz: it can show with very great probability whether a sample of water contains or does not contain sewage, cess-pool, privy, or barn-yard contamination. This is accomplished by determining the quantities of: 1, total dissolved contents, organic and mineral; 2, chlorine (i. e., common salt); 3, ammonia free or as carbonate; and 4, "albuminoid ammonia," i. e., the ammonia yielded by albumin and various nitrogenous organic matters under certain chemical treatment.*

* The processes of chemical analysis have been recently so refined that the estimations of chlorine and ammonia in waters are made with comparatively great ease and with exceeding delicacy by the methods of Chapman and Wanklyn.

Urine and intestinal evacuations always accompany each other in privy-vaults, sewers and barn-yards. If blended directly with water they occasion by their decomposition almost immediate formation of *free ammonia*, and they yield by chemical treatment what is called albuminoid ammonia, in addition. Urine contains most of the salt (*chlorine*) of the food of animals. If, then, a water be free from these substances, or give no greater quantities of chlorine, free and albuminoid ammonia, than pure waters, the absence of sewage or privy contamination is reasonably certain.

If much chlorine be present, but no ammonia, then (unless some other special source of chlorine be obvious) it is made probable that the salts of urine have filtered through the soil into the water, but that the organic matters, and with them any disease-infection have been retained or destroyed (oxidized) in the soil, so that *contamination* has not occurred.

It is imaginable that typhoid infection might be separated from the fecal matters by which it is communicated and be used to make water poison, which our chemical analysis would pronounce pure, but the chances of such an occurrence must be regarded as infinitely small. Again, analysis may indicate gross sewage or privy contamination, and yet the water be free from the specific typhoid contagion, and only capable of producing diarrhœa or malarial fevers, or even be not sensibly deleterious to vigorous constitutions.

The analysis of the water from Middletown is given below, in comparison with some other waters, pure and impure.

Analyses of Waters.

	Grains in U. S. gallon =58,372½ grs.		Parts per million.	
	Total Solids.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.
New Haven city water, from Lake Whitney	4 to 5	.13 to .22	.000 to .008	.02 to .033
Thames water, England, where taken for supply of London			.01 to .04	.28
Thames water, efficiently purified and supplied to London	15.6	1.20	.00 to .01	.06 to .08
Thames water, imperfectly purified and supplied to London	15.6	1.20	.03 to .06	.10 to .16
Water sent by J. M. Hubbard, Middletown, Conn.	4.2	.32	None.	.006
Water from well on Howard ave., New Haven, very near water-closet cess-pool	73.8	6.89	.001	.016
Sewage from ditch of Canal R. R., New Haven			18·6	3.4

These figures indicate that the water received from Mr. Hubbard is extremely pure. The total solids are unusually small, the chlorine and ammonia are present in quantities so minute as to preclude the idea of any contamination. The water is in fact purer in these respects than the very pure water supplied to New Haven city.

In a letter dated Jan. 2d, 1878, Mr. Hubbard gives particulars regarding the well, which has been in use for two and a half years. The well stands close upon the highway, between a barn-yard now used and an old one for some time disused and filled up some 2 or 3 feet, to level the ground. The well is not more than 10 feet from the boundary of the barn-yard now used. The well is dug through 2 to 3 feet of rather heavy loam, and thence through some 13 to 14 feet of clayey subsoil, its bottom being the surface of the sandstone rock. The water stands at present within 6 feet, and in wet seasons rises to within 2 feet of the surface.

The attending physician does not consider the well to be in fault, but believes that the fever was brought to the family by one of its members, who had been living away from home for nearly a year, and was the first to suffer.

As has been intimated already, the weight of evidence with regard to outbreaks of typhoid is in favor of the view that ordinary filth in drinking waters or in food does not produce that disease, although such filth probably predisposes to attack, and may produce febrile disturbance. If the sample of water analyzed faithfully represents that which the family have all along consumed, the facts of this case substantiate the doctrine that typhoid is the result of a specific virus, as is known to be the case with small pox, scarlet fever, etc.

The purity of water so near a barn-yard is in accordance with the facts of soil-absorption which have been so fully studied of late years. The clayey matter of soils not only very completely deprives water filtering through it, of organic coloring matters, ammonia, potash, and phosphoric acid,* but a something in the soil rapidly destroys ammonia and organic substances by oxidation. The former process of absorption operates most effectually

* The soil has little or no retentive power for lime, soda, chlorine, sulphuric acid, carbonic acid and nitric acid, so that common salt, sodium chloride and calcium nitrate, as well as calcium sulphate (gypsum) and calcium carbonate, are abundant in the water of wells when abundant in the adjacent soil.

in clayey or loamy soils. The latter process of oxidation goes on energetically in sandy soils. The well in Howard avenue, New Haven—see table of analyses—is situated between two cesspools, one distant twenty-two feet, the other eleven feet, horizontally. The latter has for five years received the water-closet waste of a small family. The well however is deep, and the liquid contents of the cesspool have to traverse diagonally about twenty-two feet of earth before reaching the well. The water contains abundance of solids and of chlorine, which evidences the passage of salt from the cesspool, but the animal matters are effectually destroyed in the intervening soil, and their nitrogen is converted into harmless *nitrates*, which were abundant in the water, though their quantity was not estimated.

The soil thus purifies impure water which *filters through* it, but there is a limit to its power in this respect, and when the mass of earth through which the water has to pass is small and the mass of impurity is large, experience shows that after a time the water may carry poison with it through a considerable thickness of earth.

It is especially to be cared for that contamination does not enter wells at the surface of the ground. Wells situated near sources of danger from this cause should always be banked up, best with clay or clay-loam, so high and so effectually that no sudden rain or flood can enter them from above.

Preparation of Soda-lime for Nitrogen Determinations.

In 1872, the writer found that the mixture of caustic soda and caustic lime known as "soda-lime," which had long been used in chemical analysis to determine nitrogen quantitatively, might be replaced by a much more easily prepared mixture of equal volumes of dry carbonate of soda and slaked lime. See *American Chemist*, vol. iii, p. 161. On beginning Station work in July, we experienced difficulty in obtaining carbonate of soda suitable for this use. The super-carbonate which could be readily dried contained nitrogen, and the crystals of sal-soda that after washing were free from nitrogen could not be quickly dried to a *fine* powder. After various trials the following process of preparing an effective soda-lime was devised. Equal parts of sal-soda in clean (washed) large crystals and of good white and promptly-slaking quick lime are separately so far pulverized as to pass holes of $\frac{1}{16}$ inch, then well mixed together, placed in an iron pot which should not be more than half filled and smartly heated, at first without stirring. The lime soon begins to combine with the crystal water of the carbonate of soda, the whole mass heats strongly, swells up and in a short time yields a fine powder which may then be stirred to effect intimate mixture and to dry off the excess of moisture. When cold it is secured in well-closed bottles or fruit jars and is ready for use.

Use of Iron tubes in Nitrogen Determinations.

In a number of comparative trials made in glass and iron tubes, we have found that the use of the latter commonly gives 0.2 to 0.5 per cent. less of nitrogen than the former. The same deficiency occurred in one combustion made in a glass tube containing a short layer of small iron tacks anterior to the mixture. All our nitrogen estimations are consequently made in glass tubes.

Beet Sugar.

The subject of sugar production from the beet is one which those who are conversant with the facts consider to be highly worthy of the serious attention of farmers and capitalists in the Middle and New England States. Beet sugar industry flourishes in Germany, Austria, Belgium and France, against all competition from the sugar cane cultivators of tropical regions, and in spite of heavy Government taxation.

Mr. Henry C. Humphrey, of Stamford, who has made a practical study of sugar manufacture and refining, and during the last autumn has successfully put up and operated an experimental beet sugar works in New Jersey for Joseph Wharton, Esq., of Philadelphia, has kindly furnished the following statistics on this subject, and has at my request prepared the subjoined paper, which gives definite instructions as to the cultivation of sugar beets. The Station is ready to assist parties in Connecticut who may wish to experiment in this direction in procuring suitable seed, and will undertake to analyze next autumn, free of charge, the beets that may be produced. Immediate application should be made to the Station by those wishing to secure its coöperation in carrying out practical trials of the adaptation of their lands to sugar raising.

Sugar Statistics.

In Germany and Austria every 110 pounds avoirdupois of beets pay about nineteen cents tax. In France 114.4 pounds sugar (=2,200 pounds beets) pay $2.66 tax. The annual production of beet sugar in Europe is as follows:

German Empire	346,666 tons.
France	462,259 "
Russia and Poland	245,000 "
Austria and Hungary	153,922 "
Belgium	79,796 "
Holland and elsewhere	30,000 "
Total beet sugar	1,317,000 "
The total cane crop is	2,140,000 "
Grand total	3,457,000 "

In 1874–5 the average prices in Germany were, for new sugar six to seven and a half cents, for better grades of refined sugar eight and four-fifths to ten and two-fifths cents per pound. The quotations in American markets, February 1st, 1878, were, for raw sugar six and a quarter to eight and a quarter, for refined seven and a quarter to ten and a half cents, notwithstanding a considerable decline within nine months, so that beet sugar is not more costly in Europe than cane sugar is with us. In fact, beet sugars have been imported to some extent into the United States of late years.

The consumption in this country during 1876 was—

Cane sugar of foreign production	561,367 tons.
" " " home "	77,000 "
Maple sugar (estimated)	13,000 "

The average annual cost of our imported sugars at ports of shipment for five years (1871 to 1876), was $89,400,000 gold; to this must be added ten per cent. for cost of shipment, making a yearly expenditure of nearly $100,000,000.

The comparative cost of producing cane and beet sugar, under favorable circumstances, is given by Mr. Humphrey, as follows, per acre:

	Cane.	Beet.
Sugar,	1,700 lbs. at 8 cts.=$136	2,400 lbs. at 8 cts.=$192.00
Molasses,	75 galls. at 28 cts.= 21	4.00
Refuse (root-pulp, cattle-food)		3.7 tons at $5 = 18.50
Leaves and tops,		5.00
Manure,		4.00
	$157	$223.50
Cost of production,	60	49.00
" " manufacture,	35	100.00
	$95	$149.00
Profit,	$62	$74.00

On the Cultivation of the Sugar Beet. By Henry C. Humphrey, Esq., of Stamford, Conn.

A beet from which sugar can be profitably extracted contains twelve per cent. of sugar. Eighty per cent. and over of the total solid contents of the juice should be sugar. A beet of this quality is usually long, smooth and tapering in form, grows very much under ground, weighs from one to two and a half pounds, and during the season of growth has a large number of healthy leaves.

To obtain such a beet, the following conditions should be observed:

It is absolutely necessary to have reliable seed. Deep tillage is indispensable, in order that the beet may easily force its way into the earth. Beets should be placed at the proper distance, that they may obtain sufficient nourishment from the soil and yet not too much. Beets weighing over two and a half pounds are usually poor in sugar. Lime has always been found in good beet lands. Fresh nitrogenous manures have been shown to cause a decrease in the amount of sugar. Beets succeed best after a well manured crop of rye, wheat, corn, etc. A rotation of crops is necessary, beets being planted every third or fourth year. Potash salts and phosphates appear to exert a beneficial action upon the production of sugar.

There can be no fixed rules laid down as to the best method of cultivation. In each locality there must be a variation induced by differences of climate, soil, etc. Each farmer must use such means as his farm will allow, to bring about the desired result.

The following are some general directions as to the proper method to be used:

Select a well cultivated, light, sandy loam, with a permeable subsoil. If possible, choose land which has been well manured the year preceding and on which a crop has been grown. This should be plowed in the autumn, and if the land is heavy the furrows should be exposed to the action of the frost. Plow as deeply as the nature of the soil will allow. The Germans often plow to the depth of eighteen inches. In the early spring broadcast two hundred to three hundred pounds of sulphate of potash, and five hundred pounds of some good phosphate to the acre. Plow, harrow and roll the ground.

The planting of the seed should take place as early as possible after the frost is out of the ground, about the first of May. Sow the seed at a depth of three-quarters to one inch, in rows of from two feet to two and a half feet apart, according to the richness of the ground. Fifteen pounds should be used per acre. After the plants are of sufficient size they should be thinned out so that a space of five, six to ten inches separates them.

Keep the weeds down by continual cultivation until the beet is of such size that it cannot be injured by their growth. Hoe the earth around the top.

About the middle of October the leaves turn yellow and flabby, and are ready for harvesting. Before the heavy frosts, the leaves should be cut off and the roots buried. Six or more beets representing an average of the crop, should be wrapped in paper and forwarded for analysis.

Full information should be sent in on the following points, viz:

1. Condition and quality of land. What and how large crops have been raised during the last two years. What manures were used?
2. When was seed planted?
3. How were beets cultivated?
4. When harvested?
5. Weight of crop, without the leaves?
6. Amount of land planted?
7. For how much could an acre of such beets be raised?
8. The time of the first killing frosts.
9. Number of days on which rain fell.