Lawes, J. B. 1847. On agricultural chemistry - turnip culture. *Journal of the Royal Agricultural Society of England.* 8 (2), pp. 1-27.

ON

AGRICULTURAL CHEMISTRY.

TURNIP CULTURE.

By JOHN BENNET LAWES.

LONDON:
PRINTED BY W. CLOWES AND SONS, STAMFORD STREET,
AND CHARING CROSS.
1847.

REPRINTED BY SPOTTISWOODE & CO., NEW-STREET SQUARE.
1896.

FROM THE
JOURNAL OF THE ROYAL AGRICULTURAL SOCIETY OF ENGLAND,
VOL. VIII., PART II., 1847.

NOTE ON REPRINTING IN 1896.

This paper, which was published in 1847, now nearly fifty years ago, records experimental results and conclusions which are still of interest and importance; but there are some points to which it seems desirable that reference should here be made. Thus, it is throughout assumed that the carbon of the "*organic*" manures used, such as farmyard manure, rape-cake, &c., was an important source of the carbon of the crops, but it is not now supposed that it is so in the case of chlorophyllous vegetation. Independently of the benefits arising from the mechanical effects of farmyard manure, such "*organic*" manures are specially valuable for the nitrogen and the mineral matters they supply; the carbonic acid yielded on the decomposition of their carbonaceous constituents being chiefly useful in aiding the solution of the mineral constituents of the soil or the manures. The nomenclature is also in some cases not such as would now be used. For example, the turnip is throughout called a "bulb," instead of a *root*, as it is more properly designated.

AGRICULTURAL CHEMISTRY.

TURNIP CULTURE.

Experience is a legitimate and trustworthy guide in all the great practical arts affecting the physical condition of the human race, and, for agriculture, as for many other branches of industry, has attained a considerable degree of progress independently of the aid of science; but in so far as experience, as distinguished from principle, is relied upon, must we be content that the soundest practices should only be adopted by that small proportion of the entire masses who exercise an intelligent observation, and have arrived at rules for future guidance more or less by the lessons of past error. But although the results of investigation into the rationale of well recognised practices should prove them to be in the main consistent with philosophy, rather than show them to be fundamentally erroneous, yet, when it is remembered that a well understood and simply explicable principle is much more easily acted upon and by a much greater number of individuals than are the dictates of the most acute empiricism, the claim of science as an improver, as well as an exponent of the economic arts, must be fully admitted. The young man of average talent and education, by the assistance of principle, attains comparatively early the position which otherwise half a life is spent in seeking. Granting, however, what we are by no means called upon to do, that the best practices of the age are beyond the aid of science, and that their more current adoption rather than their improvement is to be expected, a better knowledge than is now prevalent, regarding the first principles of vegetable growth, will serve to protect the farmer from the many snares into which either fraud or ignorance would lead him. If, then, the results of investigation should tend to explain and to enforce good old practices, rather than to put forth those which are new and untried, the utility or even the necessity of the application of science to the improvement of our national agriculture will not be the less evident.

The question with the agriculturist is not so much what are the constituents which must exist in his soil for the growth of a given amount of produce? but what constituents or class of constituents does this or that crop exhaust, relatively to another constituent or class of constituents? Looking at the subject in this point of view, we are of opinion that the increased growth of corn may be considered to have a very intimate relationship to the amount of nitrogen supplied to the soil: and since, owing to the scarcity and high price of ammoniacal salts, or other direct nitrogenous supplies, it is impossible to rely upon these sources, a rotation of crops, and the importation of food for stock, come to be not merely the only generally applicable, but the most economical, means of restoring fertility to the soil. Under such a course for the special accumulation of nitrogen, it will be found that there is always secured an abundant coincident supply of mineral and carbonaceous substances, and hence the direct importation of these latter substances is seldom necessary.

The results of our experiments upon wheat and other plants of the gramineous family have indeed shown, beyond a doubt, that the character of the exhaustion which the soil suffers by their growth is essentially and pre-eminently nitrogenous; and since common usage bears ample testimony to the efficiency of alternate cropping, it is to be supposed that an examination into the composition, habits, and sources of growth of the plants which enter into a rotation, would bring to view important functional differences and peculiarities in the different plants, and such as should give confidence in general principles and tend to improvement and economy in practice.

The greatly varying form and appearance of the various agricultural plants, implying, as undoubtedly they do, essential differences in their sources of nutriment, have led, from but superficial observation of them, to erroneous assumptions regarding the true office of certain plants in a course of agricultural cropping. Thus it is by some maintained that the large surface of leaf put forth to the atmosphere by the turnip, taken in connexion with the general character and utility of the crop, bespeaks an almost exclusive reliance upon the natural resources of the atmosphere for its carbonaceous supply; and the direct application of nitrogenous manures has accordingly been recommended with the view of favouring to the greatest extent the development of leaf as a means of securing bulb.

Again, agricultural plants have been arranged according to their botanical alliances; and distinctions between the necessary conditions of artificial supply of certain constituents have been made, which are inconsistent with the dictates of experience, and equally so with those to which we are led when other circumstances besides the (nevertheless important) botanical distinctions are brought into consideration. The varying quantitative reliance upon the atmosphere and the soil of different natural families of plants constitutes indeed a most interesting and important point of study, and the principles upon which the *natural system* is founded may derive essential confirmation from chemical researches; but in referring the varying agricultural value of different plants to the functional characters of the several natural orders to which they belong, it must always be first decided that the natural aim and tendency of the plant and order are favoured by our methods and objects of cultivation, and that the agricultural value of the plant is in no way dependent on a monstrous or artificial development at variance with that of its individual health and reproductive tendencies.

The cultivation, habit, and uses of the turnip are well suited to form a contrast to those of our grain crops; and the plant itself may, to some extent, be taken as the type of the green or fallow crops, a main effect of which is the preparation of the soil for the after-growth of corn. The essentially artificial condition which is induced in the cultivation of the turnip plant, for feeding and manuring purposes, is most strikingly illustrated by the effect of climate and manures upon the quantity and composition of the produce.

We shall now proceed to discuss in detail the results of experiments which have been in progress in the field and in the laboratory for several years, and which were undertaken with the view of elucidating some of the general effects of rotation. From the commencement of the inquiry it has been our wish to avoid, as far as possible, the bias of any of the conflicting opinions which have of late years been put forth upon the important subject under examination, and it will be our endeavour, as we proceed in our Report, impartially to lay before our readers such results of direct experiment as will enable them to form their own estimate of the soundness of any views which we may advocate or adopt.

At the outset, however, it may be well to caution the agriculturist against expecting what we by no means presume to exhibit. The object of the experiments has not been the production of immense crops, but to trace, as far as we were able, the real conditions of growth required by the turnip, and to distinguish these from those of the crops to which it is to a great extent subservient. To attain our object it will be necessary to speak of amounts of produce which may at first sight excite the ridicule of those who do not fully appreciate the nature of the question at issue; but those who choose to go through the details which we are about to quote will, it is thought, find that a true understanding of them tends much to explain the principles upon which the best agriculture is founded.

Before entering upon a consideration of the turnip results themselves, we shall remind the reader of some of the leading facts which may be assumed, regarding the conditions of growth of the wheat plant.

In the paper on "Agricultural Chemistry" in the last number of this Journal, a series of experiments was quoted for the purpose of showing the effect of *season* and *manuring* upon the growth of wheat; and a careful consideration of them led to some very important conclusions regarding the nature of the exhaustion by corn-cropping, and also as to the varying nutritive and marketable value of specimens of grain having different characters and composition, traceable to known conditions of growth.

It was seen that the varying quantity and the quality of the produce of a plot of land, unmanured during several successive seasons, were materially dependent on the number of rainy days, the inches of rain and the temperature, of the months of May, June, July, and August, during which periods the accumulative and elaborative processes of the wheat plant are most actively determined. The average annual produce of the soil and season, unaided by manure, amounted to about three-fourths of the estimated yield of the neighbourhood under ordinary cultivation—to two-thirds of that of a plot manured by farmyard-dung—and to fully half as much as might be expected from as high a course of farming as the soil and the climate with which we have to deal would justify us in adopting. It is remarkable too that, whilst the quality of this natural produce, as indicated by the relation of corn to straw, and the weight per bushel of the corn, varied year by year according to season, yet the characters of the crops grown by very various and, in some cases, rather high manures, were for each season somewhat similar to those of the produce of the unmanured plot. It is evident, then, that the conditions favourable to an increased growth of wheat are perfectly consistent in *kind* with the natural tendencies of the plant, and that they only differ *quantitatively* from the natural resources of soil and season, and less indeed in this respect than might have been supposed.

The following table exhibits the influence of season upon the produce of turnip-bulb unaided by the supply of manure. The soil upon which the experiments were conducted was a somewhat heavy loam, not well suited for turnips: the previous crops since manure having been wheat, clover, wheat:—

Season.	No Manure. Bulb per Acre in Tons.	cwts.	qrs.	lbs.	Average weight of bulbs in lbs. and tenths.
1843	4	3	3	2	0·52
1844	2	4	1	0	0·36
1845	0	13	2	24	0·11

It is seen that in three years the produce of this unmanured plot was reduced from 4¼ tons to 13½ cwts. per acre; in the fourth season (1846) the bulbs only averaged the size of a radish, and were considered to be not worth weighing. This result strikes us as the more remarkable when we reflect that to the turnip is attributed a power of reliance upon the atmosphere for its organic constituents, to which it is supposed is due its efficacy in restoring fertility to the soil, and increasing the after-growth of corn, which itself attains to a moderate crop under the influence of soil and season alone. The evidence here afforded of the totally artificial conditions which are induced in the cultivation of the turnip for feeding and manuring purposes, is of the clearest kind; and we shall have occasion further on to refer to other points than those here given, as illustrating so curious a result.

Our present object is to show the entire absence of any beneficial influence of season upon the growth of the turnip, independently of artificial supply of constituents. An inspection of the two following tables, giving the results obtained by various manures during three seasons, and the characters of the seasons themselves, affords some insight into the general influence of climate upon the growth of the *cultivated* turnip. It must be admitted, however, that the relation is by no means so quantitatively definite as in the case of wheat; whilst the conditions suited to the favourable growth of the two plants are very opposite in kind:—

Season.	Bulb per Acre, in Tons, cwts., qrs., and lbs.												Average weight of Bulbs in lbs. and tenths.		
	12 Tons Farmyard-dung.				Superphosphate of Lime.				Mixed earthy and alkaline Phosphates and Sulphates.				12 Tons Farmyard-dung.	Superphosphate of Lime.	Mixed earthy and alkaline Phosphates and Sulphates.
	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.			
1843	9	9	2	9	12	3	2	8	11	17	2	0	1·36	1·47	1·35
1844	10	15	1	0	7	14	3	0	5	13	2	0	1·19	0·81	0·68
1845	17	0	3	6	12	13	3	12	12	12	2	8	1·61	1·17	1·16

A detailed consideration of the produce of the several seasons under different conditions of manuring, as just given, cannot fail to show in which were the climatic influences most favourable to the growth of the cultivated turnip. It will be remembered that, without manure, the produce of the first of the three seasons was much below the most meagre agricultural amount; and that in the third and fourth it dwindled to almost nothing. This table, on the other hand, shows that under a course of manuring the third season yielded the largest crop, and the second invariably the least. The average produce of the first season, where farm-yard-dung is employed, is not superior to that of the second season under similar conditions of supply, though it is so in each of the cases where mineral manures alone are used. If we look to the average weight of the bulbs, however, as given in the table, it will be seen that the development was superior in the first year to that in the second, though inferior to that in the third. The seeming depreciation in the first season, indicated by the acreage yield, arose from the adventitious circumstance of the greater destruction of plants by disease in that season, from which cause their number was greatly diminished. The discrepancy is, therefore, apparent rather than real; the result being dependent, not upon the *amount* of supply by season and manure, but upon injury which is more frequently connected with rich than with poor manuring. Again, neither the acreage produce nor the average weight of bulbs, where mineral manures alone were employed, shows so marked a superiority of the third season as compared with the first, as is evinced in the case of the farmyard-dung, by which a large amount of *organic matter* was supplied to the plants. We shall have occasion to show, however, when treating of the effects of *manures* upon the growth of the turnip, that there was a deficiency of *carbonaceous supply in the soil* in the cases where mineral manures alone had been used, which gave to the farmyard-dung its superiority in the third season. Upon the whole it is evident from the results, that of the three seasons the third was by far the best suited to the growth of the turnip for feeding purposes, and that the second was the least so.

Of the real character of these seasons some judgment may be formed by an inspection of the following table, in which is given a summary of the statistics provided by the rain-gauge and the register thermometer, in reference to the climate of the three seasons during the months of July, August, September, and October, which may be considered to include the period of the active growth of the turnip:—

During July (last 14 days).				During August.			
Season.	Mean Temperature.	No. of rainy days.	Inches of Rain.	Season.	Mean Temperature.	No. of rainy days.	Inches of Rain.
1843	59·7	11	1·04	1843	63·4	12	3·38
1844	65·8	3	0·55	1844	59·7	14	1·84
1845	59·4	7	0·97	1845	59·0	17	2·79

During September.				During October.			
Season.	Mean Temperature.	No. of rainy days.	Inches of Rain.	Season.	Mean Temperature.	No. of rainy days.	Inches of Rain.
1843	61·9	5	0·98	1843	49·0	15	2·62
1844	58·9	14	1·38	1844	50·2	17	4·13
1845	54·8	14	1·77	1845	50·0	10	1·39

By such a summary as is here given, of course only the general differences in the seasons are brought to light; but our readers will probably admit that the greatly increased labour of examination, were the table more extended and in detail, would scarcely be compensated for, if the main characters, requisites, and offices of the *turnip season* can be ascertained without it.

A relatively large number of rainy days, an enhanced actual amount of rain, and a low degree of temperature, are prominently the characters which distinguish the assumed turnip season of 1845 from that of the two preceding years, and during a considerable portion of the period, especially, from that of 1843.

Thus, taking the items somewhat in the order in which they are given, we find that in the latter half of the month of July, upon the character of which so materially depended the early development of the plant, and on this its future growth, in the seasons of 1843 and 1845 the temperature was lower than in 1844; and in 1845 the number of rainy days is more than double that in 1844, though somewhat less than in 1843, whilst the total amount of rain was much greater in 1845 than in 1844, and nearly equal to that in 1843. In August we have in 1845 the lowest temperature, the greatest number of rainy days, and, though not the largest actual amount of rain, a quantity large compared with 1844, though below that in 1843. September indicates still the lowest temperature in 1845, a number of rainy days equal to 1844 and far exceeding 1843, and also the largest actual amount of rain. The month of October, on the other hand, shows in 1845 the *smallest* number of rainy days, as well as actual fall of rain, and a mean temperature not so low as in 1843.

In these facts, even though so general and limited in their indications, there is scarcely one which does not show that the most favourable conditions of growth for our cultivated, bulb-forming turnips are, relatively to those for the seed-producing gramineous plants, a low degree of temperature, a large number of rainy days, and a large actual amount of rain. The seeming deviation from this general postulate, which is indicated by the character of the month of October in the third or best turnip season, is, however, by no means inconsistent with our estimate of the requisites of such a season, but rather conduces still further to account for the observed superiority of effect; for whilst, compared with plants which are cultivated for highly elaborated products, such as the cereal grains, we should expect the mainly accumulative and deficiently elaborative processes of the bulb and leaf forming turnip would require a lower degree of temperature and a greater amount of moisture favouring the circulatory determinations of the plants, there is, nevertheless, a point at which depreciation in temperature is injurious to vegetation. Indeed, the full growth of the turnip crop depends greatly on the postponement of the winter temperature, and hence probably arose a real advantage from the relatively high (though actually low) temperature in the October of 1845. Again, the lower the temperature, the less important are a continuity and large amount of rain.

As a general fact it is evident that the amount of the produce of the turnip is very materially dependent upon the climatic character of the season, not only as in itself a *resource*, but as an *essential agent* in the appropriative power of the plant, however liberal and complete may be the supply of constituents within the soil. Whilst, however, it may frequently happen that the physical characters of the season may be such as not to render available to the plant, and at once profitable to the farmer, the constituents which he has provided by manure, it is evident from the results which have been given, that, *without* an ample manuring, the best adapted season is incapable of yielding an agricultural amount of turnips. It is to be feared, however, that it is more frequently the essential condition of artificial aid, rather than that of natural climatic agency and resource, that is in defect.

Common usage seems to attribute to the turnip, and green crops generally, a power of collection from the atmosphere which is not recognised in our grain-yielding plants; and it may at first sight appear inconsistent with this view, that the growth of the turnip in agricultural quantity should be so essentially dependent on artificial supply as our results would show to be the case. There can be no doubt that there is some truth in this current supposition, but there is little doubt that the power of collection from the atmosphere very materially depends upon the quantity and quality of the supply to the soil by manures; in fact, that upon the judicious and liberal provision of certain constituents by art we must rest our hopes for atmospheric accumulation.

Having shown, then, that climatic agencies constitute an important element in the necessary conditions of growth of our cultivated turnip, and that these are only available when associated with an abundant artificial supply of certain constituents, the question arises—What are the substances which it is essential should thus be provided? This brings us to the second branch of our subject, namely, the influence of *manuring* upon the growth of the turnip.

Having discussed in some detail the comparative characters of the first three seasons during which we have been conducting an extensive series of experiments, under very various yet known conditions of manuring, we are prepared to consider the results of those experiments; and it is believed that those of them which were obtained in the three years referred to will amply suffice to indicate the nature of the necessary supply by manure, and also to lead to some interesting and important explanations regarding the true office of the turnip in a course of agricultural cropping, and the sources of its economic value. We would again remind our readers that the object of the experiments was not the production of large crops, but to learn, by the effects of different and known conditions of supply, in what respect and to what extent the plant was dependent upon the resources which must be kept up by the farmer, and how far he may rely upon the natural yield of the atmosphere; for it is the item of *source* of constituents, as well as that of quantity and quality, which should influence our selection of plants and manures under a truly rational and economic system of agriculture.

The experiments were commenced in the season of 1843, the early part of which, it will be remembered, was greatly superior to that of 1844, and equal to that of 1845 in suitableness to the growth of the turnip; but in the middle and latter periods it was inferior to either of the two succeeding seasons. The soil was a somewhat heavy loam, not well adapted for turnips; but as the plant is cultivated on such land with admitted advantage for rotation purposes, it was well fitted to answer our special ends. The previous crops since manure had been wheat, clover, wheat; so that in an agricultural point of view the soil might be considered as somewhat exhausted, and therefore in a favourable condition for an inquiry into the influence of supply by manuring. The description of seed was Norfolk Whites. The manures and seed were drilled together on ridges, there being 25 inches between the rows. The plots allotted to each experiment comprised six rows, and consisted of about one-third of an acre. The crop was calculated from weighed quantities taken from measured portions of land, of about one-eighth of an acre for each lot, and extending across the series in three different places.

TABLE showing the results of EXPERIMENTS upon the GROWTH of TURNIPS by MANURES, at ROTHAMSTED FARM, HERTS.

First Season, 1843.

Plot Numbers.	DESCRIPTION OF MANURES. Quantities expressed in weight per acre. Each lot made up at the rate of 14 bushels per acre, with clay and weed-ashes.	Average weight of Bulbs in lbs. and tenths.	Number of plants per acre.	Bulb per acre, compared with No. 2 as 1000.	Bulb per Acre in tons, cwts., qrs., and lbs.				Bulb per Acre, if 4 plants in a square yard = 19,360 in an acre.			
					Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.
1	12 tons farmyard-dung	1·36	15,571	2262	9	9	2	9	11	15	0	9
2	No manure	0·52	17,940	1000	4	3	3	2	4	9	2	6
3	6½ cwts. rape-cake	1·08	17,043	1967	8	4	3	12	9	6	2	21
4	5½ cwts. rape-cake, 2 bushels yeast ..	1·16	15,467	1926	8	1	1	11	10	0	2	1
5	8 bushels yeast	1·21	20,240	2622	10	19	2	19	10	9	0	17
6	2½ cwts. superphosphate of lime, 12 lbs. sulphate of ammonia, 4 bushels of yeast	1·33	19,573	2796	11	14	0	22	11	9	3	17
7	56 lbs. sulphate of ammonia	1·03	14,996	1653	6	18	1	25	8	18	0	5
8	2½ cwts. superphosphate of lime, 3¾ cwts. rape-cake..	1·69	16,096	2894	12	2	1	21	14	12	0	14
9	1¼ cwt. superphosphate of lime, 5½ cwts. rape-cake..	1·52	15,295	2490	10	8	2	5	13	2	2	17
10	3¾ cwts. superphosphate of lime, 1 cwt. rape-cake..	1·58	18,019	3042	12	14	3	6	13	13	0	13
11	Refuse matter containing much precipitated phosphate of lime, rape-cake, &c.	1·42	17,928	2734	11	9	0	5	12	5	1	23
12	2½ cwts. superphosphate of lime, 2 cwts. rape-cake, 20 lbs. sulphate of ammonia	1·48	17,112	2720	11	7	3	7	12	15	3	9
13	1¼ cwt. superphosphate of lime, 1 cwt. rape-cake, 40 lbs. sulphate of ammonia	1·42	16,617	2531	10	12	0	5	12	5	1	23
14	1¼ cwt. superphosphate of lime, 3¾ cwts. rape-cake, 10 lbs. sulphate of ammonia	1·23	17,790	2340	9	15	3	25	10	12	2	12
15	3¾ cwts. superphosphate of lime, 2¾ cwts. rape-cake, 20 lbs. sulphate of ammonia	1·75	15,088	2841	11	17	3	18	15	2	2	0
16	3¾ cwts. superphosphate of lime, 1½ cwts. phosphate of magnesia-manure ..	1·39	19,975	2974	12	9	0	15	12	0	1	2
17	3¼ cwts. superphosphate of lime, 150 lbs. phosphate of potass-manure	1·36	19,228	2804	11	14	3	19	11	15	0	9
18	3¼ cwts. superphosphate of lime, 84 lbs. phosphate of magnesia, 75 lbs. phosphate of potass	1·35	19,642	2835	11	17	2	0	11	13	1	12
19	As 18, with 30 lbs. sulphate of ammonia	1·49	19,113	3045	12	5	0	13	12	17	2	6
20	3¼ cwts. superphosphate of lime, 1½ cwts. rape-cake, 16 lbs. sulphate of ammonia	1·58	16,916	2860	11	19	1	23	13	13	0	13
21	Unburnt bones decomposed by sulphuric acid, 7 bushels	1·48	17,675	2804	11	14	3	19	12	15	3	9
22	4½ cwts. superphosphate of lime	1·47	18,446	2908	12	3	2	8	12	14	0	10
23	Clay and weed-ashes only, 15 bushels ..	1·32	18,745	2650	11	1	3	21	11	8	0	20

The terms superphosphate of lime, phosphate of potass, phosphate of soda, and phosphate of magnesia as found in this table, and others which follow it, are not to be understood as representing the pure chemical substances bearing those names. The composts were formed by acting upon calcined bone-dust by means of sulphuric acid in the first instance; and in the case of the alkaline salts, and the magnesian one, neutralising the compound thus obtained, by means of cheap preparations of the respective bases.

Were we to look at the results of this Table with a purely agricultural eye, the column of acreage weight of bulb would be sufficient to guide our judgment as to the efficiency of the various manures; but since the object of the experiments is rather to provide a key to the requirements of the turnip than to afford exact examples of manuring, other items than that of the actual acreage results obtained must be taken into consideration in forming an estimate respecting the nature of the conditions which cultivation should be calculated to supply. Manures, indeed, cannot be regarded only as containing certain constituents convertible into the substance of the crops, but also as agents acting beneficially or otherwise according to the form or combinations in which they are supplied, and their adaptation to soil and season. Thus it is known that the casualties and tendencies to disease or prevalence of insects often prove more destructive to the young turnip-plant under high farming, when the soil abounds in animal and vegetable matter, than when it is deficient in such substances; and the number of plants per acre may by such causes be so greatly reduced as to show a better acreage yield under bad than under liberal cultivation. The number of plants per acre must not therefore be overlooked in considering the results of the Table. The average weight of bulb may also be taken as to some extent indicating the relative effects of different conditions of growth. Where we have an increased average weight, as well as a large number of plants, both *agency* and *supply* have been favourable to the requirements of the plant; and although the efficiency of either of them is dependent on that of the other, it may as a general fact be assumed that a high number of plants indicates a favourable *condition*, and a large average weight a favourable *amount* of supply. Bearing in mind these considerations, we have given in the last column of the Table the estimated acreage yield, calculated from the actual average weight of bulb, and supposing a uniform number of plants per acre, namely, 19,360, or 4 in a square yard. Such an arrangement would give about 12½ inches from plant to plant along the rows, and may be taken as affording a more just view of the effects of the manures, independently of the contingencies arising from the manner of their application.

In reference to the results of this first season it must further be remarked, that the previous course having been wheat, clover, wheat, the *peculiar* exhaustion of the soil would be that induced by *corn-cropping*; and if there be any truth in the opinions which we have given elsewhere on this subject, this would imply a deficiency of nitrogen relatively to other constituents, so far as the future growth of wheat would be concerned; and it would appear from the amounts of produce without manure during the three seasons, as already given, that in some important respects the conditions of exhaustion most favourable to an investigation into the effects of *supply* for the growth of the turnip, were not so prominent in the first season as afterwards, when the unaided yield was little more than a weed, so that the entire produce under manures could then be attributed either to their *agency* or their *supply*.

The following selected results, showing the average weight of bulbs and number of plants per acre, yielded by manures which, compared with each other, are respectively mineral, nitrogenous, or carbonaceous, will point to some of the conditions which it is essential to provide for the healthy and rapid growth of the turnip :—

SELECTED RESULTS.

Plot Nos.	Description of Manures.	Number of Plants per Acre.	Average Weight of Bulbs in lbs. and tenths.
2	No manure	17,940	0·52
3	6½ cwts. rape-cake	17,043	1·08
7	56 lbs. sulphate of ammonia	14,996	1·03
16	3¼ cwts. superphosph. lime, 1½ cwt. phos. of magn. manure	19,975	1·39
17	" " " 150 lbs. phos. potass manure	19,228	1·36
18	" " " 84 lbs. phos. mag. 75 lbs. phos. pot. manure ...	19,642	1·35
22	4½ cwts. " "	18,446	1·47

The figures in the first column show a great destruction of plants under direct ammoniacal supply, as well as considerable depreciation where rape-cake was used; and common experience teaches us that, however useful rape-cake and ammoniacal salts, or guanos containing much ammonia, may be as manures for turnips, substances of their description are never safely applied near to the seed. Other instances than those quoted above from the table at page 12 distinctly show the injurious influence of organic manures when drilled with the seed; indeed, it may be laid down as a general rule that, especially for all spring crops, it is much more safe to apply such matters broadcast, and incorporate them well with the soil. The conflicting accounts which are given of the effects of guano and ammoniacal salts when they are supplied to spring corn crops, and of these manures and rape-cake when used for turnips, are, it is believed, mainly attributable to differences in the manner of their application; and whilst with a very wet season no injury, or perhaps benefit, may arise from the use of the manure drill in such cases, by far the safest course is to sow broadcast.

The second column of the selected results shows for this season of 1843 a considerable superiority in point of *development*, as well as *number*, of surviving plants, under purely mineral by the side of organic manures; and, compared with the unmanured plot,

those having manures only mineral indicate a growth almost threefold in the same space of time, whilst the actual acreage amount of produce is in these cases very nearly as great as in any of the series; indeed, mineral manures alone have nearly trebled the unaided produce of the soil and season.

These results might almost lead us to question the importance of organic manuring for the turnip crop, and to assume that a deficiency in mineral matters was the source of impoverishment in the case of the soil selected for experiment; but as we proceed it will be seen that, however marked may have been the effect of mineral matters in developing the powers of growth of the plant, as long as a sufficiency of organic food remained, yet a point of exhaustion was arrived at when, by a less amount of mineral matter, if in conjunction with organic supply (especially such as could yield *carbon* to the plants), the rapidity of *bulb* formation was materially enhanced.

Before leaving these results it is as well to observe, that notwithstanding the large amount of potass required by the turnip, the direct supply of that alkali did not give a produce superior to that by superphosphate of lime. We shall have occasion to recur to the question, whether part of the effect of the latter manure is not due to its liberation in the soil of alkalies not otherwise available to the plant. All we wish to call attention to at the present is, that there was an abundant amount of alkalies in this corn-exhausted soil, which could be rendered serviceable under suitable management.

The next quotations which we shall make from the table (page 12) will serve to illustrate the effect of the artificial supply of matter for organic formations, aided by certain mineral agency and constituency :—

SELECTED RESULTS.

Plot Nos.	Description of Manures.	Average weight of Bulbs.	Number of Plants per Acre.
8	2½ cwts. superphosphate of lime, 3¾ cwts. rape-cake	1·69	16,096
9	1¼ " " 5½ " "	1·52	15,295
10	3¾ " " 1 " "	1·58	18,009
12	2½ cwts. superphosphate of lime, 2 cwts. rape-cake, 20 lbs. sulphate of ammonia	1·48	17,112
13	1¼ cwt. superphosphate of lime, 1 cwt. rape-cake, 40 lbs. sulphate of ammonia	1·42	16,617
14	1¼ cwt. superphosphate of lime, 3¾ cwts. rape-cake, 10 lbs. sulphate of ammonia	1·23	17,790
15	3¾ cwts. superphosphate of lime, 2¾ cwts. rape-cake, 20 lbs. sulphate of ammonia	1·75	15,088
19	3¼ cwts. superphosphate of lime, 84 lbs. phosphate magnesia, 75 lbs. phosphate of potass, 30 lbs. sulphate of ammonia	1·49	19,113
20	3¼ cwts. superphosphate of lime, 1½ cwt. rape-cake, 16 lbs. sulphate of ammonia	1·58	16,916

It may be objected that the average weight of bulbs, as stated above, is in itself small, and that the differences exhibited are too slight to be relied upon as showing a result. We would beg to say, however, that the estimations were taken from the whole of the bulbs that were weighed in each case, amounting to nearly 2000, and that we believe they may be depended upon for our present purpose.

It will be remembered that with mineral manures alone there were, on an average, rather more than 19,000 plants per acre, but a glance at the results just given will show how uniformly the direct supply by the drill of "organic manures" tended to lessen the number. Again, it has been seen that the highest average weight of bulbs (indicating the degree of development) was, by purely mineral manures 1·47 lb., by sulphate of ammonia 1·03, and by rape-cake alone 1·08 lb. The fact that these conditions of manuring, employed singly, fall far short of their effects when combined, help us to form some judgment as to the point at which the one or another class of constituents seems to fail, either in quantity or in adaptation to the wants of the plant.

Taking the lots 8, 9, and 10, we find the *largest* number of plants where the proportion of mineral supply to that of rape-cake is the greatest, and the *smallest* number where the rape-cake is relatively in excess. The weight of bulbs is *least* where the mineral matters are most in defect, and *greatest* where neither condition was to the other so prominent as in the other two cases.

Again, taking Nos. 12, 13, 14, and 15, in which superphosphate of lime was united with both rape-cake and ammoniacal salt, the largest weight of bulb in the entire series of the season is found to be in that case where, with a fair supply of each, no one of the several manures predominated so much as in either of the three other instances just mentioned.

Were we to place unconditional reliance upon mere supply of constituents for *actual conversion into the substance of the plant*, we should expect that the farmyard-dung would give, in every respect, the best crop in the series; but *agency*, as distinguished from mere *supply*, seems to constitute a most important item, affecting the development of those truly artificial conditions of growth which the cultivation of the turnip, for feeding and manuring purposes, so pre-eminently implies. In the farmyard-dung we had undoubtedly the largest provision of nitrogenous, and especially of carbonaceous matter, and it may be supposed that it also brought to the soil such an abundance of all the mineral substances as would be contained in a much larger crop than was produced by it.

The results arranged below will sufficiently prove that, however liberal the supply of all required constituents, the health and vigour of the plant, or its power of appropriating the food presented to it, depends upon other circumstances than the mere *amount* of that food.

SELECTED RESULTS.

Plot Nos.	Description of Manures.	Average Weight of Bulb.	Number of Plants per Acre.
1	12 tons farm-yard dung	1·36	15,571
8	$2\frac{1}{2}$ cwts. superphosphate of lime, $3\frac{3}{4}$ cwts. rape-cake	1·69	16,096
15	$3\frac{3}{4}$ cwts. superphosphate of lime, $2\frac{3}{4}$ cwts. rape-cake, 20 lbs. sulphate of ammonia	1·75	15,088
18	$3\frac{1}{4}$ cwts. superphosphate of lime, 84 lbs. phosphate of magnesia, 75 lbs. phosphate of potass	1·35	19,642
22	$4\frac{1}{2}$ cwts. superphosphate of lime	1·47	18,446

We see that the farm-yard dung gave a number of surviving plants nearly as small as any in this series, and very far short of that obtained by mere mineral, or frequently by mixed mineral and organic supply. Again, the weight of bulbs is only equal to the lowest resulting from pure mineral manuring, and inferior to that in other cases of such manuring. In Nos. 8 and 15, on the one hand, the *amount* of supply, especially of matter for organic formations, was much less than in No. 1, whilst the average weight of bulb was materially greater. On the other hand, the mineral supply was in these cases less than in 22; but there being in that instance no provision by manure of organic matter, the increased mineral supply was unavailing.

Clay and weed-ashes alone, as in No. 23, are seen to more than double the unaided produce of the soil and season, to give a fair number of plants, and an average weight of bulb nearly three-fourths as great as in any case in the series. This is a curious result, and indicates that certain mechanical as well as chemical conditions of soil, in immediate proximity to the young plant, are essential to a favourable and healthy development of its organs of collection. We learn, too, that in some important respects the resource of food within the soil itself could not have been so low in this first year as it appears afterwards to have been.

There are other points indicated by the results already given, than those to which we have directed attention; but as a consideration of the experiments of the succeeding years will bring them before our readers, we need not enter upon them in this place.

Having examined in detail the results of the first year's experiments, it may be well to reiterate some of the more general and important facts and conclusions which have been elicited. It is clearly shown that, under the influence of the same season, and in a soil which, by corn-cropping, had been brought to that condition of exhaustion which common usage would remedy by the growth of turnips or other green crops by means of manure, the attempt to grow such *restorative* crop without *supplied* aid,—that is, manure,—is quite unavailing. We see that *agency* as well as *supply* is an essential element to be considered in the choice of manures, and that unless such agency or condition of healthy function be secured, a liberal provision of the *materials* of which the plant is built up may frequently, to a great extent, be useless to it. The matters which are most favourable to the healthy action and rapid accumulation and assimilation by the turnip, are the so called "*mineral manures*," under the influence of which a great regularity of plant and vigorous power of growth are attained. At any rate, in the soil in question, when in a condition of *agricultural exhaustion*, the supply of *potass* by direct manures seems unessential. But the direct supply of phosphoric acid, whether by its reaction upon the soil or a special effect upon the young plant, or from a combination of these influences, seems to enhance the assimilating actions of the turnip to a degree much beyond what could be attributed to it as a *mere constituent*, rather than in some sort an *agent* also. We shall recur further on to this interesting subject.

Of the substances which we may term pure *constituents*, "*organic matters*," and especially such as abound in *carbon*, must be supplied for the production of agricultural crops of turnip-bulbs. These manures, as well as those which are chiefly nitrogenous, should never be concentrated near to the plant in its earliest stages of growth, but only within its reach, when, under the immediate influence of mineral manures, the young plant has so far developed its organs of accumulation, and its healthy vigour, as to be competent to grow faster than the natural atmospheric and soil resources of nitrogen and carbon enable it to do. These are, we conceive, the most prominent indications afforded by the results of this our first season of experimenting upon the cultivation of the turnip. As we proceed in our inquiry we shall see how far they are confirmed by those which succeeded them, and which we shall now endeavour to detail.

The whole produce, leaf and bulb, of 1843, was carted off the land. In the second year the manures had some reference to the condition of soil as affected by the first year's treatment, and the same division of the land, and numbering of the plots, were adopted. The manures were again drilled with the seed, and the mechanical culture of the land before and after sowing, the estimation of the crop, and its entire removal, were conducted as before.

The entire series of results of this second season (1844) are given in the following Table at one view, but we shall make selections as before, for the convenience of detailed examination.

TABLE showing the results of EXPERIMENTS on the GROWTH of TURNIPS by MANURES at ROTHAMSTED FARM, HERTS.

Second Season, 1844.

Plot Numbers.	DESCRIPTION OF MANURES. Quantities expressed in weight per acre. Each lot made up at the rate of 14 bushels per acre, with clay and weed-ashes.	Average weight of Bulbs in lbs. and tenths.	Number of plants per acre.	Bulb per acre, compared with No. 2 as 1000.	Bulb per Acre in tons, cwts., qrs., and lbs.				Bulb per Acre, if 4 plants in a square yard = 19,360 in an acre.			
					Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.
1	12 tons farm-yard dung	1·19	20,096	4875	10	15	1	0	10	15	2	22
2	Unmanured	0·36	13,736	1000	2	4	1	0	3	2	0	25
3	7 cwts. rape-cake	0·27	5,488	294	0	13	0	0	2	6	2	9
4	4 cwts. superphosphate of lime, ½ cwt. phosphate of ammonia	0·92	16,768	3138	6	8	2	0	7	19	0	3
5	4 cwts. superphosphate of lime, ½ cwt. sulphate of ammonia	0·87	14,256	2498	5	10	1	0	7	10	1	15
6	3 cwts. superphosphate of lime, 15 lbs. phosphate of ammonia	0·65	21,632	2867	6	6	2	0	5	12	1	12
7	3 cwts. ground apatite	0·38	17,864	1382	3	1	0	0	3	5	2	20
8	3 cwts. mixture of apatite and sulphuric acid, containing 200 lbs. apatite	0·71	21,232	3076	6	15	3	0	6	2	2	25
9	As No. 8, with 56 lbs. hydrochloric acid added (sp. gr. 1125)	0·80	20,392	3320	7	6	2	0	6	18	1	4
10	4 cwts. superphosphate of lime, 4 cwts. rape-cake	1·18	13,256	3173	7	0	0	0	10	3	3	24
11	4 cwts. superphosphate of lime, 4 cwts. rape-cake, 15 lbs. phosphate of ammonia	1·29	10,320	2697	5	19	0	0	11	2	3	26
12	5 cwts. superphosphate of lime, land dug 6 inches deep	0·97	20,152	3968	8	15	1	0	8	7	2	19
13	4 cwts. superphosphate of lime, 4 cwts. rape-cake, 2 cwts. common salt ..	0·30	7,952	482	1	1	1	0	2	11	3	12
14	5 cwts. superphosphate of lime, land trenched with the spade 18 in. deep	0·99	13,360	2683	5	18	1	0	8	11	0	14
15	1 cwt. superphosphate of lime, 4 cwts. phosphate of soda	0·76	19,504	3013	6	13	0	0	6	11	1	13
16	1 cwt. superphosphate of lime, 4 cwts. phosphate of magnesia	0·70	21,336	3024	6	13	2	0	6	1	0	0
17	1 cwt. superphosphate of lime, 4 cwts. phosphate of potass	0·66	20,552	2775	6	2	2	0	5	14	0	9
18	2 cwts. superphosphate of lime, 1 cwt. each of phosphate of potass, soda, and magnesia	0·68	18,624	2572	5	13	2	0	5	17	2	4
19	Same as No. 18, with 15 lbs. phosphate of ammonia	0·73	20,352	3107	6	13	1	0	6	6	0	20
20	2 cwts. superphosphate of lime, 4 cwts. rape-cake, 56 lbs. sulphate of ammonia	0·78	6,832	1084	2	7	3	0	6	14	3	8
21	374 lbs. mixture of apatite decomposed by sulphuric acid, containing 104 lbs. sulphuric acid, 270 lbs. apatite.. ..	0·85	18,728	3247	7	3	1	0	7	6	3	20
22	5 cwts. superphosphate of lime	0·81	21,205	3503	7	14	3	0	7	0	0	1
23	2 cwts. superphosphate of lime, 56 lbs. sulphate of ammonia, 1½ cwts. nitrate of soda	0·83	10,072	1700	3	15	0	0	7	1	2	20

On reference to the summary as already given of the climatic conditions of the turnip seasons of 1843 and 1844, it will be seen, that in the latter half of the month of July, the low degree of temperature, the number of rainy days, and the actual amount of rain, are all most favourable to the early stages of the plant in 1843. Throughout the months of August, September, and October, on the other hand, the conditions of turnip growth, so far as season is concerned, are more favourable in 1844 than in 1843.

A glance at the mean results of the two years will, however, clearly show that if the climatic influences of the second year were in the main superior to those of the first, some other circumstances must be looked for, as accounting for the great falling off in the development of the plant.

SELECTED AND MEAN RESULTS.

Description of Manures.	Average Weight of Bulbs.		Number of Plants per Acre.	
	1843.	1844.	1843.	1844.
No manure	0·52	0·36	17,940	13,736
Mean of mineral supply	1·39	0·73	19,323	20,377
Rape-cake only	1·08	0·27	17,043	5,488
Mean of mixed mineral and organic supply	1·50	0·97	17,230	14,774

It is here seen, that with a more favourable season, excepting during the first few weeks, in 1844 than in 1843, we have nevertheless an inferiority of development under every variety of manuring, and a very marked depreciation in the number of plants, unless where mineral manures alone were used. The destructive effects of organic manures, especially in the absence of rain during the early stages of growth, are here very evident; and the maintenance of healthy action, even under these same climatic circumstances, when purely mineral manures are employed, is clearly shown. We observe, too, that whilst under the influence of this defect of rain during the first period of the season, both the weight of bulbs and number of plants are much less where rape-cake is used alone than even where no manure at all is provided, yet the admixture of mineral manures with the organic gives the best result in the series so far as development is concerned.

That the cause of the depreciation in average weight of bulbs during this season was, nevertheless, connected with a deficiency of matter for organic formations, and not of mineral supply, the following extracted results will show :—

SELECTED RESULTS.

Plot Nos.	Description of Manures.	Average Weight of Bulb in lbs. and tenths.
15	1 cwt. superphosphate lime, 4 cwt. phosphate soda manure ...	0·76
16	1 ,, ,, 4 ,, phosphate magnesia manure	0·70
17	1 ,, ,, 4 ,, phosphate potass manure	0·66
18	2 ,, ,, 1 ,, each, phosphate potass, soda, and magnesia, manure	0·68
19	As 18, with 15 lbs. phosphate ammonia	0·73
22	5 cwts. superphosphate lime	0·81
5	4 ,, ,, ½ cwt. sulphate ammonia	0·87
10	4 ,, ,, 4 ,, rape-cake	1·18
11	4 ,, ,, 4 ,, ,, 15 lbs. phos. amm.	1·29

Thus, of the purely mineral manures, the superphosphate of lime (No. 22), as in the first year, gives a higher weight of bulb than any of those where alkalies are also supplied. The substitution of 1 cwt. of superphosphate of lime, by half a cwt. of sulphate of ammonia (*see* Nos. 22 and 5), raises the weight of bulb from 0·81 to 0·87; by 4 cwts. of rape-cake (No. 10) to 1·18; and by 4 cwts. of rape-cake, with 15 lbs. of phosphate of ammonia, to 1·29, the highest weight obtained during this season—that by dung not excepted.

The farm-yard dung, as in the previous year, must be supposed to have afforded the most liberal supply of all the matters necessary for conversion into the substance of the plant; yet we find that 4 cwts. of superphosphate of lime, with 4 cwts. of rape-cake, and 15 lbs. of phosphate of ammonia (No. 11), give a higher average weight of bulb than the farm-yard dung; that by the former being 1·29, and by the latter 1·19. We have, however, 20,096 plants per acre by farm-yard dung, and only 10,320 by the artificial organic compost. This deficiency of plants is, however, easily accounted for, by the fact that the dung was ridged in, and the artificial compost *drilled with the seed*; so that the defect of rain during the early stages of the plant, whilst it might only retard growth in the one case, would lead to positive destruction in the other.

The very great destruction of plants, as well as the small weight of bulb, in the case of No. 3, where rape-cake alone was drilled with the seed, further show the impropriety of applying organic manures near to the seed or young plant, and the inefficiency of mere supply of constituents if the healthy development of the collective apparatus of the plant be not secured. The effects of ammoniacal salts, as they have been before described, depending upon a proper combination with other constituents, are further exhibited in the results of this second year. The variations in the number of plants and weight of bulbs, in Nos. 4, 5, and 6, and also in the results of these numbers as compared with those of Nos. 11 and 20 here given, may be adduced in illustration of this fact.

SELECTED RESULTS.

Plot Nos.	Description of Manures.	Average Weight of Bulbs in lbs.	Number of Plants per Acre.
4	4 cwts. superphosphate lime, ½ cwt. phosphate ammonia	0·92	16,768
5	4 ,, ,, ½ cwt. sulphate ,,	0·87	14,256
6	3 ,, ,, 15 lbs. phosphate ,,	0·65	21,632
11	4 cwts. superphosphate lime, 15 lbs. phosphate ammonia, 4 cwts. rape-cake	1·29	10,320
20	2 cwts. superphosphate lime, ½ cwt. sulphate ammonia, 4 cwts. rape-cake	0·78	6,832

Thus there is a slight superiority in No. 4 over No. 5, both in development and number of plants; phosphate of ammonia being used in the former, and sulphate in the latter. In No. 6, as compared with the two preceding, the amount of phosphoric acid is diminished, but in a greater degree that of ammonia, to which body may be attributed an injurious effect upon the health of the plant when in excess, or not sufficiently incorporated with the soil, and a beneficial one after not only necessary diffusion has taken place, but the plants themselves have attained some strength and vigour. As might be expected, then, the number of plants is greater, though the average weight of bulbs is less in No. 6 than in 4 and 5.

Comparing with each other Nos. 6 and 11, in which the amount of ammoniacal salts supplied by manure was identical, we find that an increase of superphosphate of lime by 1 cwt., and the addition of 4 cwts. of rape-cake (No. 11), whilst they reduced the number of plants from 14,256 to 10,320 (an effect certainly not due to the superphosphate of lime), at the same time raised the average weight of bulb from 0·65 to 1·29; showing the benefit of the supply of *organic matter* in those cases where it had not proved injurious or destructive to the plants, and the other conditions were such as to favour their healthy growth. Again, in No. 20, as compared with No. 11, the amount of supply by rape-cake is equal; that of ammonia-

salt much greater; but that of the important constituent and agent, superphosphate of lime, is diminished. The result is a very great depreciation, not only in number of plants, but in the average weight of bulbs.

We have now given and examined the results of the first two seasons of our experiments upon the joint effects of *climate* and *manures* on the growth of the turnip bulb; and comparing the general character of the one season and its results with that of the other, we see, that although the climatic or vehicular and accumulative agencies were, during the largest portion of the time of growth, more favourable in 1844 than in 1843, yet the produce was, in the main, much inferior under the superior circumstances of climate. This can only be attributed to deficiency in some essential agency or supply, apart from those of season alone; and since those instances in this season, in which mineral supply is most liberal, show by the number of plants a degree of healthy condition, and yet an inferior rate of growth, we conclude that the soil was exhausted of matter for organic formations. That the defect is carbonaceous rather than nitrogenous, is learnt from a careful comparison of the effects of rape-cake and of ammoniacal salts.

Again, the conclusions elicited by a close examination of this second year's experiments, are seen to be identical in kind with those to which we were led by the first year's results; and in their degree afford even clearer testimony—rather than mere confirmation—on most of the points which had been previously discussed. It is the less important, however, to give a recapitulation in this place, as we have yet the entire results of the third season (1845) to detail; and, having accomplished that part of our task, we shall be prepared to give a *résumé* of the three years' series.

The destructive effects of some substances, when applied near to the seed, led us to sow the manures and the seed separately in the third year of our experiments. The same division into plots was observed as previously; but besides the drilled manures, which, though for the most part mineral, were sown before the seed, and at a somewhat greater depth, the entire series of plots was crossed by bands 72 yards in width; these were sown respectively with rape-cake, ammoniacal salt, and rape-cake and ammoniacal salt together, a sufficient portion being left having drilled manures only. These cross-dressings were sown broadcast, before the ridges first drawn out had been split and turned over, so that there could be little danger of injury to seed and young plants. By this arrangement of manuring, for each of the more than 20 conditions of 'ash-constituent' supply, 4 of varying resource of matter for organic formations were secured; so that the number of experiments was raised to nearly 90.

It is to be regretted that, in the first two seasons of our experiments, the acreage produce of leaf, and the relation of leaf to bulb, were not taken; as climate and manuring have a marked influence on the character of the turnip-crop in this respect, besides that which is known to depend upon the mechanical qualities of soil. A consideration of the relative and actual amount of leaf is, moreover, found to be of material importance in estimating the feeding value, degree of maturity, and probable resources of further growth of the plant. All the statement which we are able to give on this subject in reference to these two years is, that both the acreage weight of leaf, and the proportion of leaf to bulb, were much greater in 1843 than in 1844; there being in the former case a much more liberal provision of organic matter remaining in the soil, though, at the same time, a less amount of rain and a higher temperature. The leaves were weighed in the third year, and so far as the effects of different conditions of manuring, under the influence of one and the same season, are concerned, the results obtained are of some interest.

The results of the third year (1845) are given in five sections or divisions (pp. 26-30), and, for the convenience of reference and examination, the statement of the manures is attached to each of these divisions. The different degrees of maturity exhibited under the influence of the varying supply for organic formations, provided by the cross-dressings, led us to weigh some of the crops at twice, that their progressive changes might be ascertained. The order of maturity which was observed was as follows:—

1st. The lengths under drilled manures only (chiefly mineral).
2nd. Those having rape-cake added.
3rd. Those having ammoniacal salt added.
4th. Those with both rape-cake and ammoniacal salt in addition to the mineral manures.

The first weighing was taken in December, when the leaves under mineral supply had considerably drooped and changed colour; the rest exhibiting degrees of retained vitality in the inverse order indicated above. The second weighing was taken early in January, and three weeks later than the first, as will be seen on inspection of the tables.

	72 yards, crossed with Rape-cake.	72 yards, crossed with Rape-cake and Ammoniacal Salt.	72 yards, crossed with Ammoniacal Salt.	110 yards, minerals only.	
1					1
2					2
3					3
4					4
5					5
6					6
7					7
8					8
9					9
10					10
11					11
12					12
13					13
14					14
15					15
16					16
17					17
18					18
19					19
20					20
21					21
22					22
23					23
24					24

The plan of the field given above will further show the method of manuring adopted in 1845. In the two previous years each experiment extended from one end of the field to the other; in 1845, bands each of 72 yards down the field, were sown, by hand, across the rows, respectively, with rape-cake equal to 10 cwts. per acre; 10 cwts. rape-cake and 3 cwts. sulphate of ammonia; and 3 cwts. of sulphate of ammonia: the manures given as drilled manures being then drilled down the entire length of the field. Thus, from 3 to 24 inclusive, each plot of land forming one experiment in 1843 and 1844 was, in 1845, divided into 4. The figures represent the same spaces of land each year. For example, No. 2 was unmanured in 1843 and 1844; in 1845 one part was unmanured, one was crossed with rape-cake, one with rape-cake and ammoniacal salt, and one with ammoniacal salt. The plan adopted in 1845 has been continued in 1846 and 1847.

DIVISION 1.—QUANTITY of BULB per Acre, in Tons, cwts., qrs., and lbs.

Plot Numbers.	DESCRIPTION OF DRILLED MANURES. Quantities expressed in weight per Acre.	Drilled Manures only.	Drilled Manures, and 10 cwts. Rape-cake, per Acre.	Drilled Manures, and 3 cwts. Sulphate of Ammonia per Acre.		Drilled Manures, with 10 cwts. Rape-cake and 3 cwts. Sulphate of Ammonia per Acre.	
				First Gathering.	Second Gathering (3 weeks later).	First Gathering.	Second Gathering (3 weeks later.)
		Tons. cwts. qrs. lbs.	Tons. cwts. qrs. lbs.	Tons. cwts. qrs. lbs.	Tons. cwts. qrs. lbs.	Tons. cwts. qrs. lbs.	Tons. cwts. qrs. lbs.
1	12 tons farm-yard dung, ridged in; no drilled manures	17 0 3 6	..	14 18 3 12	..	..	..
2	Unmanured	0 13 2 24	7 10 0 16	0 9 0 24	1 13 0 0	5 14 1 4	5 0 2 24
3	8 cwts. rape-cake	4 16 0 16	9 8 2 24	4 7 1 20	5 8 2 8	7 3 0 16	8 0 2 8
4	130 lbs. calcined bone-dust, 130 lbs. sulphate of ammonia, 130 lbs. hydrochloric acid (sp. gr. 1·18)	8 17 1 20	12 2 2 8	7 12 0 0	9 7 0 16	7 4 0 0	9 16 2 8
5	160 lbs. superphosphate of lime, 130 lbs. sulphate of ammonia	5 16 1 18	9 9 2 18	6 7 1 14	8 7 1 20	7 0 3 12	8 6 3 12
6	160 lbs. superphosphate of lime, 5 cwts. train oil	6 10 0 16	9 8 1 4	6 3 2 24	6 16 3 12	6 13 2 24	8 19 2 24
7	12 cwts. sulphate of lime (the refuse of tartaric acid manufacture)	5 13 2 24	10 1 0 0	4 15 1 20	4 8 1 4	7 3 1 20	8 10 2 8
8	400 lbs. calcined bone-dust	10 4 0 16	11 13 3 12	9 12 0 0	10 4 0 0	10 6 0 0	10 12 2 8
9	400 lbs. calcined bone-dust, and hydrochloric acid (equivalent to 268 lbs. sulphuric acid, sp. gr. 1·70)	9 9 1 20	8 13 1 4	8 11 1 20	8 12 2 8	7 1 0 16	7 19 2 24
10	400 lbs. calcined bone-dust, 134 lbs. sulphuric acid	12 18 2 6	13 18 1 4	12 9 2 24	12 14 2 8	12 2 0 0	11 17 1 20
11	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid	13 11 0 0	14 0 1 4	12 9 0 16	12 18 2 8	11 16 0 0	12 17 2 24
12	11 cwts. superphosphate of lime (land dug 9 inches deep in 1844)	13 8 2 8	14 5 1 4	12 11 0 16	12 14 0 0	11 4 1 4	13 9 1 20
13	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid, 134 lbs. common salt	14 10 0 4	13 1 2 8	12 9 1 20	12 6 0 0	9 14 0 0	11 12 1 4
14	11 cwts. superphosphate of lime (land trenched 18 in. deep in 1844)	14 4 0 0	14 9 0 0	13 18 1 4	14 10 0 0	12 8 1 0	13 12 1 4
15	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 315 lbs. soda ash	11 15 3 12	12 8 3 12	12 8 2 8	13 0 0 0	11 3 1 20	11 13 2 24
16	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 220 lbs. magnesian limestone	12 1 0 0	14 3 2 24	12 14 3 12	12 19 0 16	11 17 2 24	13 4 2 8
17	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 470 lbs. pearlash	10 19 0 16	12 19 0 0	12 4 1 14	12 0 0 0	11 13 0 16	11 17 2 24
18	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 105 lbs. soda ash, 74 lbs. mag. limestone, 157 lbs. pearlash	12 12 2 8	13 18 2 24	12 16 3 22	13 12 0 0	13 1 3 6	13 15 1 20
19	As No. 18, with 1 cwt. sulphate of ammonia	12 7 0 0	11 5 2 8	10 0 3 12	10 16 1 4	9 16 0 0	11 8 2 8
20	As No. 18, with 3 cwts. rape-cake	14 7 2 8	14 6 0 0	12 8 2 10	13 8 0 0	12 9 2 24	12 18 0 0
21	400 lbs. calcined bone-dust, 400 lbs. sulphuric acid	13 2 2 24	14 8 1 20	11 13 1 20	12 6 0 0	12 4 0 0	13 4 2 8
22	11 cwts. superphosphate of lime	12 13 3 12	14 0 2 0	11 0 3 12	11 9 2 24	12 10 3 4	13 5 0 16
23	3 cwts. sulphate of ammonia	..	..	3 4 1 4	..	..	..
24	Mean mixture of all other drilled manures, exclusive of Nos. 1 and 23	13 17 0 0	..	..	..	..	..
	Mean Results	10 10 0 16	12 3 1 24	9 17 3 12	10 9 2 14	10 0 1 13	11 1 0 16

DIVISION 2.—QUANTITY of LEAF per Acre, in Tons, cwts., qrs., and lbs.

Plot Numbers.	DESCRIPTION OF DRILLED MANURES. Quantities expressed in Weight per Acre.	Drilled Manures only.	Drilled Manures, and 10 cwts. Rape-cake per Acre.	Drilled Manures, and 3 cwts. Sulphate of Ammonia per Acre.		Drilled Manures, with 10 cwts. Rape-cake and 3 cwts. Sulphate of Ammonia per Acre.	
				First Gathering.	Second Gathering (3 weeks later).	First Gathering.	Second Gathering (3 weeks later).
		Tons. cwts. qrs. lbs.	Tons. cwts. qrs. lbs.	Tons. cwts. qrs. lbs.	Tons. cwts. qrs. lbs.	Tons. cwts. qrs. lbs.	Tons. cwts. qrs. lbs.
1	12 tons farm-yard dung, ridged in; no drilled manures	7 7 3 2	..	10 8 12	..	..	..
2	Unmanured	0 14 1 4	4 16 2 24	0 6 2 16	0 18 0 0	4 16 0 0	4 10 0 0
3	8 cwts. rape-cake	4 5 0 0	8 9 1 4	4 14 1 4	4 6 2 8	8 8 1 6	7 18 3 12
4	130 lbs. calcined bone-dust, 130 lbs. sulphate of ammonia, 130 lbs. hydrochloric acid (sp. gr. 1·18)	4 9 1 4	6 6 0 16	6 7 0 16	5 12 0 0	8 2 0 0	6 14 2 8
5	160 lbs. superphosphate of lime, 130 lbs sulphate of ammonia	4 8 1 4	6 0 2 24	6 6 3 12	6 0 1 4	8 4 0 0	7 15 0 16
6	160 lbs. superphosphate of lime, 5 cwts. train oil	3 0 3 12	4 9 1 20	5 4 0 0	4 14 6 12	7 5 0 16	5 19 1 20
7	12 cwts. sulphate of lime (refuse of tartaric acid process)	2 19 3 12	4 17 0 0	3 6 3 12	2 8 2 8	5 5 0 16	4 8 2 8
8	400 lbs. calcined bone-dust	3 12 3 12	5 8 1 20	6 12 1 4	5 2 3 12	7 14 3 12	5 17 2 24
9	400 lbs. calcined bone-dust, hydrochloric acid (=268 lbs. sulphuric acid, sp. gr. 1·70)	4 6 3 12	5 6 0 16	6 18 3 12	5 4 2 8	7 14 3 12	5 6 3 12
10	400 lbs. calcined bone-dust, 134 lbs. sulphuric acid	3 16 3 2	5 14 1 16	5 5 1 20	5 3 1 20	7 5 2 24	7 3 0 16
11	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid	4 14 1 4	5 15 2 24	6 4 0 0	5 3 1 20	7 1 0 16	6 13 1 20
12	11 cwts. superphosphate of lime (land dug 9 in. deep in 1844)	4 9 0 0	5 16 2 8	6 18 1 4	5 9 3 20	8 8 2 8	7 2 3 12
13	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid, 134 lbs. common salt	6 11 0 10	6 3 0 0	8 4 3 14	7 14 0 0	8 19 1 20	8 9 0 16
14	11 cwts. superphosphate of lime (land trenched 18 in. deep in 1844)	4 4 0 16	6 10 2 24	7 8 2 8	6 7 2 24	8 16 3 12	7 14 1 4
15	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 315 lbs. soda ash	3 10 2 14	5 2 0 16	8 0 1 4	5 12 3 12	8 8 2 8	6 12 2 8
16	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 220 lbs. magnesian limestone	3 17 1 4	4 15 0 18	6 6 2 8	5 8 3 12	7 3 2 24	6 8 0 0
17	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 670 lbs. pearlash	3 10 0 0	4 10 3 12	6 0 3 12	5 3 2 24	7 2 2 8	6 6 2 8
18	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 105 lbs. soda ash, 74 lbs. magnesian limestone, 157 lbs. pearlash	3 7 2 8	5 12 1 4	6 1 1 20	4 10 3 12	6 16 2 8	5 16 2 8
19	As No. 18, with 1 cwt. sulphate of ammonia	4 8 2 24	6 4 1 20	7 3 0 16	5 18 2 8	8 11 2 24	6 14 0 0
20	As No. 18, with 3 cwts. rape-cake	5 1 0 16	6 5 2 24	7 6 0 0	5 17 0 16	9 5 2 24	6 11 2 24
21	400 lbs. calcined bone-dust, 400 lbs. sulphuric acid	4 5 0 16	6 3 0 0	6 15 1 20	5 0 3 12	6 18 0 0	7 18 3 8
22	11 cwts. superphosphate of lime	4 8 0 0	6 0 0 0	7 0 2 8	5 0 3 12	6 8 2 24	6 13 1 20
23	3 cwts. sulphate of ammonia	..	..	1 14 0 8	..	..	..
24	Mean mixture of all other drilled manures, exclusive of Nos. 1 and 23	3 3 1 2	..	..	..	..	..
	Mean Results	4 0 0 6	5 14 2 17	6 2 2 0	5 1 3 17	7 11 1 7	6 12 1 13

DIVISION 3.—AVERAGE WEIGHT of BULBS, in Pounds and Tenths.

Plot Numbers.	DESCRIPTION OF DRILLED MANURES. Quantities expressed in Weight per Acre.	Drilled Manures only.	Drilled Manures, and 10 cwts. Rape-cake per Acre.	Drilled Manures, and 3 cwts. Sulphate of Ammonia per Acre.		Drilled Manures, with 10 cwts. Rape-cake and 3 cwts. Sulphate of Ammonia per Acre.	
				First Gathering.	Second Gathering (3 weeks later).	First Gathering.	Second Gathering (3 weeks later).
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	12 tons farm-yard dung, ridged in ; no drilled manures	1·61	..	1·45	..	..	..
2	Unmanured	0·11	0·67	0·066	0·22	0·50	0·49
3	8 cwts. rape-cake	0·49	0·87	0·47	0·55	0·56	0·80
4	130 lbs. calcined bone-dust, 130 lbs. sulphate of ammonia, 130 lbs. hydrochloric acid (sp. gr. 1·18)	0·92	1·14	0·77	0·89	0·81	0·98
5	160 lbs. superphosphate of lime, 130 lbs. sulphate of ammonia .	0·90	1·04	0·77	0·95	0·72	0·87
6	160 lbs. superphosphate of lime, 5 cwts. train oil	0·59	0·90	0·55	0·62	0·64	0·86
7	12 cwts. sulphate of lime (refuse of tartaric acid manufacture)	0·59	0·94	0·54	0·46	0·68	0·89
8	400 lbs. calcined bone-dust	0·92	1·10	0·94	0·95	0·97	1·00
9	400 lbs. calcined bone dust, hydrochloric acid (=268 lbs. sulphuric acid, sp. gr. 1·70)	1·02	1·16	0·99	0·99	0·87	0·96
10	400 lbs. calcined bone-dust, 134 lbs. sulphuric acid	1·18	1·33	1·25	1·20	1·10	1·14
11	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid	1·23	1·38	1·19	1·22	1·11	1·22
12	11 cwts. superphosphate of lime (land dug 9 inches deep in 1844)	1·20	1·39	1·19	1·23	1·07	1·25
13	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid, 134 lbs. common salt..	1·38	1·27	1·16	1·20	1·03	1·13
14	11 cwts. superphosphate of lime (land trenched 18 inches deep in 1844)	1·30	1·33	1·30	1·37	1·19	1·26
15	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 315 lbs. soda ash	1·11	1·37	1·14	1·17	1·10	1·16
16	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 220 lbs. magnesian limestone..	1·11	1·35	1·21	1·25	1·14	1·23
17	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 470 lbs. pearlash..	1·02	1·27	1·16	1·09	1·13	1·08
18	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 105 lbs. soda ash, 74 lbs. magnesian limestone, 157 lbs. pearlash	1·16	1·33	1·18	1·24	1·25	1·29
19	As No. 18, with 1 cwt. sulphate of ammonia	1·16	1·24	1·02	1·09	1·09	1·15
20	As No. 18, with 3 cwts. rape-cake	1·28	1·40	1·18	1·29	1·18	1·23
21	400 lbs. calcined bone-dust, 400 lbs. sulphuric acid	1·22	1·41	1·10	1·15	1·18	1·20
22	11 cwts. superphosphate of lime	1·17	1·33	1·06	1·24	1·17	1·24
23	3 cwts. sulphate of ammonia	..	..	0·37	..	..	..
24	Mean mixture of all the other drilled manures, exclusive of Nos. 1 and 23	1·27	..	..	..	..	..
	Mean Results	1·00	1·20	0·96	1·02	0·98	1·07

DIVISION 4.—NUMBER of PLANTS per Acre.

Plot Numbers.	DESCRIPTION OF DRILLED MANURES. Quantities expressed in Weight per Acre.	Drilled Manures only.	Drilled Manures and 10 cwts. Rape-cake per Acre.	Drilled Manures, and 3 cwts. Sulphate of Ammonia per Acre.		Drilled Manures, with 10 cwts. Rape-cake and 3 cwts. Sulphate of Ammonia per Acre.	
				First Gathering.	Second Gathering (3 weeks later).	First Gathering.	Second Gathering (3 weeks later).
1	12 tons farm-yard dung, ridged in ; no drilled manures	23,731	..	23,104	..	..	..
2	No manure	13,296	24,944	15,456	16,848	24,160	23,088
3	8 cwts. rape-cake	21,952	24,240	20,896	22,016	20,544	23,304
4	130 lbs. calcined bone-dust, 130 lbs. sulphate of ammonia, 130 lbs. hydrochloric acid (sp. gr. 1·18)	24,000	23,712	22,368	23,488	20,000	22,496
5	160 lbs. superphosphate of lime, 130 lbs. sulphate of ammonia ..	14,544	20,448	19,296	19,776	21,824	21,472
6	160 lbs. superphosphate of lime, 5 cwts. train oil	24,528	23,632	24,992	24,576	23,264	23,424
7	12 cwts. sulphate of lime (the refuse of tartaric acid manufacture)	21,408	23,952	19,584	21,376	23,488	23,616
8	400 lbs. calcined bone-dust	21,896	23,760	22,944	24,132	23,808	23,872
9	400 lbs. calcined bone-dust, and hydrochloric acid (=268 lbs. sulphuric acid, sp. gr. 1·70)	20,784	16,672	19,360	19,584	18,272	18,624
10	400 lbs. calcined bone-dust and 134 lbs. sulphuric acid	24,704	23,456	22,368	23,808	24,576	23,360
11	400 lbs. calcined bone-bust and 268 lbs. sulphuric acid	24,624	22,800	23,360	23,712	23,872	23,744
12	11 cwts. superphosphate of lime (land dug 9 inches deep in 1844)	25,120	23,072	23,606	23,136	23,520	24,160
13	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid, 134 lbs. common salt..	23,620	23,104	24,128	23,040	21,152	23,008
14	11 cwts. superphosphate of lime (land trenched 18 inches deep in 1844)	24,464	24,368	23,936	23,872	23,328	24,224
15	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 315 lbs. soda ash	23,792	20,384	24,352	24,960	22,720	22,592
16	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 220 lbs. magnesian limestone..	24,336	23,470	23,584	23,200	23,456	24,032
17	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 470 lbs. pearlash	24,160	22,800	23,648	24,608	23,200	24,544
18	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 105 lbs. soda ash, 74 lbs. magnesian limestone, 157 lbs. pearlash	24,448	23,404	24,448	24,480	23,392	24,000
19	As No. 18, with 1 cwt. sulphate of ammonia	23,888	20,448	22,112	22,304	20,222	22,304
20	As No. 18, with 3 cwts. rape-cake	25,120	22,896	23,680	23,200	23,680	23,552
21	400 lbs. calcined bone-dust, 400 lbs. sulphuric acid	24,160	22,912	23,712	23,904	23,168	24,608
22	11 cwts. superphosphate of lime..	24,352	23,544	23,424	20,800	23,936	23,872
23	3 cwts. sulphate of ammonia	..	..	19,328	..	..	..
24	Mean mixture of all the other drilled manures, exclusive of Nos. 1 and 23..	24,352	..	..	..	..	..
	Mean Results	22,962	22,763	22,440	22,705	23,028	23,233

DIVISION 5.—PROPORTION of LEAF to BULB; Bulb as 1000.

Plot Numbers.	DESCRIPTION OF DRILLED MANURES. Quantities expressed in Weight per Acre.	Drilled Manures only.	Drilled Manures, and 10 cwts. Rape-cake per Acre.	Drilled Manures, and 3 cwts. Sulphate of Ammonia per Acre.		Drilled Manures, with 10 cwts. Rape-cake and 3 cwts. Sulphate of Ammonia per Acre.	
				First Gathering.	Second Gathering (3 weeks later).	First Gathering.	Second Gathering (3 weeks later).
1	12 tons farm-yard dung, ridged in; no drilled manures	433	..	698	..	..	..
2	No manure	1,041	644	720	545	840	892
3	8 cwts. rape-cake	884	896	1,078	797	1,176	909
4	130 lbs. calcined bone-dust, 130 lbs. sulphate of ammonia, 130 lbs. hydrochloric acid (sp. gr. 1·18)	452	520	837	592	1,126	704
5	160 lbs. superphosphate of lime, 130 lbs. sulphate of ammonia	758	636	943	718	1,164	930
6	160 lbs. superphosphate of lime, 5 cwts. train oil	467	475	840	693	1,085	664
7	12 cwts. sulphate of lime (refuse of tartaric acid manufacture)	526	482	700	550	737	519
8	400 lbs. calcined bone-dust	356	463	686	504	741	553
9	400 lbs. calcined bone-dust, hydrochloric acid (=268 lbs. sulphuric acid)	458	612	809	606	1,009	669
10	400 lbs. calcined bone-dust, 134 lbs. sulphuric acid	296	410	422	445	602	602
11	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid	348	412	492	438	580	512
12	11 cwts. superphosphate of lime (land dug 9 inches deep in 1844)	331	408	550	467	751	530
13	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid, 134 lbs. common salt..	451	470	666	626	925	727
14	11 cwts. superphosphate of lime (land trenched 18 inches deep in 1844)	296	452	533	440	712	560
15	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 315 lbs. soda ash	299	410	644	434	754	561
16	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 220 lbs. magnesian limestone	320	335	496	420	604	483
17	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 470 lbs. pearlash	319	350	494	432	611	532
18	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 105 lbs. soda ash, 74 lbs. magnesian limestone, 157 lbs. pearlash ..	267	402	472	334	521	423
19	As No. 18, with 1 cwt. sulphate of ammonia	264	551	712	549	876	586
20	As No. 18, with 3 cwts. rape-cake	351	439	587	437	743	510
21	400 lbs. calcined bone-dust, 400 lbs. sulphuric acid	324	426	580	375	509	600
22	11 cwts. superphosphate of lime	345	427	636	456	512	505
	Mean Results	416	486	634	521	789	617

With such a mass of experimental evidence before us, it is difficult to select a starting-point such as will lead us to the most natural order of illustration, and the clearest comprehension of the most prominent indications and conclusions. In many respects these results are most interesting, confirming as they do the opinions suggested by those which have preceded them; and affording at the same time data, the consideration of which enables us to determine other important questions than those already attended to.

It will be recollected that the statement given of the character of this third season, compared with that of the second, was, so far as all the conditions shown to be essential to the vigorous growth of the turnip were concerned, very much in favour of the one about to occupy our attention; and it is seen that the acreage produce is pretty uniformly nearly doubled where artificial supply for organic formations is much the same. It is true that the number of plants per acre being much greater than heretofore, some of the actual acreage increase may be attributed to this cause; but all we wish to maintain is the general effect of season upon the growth of the cultivated turnip.

The absolute necessity of a liberal supply of *constituents*, even with the most favourable climatic circumstances, and under the influence of the best observed conditions of self-reliance, or collective power depending on mineral supply, is, however, clearly proved by the results of the farm-yard dung, the unmanured plot, and the mean of the purely mineral manures. They are here given in illustration.

SELECTED RESULTS.

Description of Manures.	Bulb per Acre, in				Average Weight of Bulbs in lbs. and tenths.	Number of Plants per Acre.
	Tons.	cwts.	qrs.	lbs.		
Unmanured	0	13	2	24	0·11	13,296
Mean by purely mineral supply... ...	12	8	2	3	1·16	23,882
Farm-yard dung	17	0	3	6	1·61	23,731

Thus, in the best suited of the three seasons to which our experiments refer, the unmanured plot gives a produce of only 13 cwts. per acre, an average weight of bulb under 2 ounces, and a number of surviving plants little more than half that observed under conditions of artificial supply. In this same season, on the other hand, the farm-yard dung gives the largest acreage produce obtained throughout the entire series of seasons and experiments, a weight of bulb higher than any other manure in the same season, and a number of plants nearly identical with that under mineral manures only. Again, by mineral supply alone, to which, indeed, as we have seen, may be attributed an influence upon the growth of the plant apart from that which can be traceable to the mere provision of *crop-material*, we have as many tons of produce as the unmanured plot gives cwts., a weight of bulb more than ten times as great, and a number of healthy plants nearly double. By the side of the farm-yard dung, however, which we presume to contain a sufficiency of *all the constituents* of a large crop of turnips (though, excepting under the influence of continuity of rain and a relatively low temperature, not calculated to develop the most healthy conditions of growth), we find that the purely mineral manuring, with a number of plants per acre almost identical, shows a formation of bulb within an equal period of time little more than two-thirds as great. We shall presently see that the largest weight of *bulb formed in a given time* is not to be taken as affording an unconditional index to the value or promise of the crop; but in the instances now cited it may, in a pre-eminent degree, be quoted as such; for we know that whilst the plants under minerals only had, when weighed, arrived at their full growth, those having farm-yard dung had still vitality and resources for further development.

Before tracing any further the probable source of the superiority of farm-yard over the purely mineral manure, we will refer to some other of the points which our arrangement of manuring elucidates. In the two former years it was observed that, wherever either ammoniacal salts or rape-cake were drilled with the seed, a great depreciation and irregularity in the number of plants per acre resulted; and it may have appeared to some of our readers that we have, without sufficient ground, referred the deficiency of plants to the manner of applying these organic manures; and that, omitting the indications of the actual acreage results, our reasonings are fallacious. The following summary of the number of plants obtained, when ammoniacal salts and rape-cake are sown broadcast and ploughed in, and of that resulting from the use of mineral manures alone, will show how highly important it is not only to select a manure such as the plant requires, but so to apply it as to ensure a beneficial rather than an injurious result.

The uniformity under the various classes of manures in this season, as compared with others, is very striking; though, as before, the mineral manures give somewhat the higher number. The coincidence throughout the entire series of about 90 different combinations of manures (see Division 4 of Table, p. 29) is such that, for the first time, the acreage amount of produce may be taken as a somewhat true measure of the value of the manures. The drilled manures, as has already been stated, were this year sown alone before the seed, yet the detailed results given in Division 4 of the Table still afford instances of the injurious effect arising from the proximity to the plant of certain manures, though in so slight a degree as to be almost immaterial.

SUMMARY.*

Description of Manures.	Number of Plants per Acre.
Mean of mineral manures alone	23,882
" " with rape-cake added	22,596
" " with ammoniacal salt added	23,598
" " with both rape-cake and ammoniacal salt	22,954

The influence of climatic condition, not only as of itself a source of constituents, but as rendering available the supplies provided by the farmer, is strikingly illustrated by the details next quoted, wherein it is seen that notwithstanding the comparatively large number of plants in 1845, which might be supposed to prevent individual development, there is a marked increase as compared with 1844.

Description of Manures.	Number of Plants per Acre.		Average Weight of Bulbs.	
	1844.	**1845.**	**1844.**	**1845.**
Farm-yard dung	20,096	23,731	1·19	1·61
Mean of purely mineral manures	20,377	23,882	0·73	1·16

It is here seen that, even with so great a number of plants, the average weight of bulb is very considerably higher in 1845 than in 1844. In the case of the dung the supply by manure is not supposed to be better than in 1844. In the case of the mineral manures, however, the quantities were larger than before; but the accumulation of organic constituents must have been almost entirely from atmospheric resources. A comparison of the results of the one year with those of the other, as given above, sufficiently prove then the essential influence of climatic agency for the development of the turnip-bulb in *full agricultural quantity*; but the great defect in formation of bulb within a given time, under the influence of one and the same season, when a full

* It will be remembered that in former years the plants were set out with the view of retaining about four to a square yard, or 19,360 upon an acre; the design in this third year was to increase the number to about five instead of four, which is equal to 24,200 to the acre, and hence the actual numbers in the table just given are much higher than hitherto.

supply of mineral manure only is provided, as compared with that of organic matter, also again teaches how imperative it is that there be a liberal provision of such matter in the soil, if we would produce the largest crop which the characters of the season admit of.

The results already selected from the table do not, however, show us whether this required supply by manure of matter for organic formations should be more prominently *nitrogenous*, as in the case of wheat, or *carbonaceous*. This point we shall presently recur to; but, before doing so, shall study the effects of varying the mineral supply by manure.

The average weight of bulb, as affected by the amount of *free* phosphoric acid, or superphosphate of lime, supplied to the soil by manures, is here given:—

Plot Nos.	Description of Drilled Manures.	Average Weight of Bulbs, in lbs. Drilled Manures only.	Drilled Manures, and 10cwts. Rape-cake per Acre.	Drilled Manures, and 3 cwts. Sulph. Am. per Acre.	Drilled Manures, and 10cwts. Rape-cake, and 3 cwts. Sulph. Am. per Acre.
8	400 lbs. calcined bone-dust ...	0·92	1·10	0·96	0·97
9	400 lbs. calcined bone-dust, and hydrochloric acid = 268 lbs. sulphuric acid...	1·02	1·16	0·99	0·87
10	400 lbs. calcined bone-dust, and 134 lbs. sulphuric acid	1·18	1·33	1·25	1·10
11	400 lbs. calcined bone-dust, and 268 lbs. sulphuric acid	1·23	1·38	1·19	1·11
21	400 lbs. calcined bone-dust, and 400 lbs. sulphuric acid	1·22	1·41	1·10	1·18
	Mean of the results by sulphuric acid	1·21	1·37	1·18	1·13

It is seen that, under all the varying conditions of organic supply, the undecomposed bone-dust produced less effect than the decomposed. Hydrochloric acid has caused a slight increase in bulb where there was no organic manure, and where rape-cake or ammoniacal salt only was added; but where ammoniacal salt and rape-cake were employed together, the formation of bulb was less than by undecomposed bone-dust. But a reference to Division 2 of the Table of collected results will show, however, a much larger quantity of leaf under the action of hydrochloric acid—and, in fact, there was more general growth than by undecomposed bone-dust, though but little tendency to form bulb; yet there is little doubt that eventually, if allowed to mature, the *decomposed* bone-earth would have given much the largest amount of bulb as well as entire plant.

Sulphuric acid, as the decomposing agent, indicates in every case a considerably more rapid determination to bulb than either the undecomposed bone-earth or that acted upon by the hydrochloric acid; and, excepting where ammoniacal salt is superadded, there is a perceptible progression as the amount of acid is increased. Where the ammoniacal salt was used, though the formation of *bulb* is not greater under an increase of acid, there was here, as in the case of the hydrochloric acid, a larger development of *leaf*.

The effect of an equal amount of superphosphate of lime on land ploughed in the ordinary way, or which had been dug 9 or 18 inches deep in the previous year, is here shown:—

Plot Nos.	Land, how Tilled.	Average Weight of Bulbs, in lbs. Drilled Manures only.	Drilled Manures, and 10 cwts. Rape-cake per Acre.	Drilled Manures, and 3 cwts. Sulph. Am. per Acre.	Drilled Manures, and 3 cwts. Sulph. Am. and 10 cwts. Rape-cake per Acre.
12	Land dug 9 inches in 1844 (11 cwts. superphosphate of lime)	1·20	1·39	1·19	1·07
14	Land dug 18 inches in 1844 (11 cwts. superphosphate of lime)	1·30	1·33	1·30	1·19
22	Land only ploughed (11 cwts. superphosphate of lime) ...	1·17	1·33	1·06	1·17

Excepting in column 2, the rapidity of bulb-formation is slightly the greatest where the land is deeply trenched, and in the exceptional case a larger development of leaf was found. The land dug 9 inches deep also shows a slight superiority over that which was only ploughed. The differences are not quoted as offering any adequate advantage for so expensive a process as spade-digging; but the facts themselves help to indicate the character of the conditions required in turnip culture.

We shall next show the result of the yearly supply of *alkalies*, compared with that from a plot (No. 21) which had been drained of them by a course of ordinary cropping, succeeded by the removal of two crops of turnips:—

In the first two columns, where, as we shall presently show, the *balance* of organic constituents was more favourable to *bulb*-formation than in the other cases, we find a greater development of bulb in an equal period of time by superphosphate of lime alone, than when the alkalies, either separately or united, were supplied with it. It is remarkable, too, that in No. 17, where *potass* was employed, there is a general inferiority observable. Again, of the several alkaline conditions, that where potass, soda, and magnesia are used together is the best. The differences exhibited

Plot Nos.	Description of Alkaline Manures (drilled).	Average Weight of Bulbs, in lbs.			
		Drilled Manures only.	Drilled Manures, and 10 cwts. Rape-cake per Acre.	Drilled Manures, and 3 cwts. Sulph. Am. per Acre.	Drilled Manures, 3 cwts. Sulph. Am. and 10 cwts. Rape-cake per Acre.
21	400 lbs. calcined bone-dust, and 400 lbs. sulphuric acid... ...	1·22	1·41	1·10	1·18
15	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, and 315 lbs. soda ash	1·11	1·37	1·14	1·10
16	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, and 220 lbs. magnesian limestone ...	1·11	1·35	1·21	1·14
17	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, and 470 lbs. pearlash	1·02	1·27	1·16	1·13
18	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 105 lbs. soda ash, 74 lbs. magnesian limestone, and 157 lbs. pearlash...	1·16	1·33	1·18	1·25
	Mean by alkaline supply ...	1·10	1·33	1·17	1·15

are at any rate sufficient to show that there was no advantage derived by the use of alkaline manures in this soil, which had been subjected to an unusually severe exhaustion of them.

We have, indeed, uniformly observed, not only in the case of turnips, but of other plants, that by the direct supply of alkalies no good effect has resulted in the season of the application, though the succeeding crops have apparently, to a small extent, been benefited. It is our opinion that, in the ordinary course of farming, the special supply of alkalies to the soil is exceedingly rarely requisite,—and, if ever it be so, they should never be applied in an *alkaline condition* (which seems to be very prejudicial to healthy vegetation), but always supersaturated by acids. Further, alkalies should not be drilled, but should always be sown broadcast, and well incorporated with the soil. In the case of turnips especially is this to be carefully attended to; and, indeed, it might be almost laid down as a general rule, that those manuring substances which take their value as *mere* constituents of the plant (alkalies and organic manures), should be well distributed through the soil; and those which further exercise an influence upon the health and vigour of the plant, such as superphosphate of lime, should be drilled near the seed.

Whether or not superphosphate of lime owes much of its effect to its chemical actions in the soil, it is certainly true that it causes a much-enhanced development of the *underground* collective apparatus of the plant, especially of *lateral* and *fibrous* root, distributing a complete network to a considerable distance around the plant, and throwing innumerable mouths to the surface. The extent and direction of the *underground range* of the turnip are at the same time very much dependent on the mechanical condition of the soil; and it is universally known that *tilth* is of the highest importance to the favourable formation of *bulb*. We know that the best relation of bulb to leaf, and, in fact, the best acreage produce of bulbs is in the lighter soils, where there is comparatively little obstruction to the development of fibrous root, and it is in these that the special efficacy of superphosphate of lime has been most observable. We believe that, if the turnip is to be valued for its *bulb-formation*, the aim of our culture must be, not to increase the aboveground organs of collection (the leaves), but the *underground fibrous roots*.

We shall now consider the effects of "*organic manures*" upon the production of turnip-bulb; and the facts that will come before us will tend to confirm the views just maintained regarding the essential development of rootlet- rather than leaf-accumulation, as a means of obtaining the turnip in agricultural quantity and quality.

The results collected below will illustrate some of the effects of "organic manures" upon the growth of the turnip:—

Description of Mineral Manures.	Average Weight of Bulbs, in lbs.			
	Mineral Manures only.	Mineral Manures and 10 cwts. Rape-cake per Acre.	Mineral Manures, and 3 cwts. Sulph. Am. per Acre.	Mineral Manures, 10 cwts. Rape-cake and 3 cwts. Sulph. Am. per Acre.
Mean of entire series of purely mineral manures	1·16	1·31	1·14	1·10
Mean of four experiments with alkaline supply	1·10	1·33	1·17	1·15
Mean of three experiments with superphosphate of lime	1·21	1·37	1·18	1·13

We may explain that the results in the first column were obtained by means of mineral manures alone, and that, the previous crops having been entirely removed from the land, the organic supplies must have been chiefly derived from the atmosphere. The development of *leaf* was less in these than in any of the other cases. In column 2 there was, besides these same mineral manures, 10 cwts. rape-cake, which may be estimated to provide perhaps 50 lbs. of nitrogen. It was, however, employed in these experiments as supplying a large amount of carbonaceous matter, in which it abounds. In the 3rd column the effects are due to the addition of 3 cwts. of sulphate of ammonia to the mineral manures. In these cases about 60 lbs. of nitrogen is supplied, but no carbon. In the 4th column we have the effects of the addition both of the rape-cake and of the ammoniacal salt to the standard mineral manure; consequently the supply of nitrogen by manure would amount to about 110 lbs. per acre.

It is seen that, whichever mineral condition be taken, the supply of carbonaceous matter has given the largest bulb. Of the two mineral series, the acid and the alkaline, the former exhibits a general superiority in each case, excepting in the 4th column, where the defect is very trifling. In this case, notwithstanding there was a carbonaceous supply equal to that in column 2, the excessive amount of *nitrogenous* matter has prevented a favourable formation of bulb. These mean results clearly show that carbonaceous rather than nitrogenous organic supply is favourable to *bulb-formation*, and the fact is confirmed by the following individual cases:—

SELECTED RESULTS.

Plot Nos.	Description of Drilled Manures.	Average Weight of Bulbs, in lbs.			
		Drilled Manures only.	Drilled Manures, and 10 cwts. Rape-cake per Acre.	Drilled Manures, and 3 cwts. Sulph. Am. per Acre.	Drilled Manures, 10 cwts. Rape-cake and 3 cwts. Sulph. Am. per Acre.
18	Superphosphate of lime, with potass, soda, and magnesia...	1·16	1·33	1·18	1·25
19	As No. 18, and 1 cwt. sulphate of ammonia	1·16	1·24	1·02	1·09
20	As No. 18, and 3 cwt. rape-cake	1·28	1·40	1·18	1·18

In all these cases the mineral manure was the same, and, in all, the 2nd column under the cross-dressing of rape-cake shows the best result. Further, looking at each column separately, we find that No. 20 always gives a heavier bulb than No. 19, and, excepting under the cross-dressings of ammoniacal salt, than No. 18 also. The amount of the differences is not indeed great; but when we remember that the results are calculated from nearly 2000 plants in each case, their uniformity and constancy demand that reliance should be placed in them. It is clear, then, that carbonaceous manures aid the development of turnip-*bulb*. We shall give one more quotation on this subject:—

	Average Weight of Bulbs, in lbs.			
	No Cross-dressing.	Cross-dressed by 10 cwts. Rape-cake per Acre.	Cross-dressed by 3 cwts. Sulphate Ammonia per Acre.	Cross-dressed by 10 cwts. Rape-cake and 3 cwts. Sulph. Am. per Acre.
No drilled manure (third season)...	0·11	0·67	0·07	0·50

The instances before us are of high interest in many points of

view, but we are not prepared to consider them fully until we have detailed the results of an analytical examination of the crops—a subject which we shall presently enter upon. Resuming the question in discussion, we see that whilst ammoniacal salts in no degree restored fertility to this exhausted soil, rape-cake gave a six-fold development. In the 4th column, under an equal amount of rape-cake, we find as usual that the excess of nitrogenous manure has deteriorated the tendency to bulb formation exhibited in column 2.

The contrast observed in the effects of ammoniacal salts upon wheat and upon turnips is very remarkable, and affords a striking illustration of the widely differing requirements and sources of growth of the corn-exporting "white crops," and the home-consumed, meat-producing "green" or "fallow crops," of which classes, respectively, the two plants may be considered as the types.

Hitherto we have only considered the effects of organic manures upon the formation of turnip-*bulb*, the amount of which is thought to determine the value of the crop when cultivated for feeding and rotation purposes. It has been seen that a liberal supply of available phosphates and of organic manures abounding in carbonaceous matter are pre-eminently favourable to the desired habit of the plant, and that nitrogenous supply, so essential to the increased growth of corn, is so here only to a very limited extent. Under the influence of ammoniacal manures, however, the production of turnip *leaf* is much enhanced, as the following results will show:—

Description of Manures.	Bulb per Acre, in				Leaf per acre, in				Proportion of Leaf to 1000 of Bulb.
	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.	
Mean by purely mineral manures	12	8	2	3	4	4	0	14	326
Mean of mineral manures, with 10 cwts. rape-cake added ...	13	4	2	20	5	12	0	21	421
Mean by mineral manures, and 3 cwts. sulphate of ammonia added	11	18	1	24	6	15	0	21	559
Mean by mineral manures, and 3 cwts. sulphate of ammonia (second gathering)	12	5	0	13	5	14	0	17	466
Mean by purely mineral manures, and both rape-cake and ammoniacal salt	11	6	1	11	7	9	0	22	669
Mean by purely mineral manures, and both rape-cake and ammoniacal salt (second gathering)	12	4	3	6	6	15	2	16	554

Thus, comparing lines 1 and 3, we find that whilst, by the addition of ammoniacal salt in the latter case, there is in an equal space of time half a ton less of bulb, there is an increase in leaf by 2¼ tons; and, as shown in the 3rd column, the proportion of leaf to bulb is more than half as much again. Taking lines 2 and 5, the addition of ammoniacal salt, as in 5, gives nearly 2 tons less bulb, but nearly 2 tons more leaf, the proportion of leaf to bulb being again increased by one-half. The gross produce is seen, therefore, to be greater in one of these cases, and as great in the other, under the addition of ammoniacal salts. We have before remarked, however, that whilst at the time of gathering, the crops by mineral manures alone, as in line 1, had probably more than fully arrived at maturity—the leaves having drooped and changed colour—those under rape-cake addition only had but just attained full growth, and those having ammoniacal salts, as in lines 3 and 5, evidently possessed yet unexhausted vitality, especially in No. 5, the case where rape-cake was also supplied. It might be supposed, therefore, that in due course bulbous development would succeed as the increased leaves drooped. The results of the second gathering, taken when the leaves under ammoniacal salt without rape-cake had considerably fallen (those with it being still vigorous), show this to have been the case to a greater or less degree. A comparison of lines 3 and 4 shows an increase of bulb in three weeks of 7 cwts., at the expense of 19 cwts. of fresh weight of leaf. On the other hand, line 6 gives an increase in the same period of 18½ cwts. of bulb, at the expense of only 14 cwts. of fresh leaf. Under ammoniacal salts alone there had therefore been an actual depreciation in fresh weight, indicating at least a loss of vitality, though there was probably no real loss of solid matter. Where there was rape-cake also, however, we find an actual gain in gross weight, and we had undoubtedly a vitality and resource of growth still unexhausted. Comparing line 4 with line 1, the latter has still the largest weight of bulb; and comparing line 6 with line 2, the former is still a ton in advance. Were we to admit, however, that if the crops could have been taken each at the stage of its best yield of *bulb*, there would have been a slight superiority under the nitrogenous manuring, the quantity yielding the effect in these instances could in no form have been economically obtained, even were there no other objection to its use.

The effects of an excess of nitrogen in tending to an unprofitable habit of the plant are further exhibited in page 41 :—

It is here seen that whilst farm-yard dung, itself containing some nitrogen, and certainly a very full allowance of carbonaceous matter, gives 17 tons of bulb, we have more than 2 tons less bulb when ammoniacal salt is superadded; but there are at the same time 3 tons more leaf than by dung alone. The 3rd column shows that the actual size of bulb, as well as its acreage produce,

	Bulb per Acre, in				Leaf per Acre, in				Average Weight of Bulbs.	Proportion of Leaf to 1000 of Bulb.
	Tons.	cwts.	qrs.	lbs.	Tons.	cwts.	qrs.	lbs.		
12 tons farm-yard dung	17	0	3	6	7	7	3	2	1·61	433
12 tons farm-yd. dung, and 3 cwts. sulphate of ammonia .	14	18	3	12	10	8	3	12	1·45	700

was less, under the excessive supply of nitrogen; the 4th, that under the same circumstances the proportion of leaf to bulb was increased by more than one-half. So far as supply of *constituents* is concerned, we could select from the series of experiments several instances where we may reasonably suppose that every constituent, excepting *carbon*, existed more fully in quantity and more favourably in combination than in the dung, yet with its larger *carbonaceous supply to the root* we get the largest crop of bulb in the series. The excess of nitrogenous manure, however, is seen greatly to enhance the leaf-forming tendencies of the plant, which it is true may probably aid carbonic acid accumulation from the atmosphere, but at the same time gives a less profitable appropriation of the resources within the soil; and we shall afterwards see it to be by no means clear that there is with a large production of leaf a proportional *gain* of nitrogen from the atmosphere.

Admitting, then, that the organic manure required for the growth of turnip-*bulbs* should be carbonaceous rather than nitrogenous, there is still evidence that, under the influence of a due provision of nitrogen, the vitality or longevity of the plant is greatly increased; and since the turnip crop is required to brave the winter frosts, an early and perfect ripening, such as would be induced by a defect of nitrogen relatively to carbon, whilst it might be coincident with a more *rapid* bulb formation, would by no means be a desideratum. We believe, however, that in the ordinary course of farming, the special supply of nitrogen to the turnip crop, by means of artificial manures, is seldom if ever necessary; for there is no ample source of available carbon which does not provide at the same time a considerable amount of nitrogen. As, therefore, in the case of wheat, we need not study the supply of carbonaceous manures, so, in the case of turnips, it comes to be unnecessary to devote special care to the provision of nitrogen. In the one case the means adopted specially to secure nitrogen to the soil, brings with it enough of carbon; and in the other the peculiarly carbonaceous manures are associated with sufficient nitrogen.

We have argued that for the growth of turnip-*bulb* a soil is required in such a mechanical condition as shall render it easily permeable to the atmosphere and to the fibrous roots of the plants,—that healthy action and a tendency to development of very extended underground collective apparatus should be induced by the use of the so-called "mineral manures," these never being in an alkaline state, and always containing a considerable quantity of phosphoric acid easily available to the plant,—that after the early stages of the plant are passed, its rapidity of growth depends upon an abundant provision *in the soil* of constituents for organic formations, especially of *carbon*,—that nitrogen must be provided by cultivation, though seldom by special manures,—and lastly, that all these requisites being provided by the farmer, the degree in which his efforts will be availing depends essentially upon certain climatic conditions, comprising a considerable *continuity* and *amount* of rain, as a means of taking up the stores of the soil, keeping up a vigorous circulation in the plant, and supplying the dissolved gases of the atmosphere.

These conditions compared with those which are required in the culture of wheat are opposed to one another in almost every particular, but as we proceed we shall see, that of the observed differences much is doubtless due to the essential distinctions between the tendencies of the natural families to which the plants belong; yet much of it is also attributable to the fact, that in the case of the turnip it is not the seed that is the object of our culture, but a monstrous accumulation which could only take place under a somewhat unnatural or artificial balance of the constituents of supplied food, and under such a condition of climate as should be adverse to seed-forming.

It is known that where the turnip is grown for its natural seed-product, oil, a heavier soil, richer manuring, and, during a considerable period of the growth of the plant, a much higher temperature, are required than when the bulb is to be produced. Under these circumstances there will be much less fibrous root thrown up to the surface,—the root is scarcely bulbous, but fusiform, tapping rather than spreading laterally; the leaves and stem are much larger, both actually and proportionally to the root, and the organic manures should contain more nitrogen and less carbon. Were we then to cultivate the turnip for its most natural products, the treatment it would require would much more nearly approach that adapted for wheat than at present; the deviations from it now observed, and which have been referred too exclusively to the *natural* specialities of the plants, would be greatly lessened, and the character of the plant as a "*fallow crop*" would be lost. It is no objection to this assumption that in selecting plants to transplant for *seed from which to grow bulb*, those having the most symmetrical bulb are chosen rather than

such as are more fusiform, and betray a more abundant seed-forming habit—in this case it is not the most abundant natural seed that is the object of culture, but a seed having a special habit of growth, which habit it is wished to propagate.

There being an evident understood subserviency of the leaf of the turnip to the bulb, and a sort of succession in the order of maturation of these different organs, the latter not being perfected until the former has lost much of its succulence and vigour; this fact, and the special conformation of the plant, as before adverted to, have, in theory, led to an appreciation of forcing a large amount of leaf, which is not consistent either with the full efficiency of the conditions which our researches show to favour *bulb*-formation, with the character of the soils best suited to the growth of the turnip-bulb, or that of the plant which is most approved by the practical agriculturist. It is true that relatively to wheat and many other plants, the turnip exhibits a large surface of succulent leaf, which it is admitted indicates a greater reliance in one way or other upon the atmosphere; yet all experience, when judging not between the turnip and other plants, but between one turnip and another turnip, values the one in which the proportion of leaf is least and the tendency to bulb the greatest. The description of soil which is called a turnip-soil, again, is just that which is best adapted to formation of fibrous root, and that which always yields a proportionally small amount of leaf. Moreover, the soils which yield the largest amount of leaf are known not only by their general mechanical condition, but by their comparative richness in nitrogen, to be exactly those in which the results of our experiments would lead us to anticipate that the leaf-forming tendency would predominate. In these too, as compared with the lighter ones, an excess of nitrogen in the manure is the more likely to give an undesirable development, for in the latter any increased vigour of growth arising from nitrogenous agency may more easily extend the *underground* organs and determine to bulb-formation than in the former.

We have now given a history of our experiments upon turnip culture during the first three seasons of their course, so far as the conduct of them in the field is concerned, though none, as yet, of the results obtained in the two succeeding seasons, the last of which is now drawing to a close. Details of this kind having, however, already taken up much space, and sufficed, we hope, to elucidate some established rules of practice, we shall defer until a future occasion a further consideration of this branch of our evidence, and enter at once into an account of our researches in the laboratory, as tending not only to confirm or confute conclusions otherwise arrived at, but as opening out points of interest, both in science and in practice, not hitherto brought to view.

The atmosphere and the virgin soil being originally the exclusive sources, the former of the "*organic*," and the latter of the "*inorganic*" or "*mineral*" constituents of plants, it has been supposed that the amount of produce which a given space of ground would yield must depend upon its richness in those substances proper to itself, namely, the mineral constituents; and that these being supplied in full quantity, according to the indications of the analyses of the ashes of the crops it is wished to grow, the atmosphere would always prove an ample available resource for the more peculiarly vegetable matters. It will be readily understood that on such a view as this, economy in agriculture would be attained by a very different course of practice from that required were it to be shown that cultivation should effect an artificial accumulation in the soil of those constituents primarily derived from the atmosphere, rather than of such as more especially belong to its own constitution.

The theory referred to has led to the analysis of the ashes of a great many agricultural crops, and upon the data thus obtained (rather than upon a consideration of the requirements actually induced by an artificially enhanced vegetation, or of the real source and destination of the constituents under a course of practical agriculture), recommendations to the agriculturist have been founded, the validity of which it was desirable should be tested by actual experiment, as well as by the presumed dictates of experience. The field results which we have detailed, both upon the subjects of wheat and of turnips, are unfavourable to these opinions and recommendations, and analysis will be found to bear testimony in the same direction.

A knowledge of the composition of our crops, as affected by climate and cultivation, is however of great importance, not only as showing what are the sources which must be relied upon for the various constituents, but as assisting a judgment of the feeding value of the produce, and of the *economy* of the means to the adoption of which the variations in composition may be traced. It is more especially with a view to these points of interest that our results have been sought, and that their bearings will be now considered.

In the course of an analytical examination of an agricultural specimen, the first steps are to determine the percentages respectively of dry vegetable substance and of mineral matters. For this purpose a known weight of the produce is exposed for a length of time to such a temperature as will only expel all the water it contains; a portion is then burnt to an ash, which is presumed to retain all the "*mineral*," but none of the "*vegetable*," substances of the specimen, the latter having been consumed and vaporized by the burning process. The knowledge which these simple experiments may afford is never to be overlooked in considering the composition of an agricultural product, and estimating its probable value, or the economy of the manuring, or other means which have been employed in its growth. A judgment formed thus alone, however, of the comparative characters of different specimens would be fallacious, owing chiefly to the facts that the dry matter of different specimens of the same kind of plant may differ much in composition, and that a very large proportion of our agricultural produce is not allowed to ripen its seed and attain a somewhat fixed condition of dryness not materially affected by collection, storing, and transmission, but is taken whilst the vital circulation of the plant is still proceeding with considerable vigour, causing, long after removal from the land, a rapid exhalation of watery vapour, tending very much to mislead as to the amount of dry matter really contained in the substance under examination. Unless, then, a series of such specimens—the comparative characters of which are to be estimated—be treated in every respect similarly, as to time of gathering, weighing, &c., serious errors must occur.

When ultimate ripened products are the subjects of examination, there is little difficulty in conducting a series of drying experiments, so that the results shall be true indications of the differences really dependent on climate and culture; and although in such cases the range of variation in the amount of dry matter is small, yet the variations themselves are very significant, bespeaking at once the conditions of growth, and, within certain limits, the probable qualities of the products.

There can be little doubt that, after reliable standards have been fixed, a knowledge of the true undoubted percentage of dry matter in specimens of green produce also might materially aid our judgment of their other characters; but, as yet, neither have we these standards, nor are the methods of different experimenters so uniform that their results can compare one with another. So little, indeed, is really fixed and generally admitted regarding both the methods of and the proper inferences from such experiments, that the results of the same operator will, in his own view, be the more doubted the more he learns of the lesson they are calculated to teach; and before there can be any common argument or comparison conducted on such subjects, there must be some uniformity of method agreed upon. In illustration of this necessity one or two experiments only are needed.

A quantity of turnip leaves were taken direct from the field to a barn about sunset, and were immediately weighed into lots of 25 and 50 oz. each. These bundles were laid upon straw, and on re-weighing the following morning were found to have lost more than 6 per cent. If the leaves gathered in the evening had not been weighed for drying until the following morning, an error of 1 per cent. or more in the estimation of dry matter would thus have arisen. We have elsewhere stated that 100 oz. specimens of green wheat-plant lost invariably from 7 to 9 per cent. during the process of separating from each other the leaves, the ear, and the stem, although two persons were employed in the operation.

Again, five turnips, with their leaves, were found to weigh as soon as gathered 16 lbs. 4½ oz.; after exposure two days and nights upon straw, under cover, they weighed 15 lbs. 5½ oz.; and after three days and nights more, 14 lbs. 8½ oz. Thus, if after being gathered 48 hours, 100 oz. had been taken for a drying experiment, it would have been equivalent to 106 oz. of fresh plant; and if after five days, to 112 oz. Five plants were next taken, and the leaves cut off, leaving, perhaps, two inches of stem upon the bulbs. The turnips, thus freed of their leaves, weighed 12 lbs. 8½ oz.; after 48 hours on straw, under cover, 12 lbs. 4½ oz.; and after 3 days more, 11 lbs. 3¾ oz. In this case, 100 oz. taken after being gathered 48 hours would have represented 102 oz. fresh bulb; and after 5 days, 106 oz. These turnip experiments were made in cold October weather; but the amount of loss sustained would of course depend much upon the vigour of growth of the plant, upon the state of the weather at the time, and the temperature of the place where the plants were kept.

It is evident, then, that very serious errors may arise when specimens are received from a distance, or even when they are not, unless special precautions be taken, according to the nature of the produce under examination. Indeed it is exceedingly difficult when fully aware of these circumstances, so to conduct an extensive series of comparative experiments on green or succulent substances as to obtain results which shall be both actually and relatively to each other open to no objection.

When, in the experiments quoted above, bulbs with the leaves, or the leaves alone are taken, the loss is seen to be much greater than when the bulbs alone are operated upon. This is what might have been anticipated, and shows clearly that the effect is due to the continuance of the natural circulatory processes of the leaves after removal from the land.

In operating upon bulbs or roots which are in contact with the soil, we meet with a difficulty of another kind. In such cases there is always a quantity of soil adhering to the specimens, which, if not removed, will affect to some extent the determination of dry matter, and still more seriously that of the mineral matter. A single bulb may be cleaned sufficiently by careful picking and wiping, but an extended series of determinations cannot be conducted under equal circumstances and with the necessary despatch without washing, by which soluble substances may to some extent be removed, or an absorption of water may take place. With the view of ascertaining the degree of error to which the washing of bulbs for drying and burning may lead, six lots, consisting each of five turnips, were taken, and the leaves were cut off, leaving a sufficient handle; three of the lots were carefully cleaned without the use of water, the other three being scrubbed with a brush in water, in which they were allowed to remain for ten minutes or a quarter of an hour; they were then taken out, rubbed dry with a cloth, sliced, and weighed. After exposure to a temperature of 212° for a sufficient time, the percentages of dry matter were as under:—

Lot.	Without washing.	With washing.
1	8·36	7·96
2	8·03	7·79
3	7·64	7·30
Average	8·01	7·68

There was evidently some difference in the specimens themselves, but the washing process gives in the main a less percentage of dry matter than the other. Without washing there must always be expected a small excess, and with it a slight deficiency. In the particular instances quoted the deficiency was likely to be greater than in the usual conduct of the process, as the operation was purposely rather prolonged, that the extreme effects might be ascertained. It is admitted, however, that washing is an objectionable procedure; but when drying and burning experiments are conducted on an extended scale, the results will be more uniform in character and more comparable one with another than were any other method adopted, as all such either take up so much time that the specimens must, with the risk of change of weather, be collected at different times, or so many persons must be employed that the desirable surveillance is impracticable.

Having given thus far some general statement as to the manner in which our drying results have been obtained, those of our readers who understand such matters will be able to decide for what purposes our figures may be relied upon, and wherein they are likely to be wide of the exact truth. For ourselves, we are of opinion that, taken in series rather than individually, they may be trusted in discussing any points with which our general knowledge of such subjects will lead us to deal, and that they very closely represent the exact facts.

The following dry-matter results (p. 49) refer only to the produce of the third year's experiments (season 1845). The entire series is tabulated.

Were we to consider each of these results *seriatim*, with a view to trace the variations in the produce to variations in the composition of the mineral or of the organic manures, we should find numerous exceptions to any generalization to which we might thus be led. When we look, however, at extreme instances, or at series strictly comparable one with another, we cannot fail to see some undoubted general connexion between the amount of dry matter on the one hand, and such character or stage of growth as we have already observed to result from certain conditions of manuring on the other. We must be careful, however, to bear in mind the nature of the substances on which we have been operating, and the various circumstances which have been pointed out as tending to vitiate the legitimacy of any comparisons; otherwise we may place undue reliance on single results, or, finding these discrepant with others, come to the conclusion that we have no lesson taught us by so extensive and laborious a course of experiments. With our present limited knowledge, it is, moreover, desirable to exercise great caution in applying to practice the indications of results of this kind.

It must be remembered, then, that the turnip plant cultivated as food for stock is gathered at no well-defined stage of its growth, but whilst containing a vast amount of circulating fluid, the proportion and concentration of which is subject to constant variation under the influence of the still active vital processes of the plant, the varying stores of moisture and of food presented to the roots, and the circumstances of temperature, light, and moisture of the atmosphere, to which the leaves are exposed. In fact, we might liken the growing turnip to an animal whose gross composition would vary according to his resources of food and drink, and the condition of exhaustion or waste to which he is exposed. At one time his stomach and blood-vessels are full, and at another their contents bear a much lessened relation to the more fixed portion of the body.

The water existing in the Norfolk-white turnip-bulb is seen to constitute more than nine-tenths of its entire weight; and if it should appear that the proportion varies according to the stage of growth, it will be admitted that the degree of maturity of a succulent plant which is to be the subject of a drying experiment, must be regarded, in deciding its probable yield of solid food, as resulting from various manures; for if the amount of water is found to decrease accordingly as the plant matures, that one which

TABLE showing the Percentage of DRY MATTER in Specimens of Turnip Bulb, grown by various Manures. Season 1845.

Plot Numbers.	DESCRIPTION OF DRILLED MANURE.	Drilled Manures only.	Drilled Manures, and Top Dressing of Rape-cake.	Drilled Manures, and Top Dressing of Ammoniacal Salt.	Drilled Manures, and Top Dressing of Rape-cake and Ammoniacal Salt.
1	12 tons farm-yard dung, ridged in; no drilled manures	7·83	7·92	7·30	8·86
2	Unmanured	...	8·68	8·71	8·29
3	8 cwts. rape-cake	7·80	7·38	7·77	7·92
4	130 lbs. calcined bone-dust, 130 lbs. sulphate of ammonia, 130 lbs. hydrochloric acid	8·20	7·66	7·71	7·55
5	160 lbs. superphosphate of lime, 130 lbs. sulphate of ammonia	8·77	7·95	7·64	7·73
6	160 lbs. superphosphate of lime, 5 cwts. train oil	8·41	8·26	7·92	7·50
7	12 cwt. sulphate of lime	8·56	8·00	8·05	8·00
8	400 lbs. calcined bone-dust	8·71	8·57	7·77	7·83
9	400 lbs. calcined bone-dust, hydrochloric acid equivalent to 268 lbs. of sulphuric acid (sp. gr. 1·70)	8·24	8·87	7·50	8·42
10	400 lbs. calcined bone-dust, 134 lbs. sulphuric acid	8·11	8·65	7·46	7·70
11	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid	8·03	7·67	7·41	7·59
12	11 cwts. superphosphate of lime (land dug 9 inches deep in 1844)	8·71	8·19	7·29	7·61
13	400 lbs. calcined bone-dust, 268 lbs. sulphuric acid, 134 lbs. common salt ...	7·77	7·41	6·65	6·77
14	11 cwts. superphosphate of lime (land trenched 18 inches deep in 1844)	9·30	7·26	6·92	7·08
15	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 315 lbs. soda ash	8·23	7·14	7·41	7·33
16	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 220 lbs. magnesian limestone	8·69	7·61	8·20	7·22
17	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 470 lbs. pearlash	8·27	8·49	7·27	7·79
18	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 105 lbs. soda ash, 74 lbs. magnesian limestone, 157 lbs. pearlash	7·95	8·36	7·42	7·77
19	As No. 18, with 1 cwt. sulphate of ammonia	7·83	7·69	7·45	6·89
20	As No. 18, with 3 cwts. rape-cake...	6·98	7·64	7·95	6·86
21	400 lbs. calcined bone-dust, 400 lbs. sulphuric acid	8·13	7·58	7·64	6·77
22	11 cwts. superphosphate of lime...	8·24	7·83	7·36	7·38
	Mean Results	8·22	7·95	7·60	7·58

after an equal period of growth is found to contain most water would, conditionally, indicate a more extended further growth, and the manure under which it had grown might be better rather than worse than that to which the more solid turnip owed its character. Again; a series of plots under different manures, though they will be characterized by an undoubted difference in the stage of maturity of the plant, will each within itself exhibit a wide range of variation in this respect, and it is impracticable to gather specimens which shall certainly and exactly represent the characters induced by the manuring of the plots. In our experiments, from ten to twenty plants of average size, and which appear to be sound and firm, are selected from each plot, and from these, when washed and sliced, a weighed quantity is taken; in some cases 100 oz., and in some 150 oz.; in some more, and in some less. The results given in the table were obtained from specimen lots of 150 oz. each, and the soil, season, variety of turnip, and time of sowing and gathering, were the same throughout.*

From these remarks, our readers will be able to judge for themselves whether too much or too little is based upon our results. We feel, however, that it will be much more conducive to the interests of agriculture that the error should be in the latter rather than in the former direction.

The following mean results exhibit the general bearings of the experiments more clearly and safely than individual selections would do:—

Description of Drilled Manures.	Dry Matter, per cent.			
	Drilled Manures only.	Drilled Manures, and Top-dressing of Rape-cake.	Drilled Manures, and Top-dressing of Amm. Salt.	Drilled Manures, and Top-dressing of Rape-cake and Amm. Salt.
Mean of 13 purely mineral manures...	8·34	7·97	7·41	7·48
Mean of 4 experiments with alkaline phosphates	8·28	7·90	7·57	7·53
Mean of 3 experiments with superphosphate of lime	8·09	7·97	7·50	7·35

These means show a striking uniformity in the amount of dry matter in each column taken separately,—that is, under the influence of various mineral manures, but a like resource for organic formations. Comparing column with column, however, we find a difference which, though not actually great, must be admitted to have some meaning, when we bear in mind the uniformity within the columns themselves. Were we to compare these

* The conditions of manuring alone were different, and we may therefore rely upon the general indications of the experiments, so far as the effects of manures are concerned.

effects of organic supply upon the percentage of dry matter with those of the same conditions upon the average acreage produce, no correspondence, either direct or inverse, would be clearly defined; for we see in the table just given a pretty uniform depreciation from the first column to the third, and the fourth is not wide of the third, but the acreage amounts of produce were as under:—

Average Acreage Produce of Bulb, in tons, cwts., qrs., and lbs.

Drilled Manures only.	Drilled Manures, and Top-dressing of Rape-cake.	Drilled Manures, and Top-dressing of Amm. Salt.	Drilled Manures, and Top-dressing of Rape-cake and Amm. Salt.
Tons. cwts. qrs. lbs. 12 8 2 3	Tons. cwts. qrs. lbs. 13 4 2 20	Tons. cwts. qrs. lbs. 11 18 1 24	Tons. cwts. qrs. lbs. 11 6 1 11

We have before stated, that at the time of the first gathering of the crops, a short time prior to which the specimens for analysis were taken, the plants growing by purely mineral manures were very markedly the *ripest*, their leaves having much drooped; next in order, in this respect, came those having rape-cake in addition; then those having sulphate of ammonia; and, lastly, those with both rape-cake and ammoniacal salt. The proportion of leaf to bulb at the time of weighing shows this to some extent. It was as under:—

	Drilled Manures only.	Drilled Manures, and Top-dressing of Rape-cake.	Drilled Manures, and Top-dressing of Amm. Salt.	Drilled Manures and Top dressing of Rape-cake and Amm. Salt.
Proportion of leaf to 1000 of bulb	326	421	559	669
Mean percentage of dry matter...	8·34	7·97	7·41	7·48

We have, then, the largest amount of dry matter with the ripest bulb and poorest supply of organic manure, very nearly the smallest amount of dry matter with the plants least advanced to the point of heaviest bulb, but which had the largest stores of food in the soil, and probably the prospect of the longest life and fullest eventual growth, at least of entire plant, if not of bulb itself. The second weighing of the crops did indeed show in this case an increase in bulb and a decline in the proportion of leaf to bulb. Here, then, the influence of manures is indirect; for the proportion of dry matter is seen to be mainly dependent upon the degree of maturity of the plant,—and that this is affected by manures has been already shown; and since the largest proportion of dry matter may show an early advanced stage of maturity, frequently arising from an exhaustion of the materials of growth, it may in fact bespeak the worst manuring condition, all other circumstances being equal. It is evident then, that, even supposing the percentage of dry matter to be an unconditional measure of the feeding value of any particular specimens, no comparison could be drawn respecting the efficiency of the manures by which they were grown, unless every other condition, whether of season, soil, maturity, or variety, were considered in their influence; and then, indeed, the effects of the manures may be due to a forcing rather than to a supporting power. We shall have further proof, however, that the amount of water existing in the turnip depends upon the proportion of circulatory to the more fixed matter, and that as the plant matures that of the former diminishes and that of the latter increases; and it will also be seen that equal weights of dry matter may differ very greatly in probable nutritive value.

Before leaving the results of the table, we may observe that by this series of nearly 100 different manures, the utmost variation in the proportion of dry matter in the Norfolk-white turnip-bulb is, after an equal period of time, 2·65, or about 2½ per cent., notwithstanding that there was a vast difference in the stage of maturity of the plants; and it is thought that if the specimens could have been taken each at the point of its fullest growth, the variation strictly dependent on manures would have been much less. The highest percentage of dry matter in the entire series is 9·3,—all the rest are below 9, more than half below 8, and several below 7; the limit of difference, even under the actual circumstances, is, however, in by far the larger number of cases within 1 per cent. Boussingault gives 7·58 per cent., which agrees pretty well with our determinations, the mean of which is 7·83; other observers having found a range in the proportion of dry matter of the turnip-bulb from this amount to nearly double, have attributed much of the variation to the conditions of manuring; but the foregoing facts, in conjunction with those we shall now state, will show that no judgment of the effects of manures in this respect can be formed unless the experiments are made with the same variety of the plant.

The specimens here referred to were grown in different fields, and by different manures, and several of them in the ordinary course of the farm. The 90 lots of experimental Norfolk-whites give a number for the mean percentage of dry matter identical with that found under farm-yard dung, and their extreme variation is 2·65. The two specimens of green common turnips show the same amount of dry matter with a difference of manuring. The various swedes again differ considerably from one another, yet in a greater degree from the common turnips. The extreme variation in the entire series quoted is from 6·65 in the Norfolk-

Description of Turnips.	Percentage of Dry Matter in Turnip Bulbs.
Norfolk White (lowest of experimental series)	6·65
„ „ (highest of experimental series)	9·30
„ „ (mean of experimental series)	7·83
„ „ by farm-yard dung in experimental series	7·83
Green common turnip, by farm-yard dung	7·94
„ „ by superphosphate of lime	7·94
Swede, Skirving's green top	9·04
„ „ purple top	9·61
„ purple top (old variety, name unknown)	12·25

whites to 12·25 in the purple-topped swede, or more than 5½ per cent.; but there is little doubt that it is dependent on the variety of plant, rather than upon any effects of manure or culture.

As a general inference from our results, we may state that the mineral and carbonaceous manures, which we have before seen to favour bulb-formation,—that is, to determine to an early maturity, are those which in a given time will yield the largest percentage of dry matter in the bulb; but nitrogenous manures, on the other hand, which when in excess do not enhance bulb-formation (a process of deposition), but rather an extension of the leaf or more vascular system of the plant, involving a prolonged tendency to active circulation, and consequently a higher amount of vehicular watery fluid in proportion to fixed substance, will afford a smaller percentage of dry matter in the produced bulb.

Were we, assuming bulb-formation to succeed leaf-formation, to judge from some analogy furnished by other plants, we might expect that the earlier organ, the leaf, would contain a less percentage of dry matter than the later one, the bulb; but inasmuch as the dry matter is frequently about twice as great in the former as in the latter, any such reasoning would imply a wrong conception of the physiological relationship of the two organs.

We regret that the entire series of leaves of this 3rd year of our experiments was not collected for drying, and that indeed none were taken until after the first weighing of the crops, a few weeks later than the specimen-bulbs were gathered. We shall not, therefore, employ the results for any more important purpose than to show how far the effects of manures are the same in kind as in the case of the bulbs, determining to the *depositing* or to the more *circulatory* tendencies of growth.

Here again we find no considerable variation, yet sufficient in amount and in uniformity to render the mean results reliable for our present purpose. The plants by mineral manures alone, in the first column, which were the furthest advanced in maturation

PERCENTAGE of Dry Matter in Norfolk White Turnip Leaf.

Plot Numbers.	Description of Drilled Manures.	Drilled Manures only.	Drilled Manures, and Top-dressing of Sulph. Am.	Drilled Manures, and Top-dressing of Rape-cake and Sulph. Ammonia.
9	400 lbs. calcined bone-dust, hydrochloric acid = 268 lbs. sulphuric acid	13·63	13·23	12·57
14	11 cwts. superphosphate of lime (land trenched 18 inches deep in 1844)	13·93	13·19	12·74
18	400 lbs. calcined bone-dust, 420 lbs. sulphuric acid, 105 lbs. soda ash, 74 lbs. magnesian limestone, and 157 lbs. pearlash	13·79	13·48	13·46
21	400 lbs. calcined bone-dust, and 400 lbs. sulphuric acid	13·33	13·12	12·68
22	11 cwts. superphosphate of lime	13·97	13·55	12·91
	Mean Results	13·73	13·31	12·87

(or almost past that point), give the highest percentage of dry matter in the leaf as well as in the bulb. Those under the addition of ammoniacal salt give in the leaf a percentage uniformly, but not so far relatively lower as in the case of the bulbs; but it must be remembered that the leaves were gathered much later, and indeed, when, in these cases as well as in those by the purely mineral manures, the point of maturity and exhaustion of soil-supplies for organic food had been approached, or passed. We find again that the more vigorous plants under both rape-cake and ammoniacal salt have, coincidently with the greater prevalence of vascular action, a less percentage of dry matter.

Whilst we are writing, the specimens of the present season's growth are being operated upon in the drying bath, but as we have not given any account of our experiments since 1845, we need only say that succeeding results indicate the same general facts on the subject of dry matter as those to which we have drawn attention.

Having argued that, supposing the dry matter in the turnip were of uniform composition, a high percentage can only indicate the amount of solid substance in a given amount of produce at the period of growth at which the determination is made, and does not by any means unconditionally show the efficiency of the manures employed, we shall turn our attention to the composition of the dry substance itself. It has been stated that dry vegetable produce contains the so-called *vegetable* or "*organic*" constituents, and the "*mineral*" or "*inorganic*," the latter being that portion which remains after the former is burnt away.

We shall first speak of the composition of the organic or vegetable part of the turnip, and shall endeavour to show its dependence on the manures by which the plant is grown, and the probable relative feeding values of different specimens.

We do not pretend to have reached further than the threshold of this inquiry, but still hope our results may furnish some interesting inferences. The organic matter of the turnip-bulb is composed of several complex bodies, some of which consist of carbon, hydrogen, and oxygen, whilst others contain nitrogen in addition to the other three elements. Other substances, such as sulphur and phosphorus, are also found in these compounds, but in small quantities, and their presence or absence is immaterial to us just now.

Those of the compounds which contain nitrogen are in less proportion in plants than those in which it is absent; but nitrogen is a very important constituent in all food, so much so indeed that the comparative feeding value of different articles of produce may frequently be estimated by the amount of nitrogen they contain; and we shall, to some extent, act upon this assumption in what we are about to detail.

Those who have read the paper on Agricultural Chemistry in the last number of this Journal, will bear in mind the remarkable fact there indicated, that the larger the amount of the nitrogen supplied by manure for the growth of wheat, the less was the percentage of that substance in the produced grain. This is not consistent with the views generally maintained on this subject, but it seemed to us not only sufficiently proved by our experiments—but, when it was remembered that wheat-grain was peculiarly a *starchy* seed, and that starch contains no nitrogen, it was thought that whatever tended to the healthy action of the plant (as nitrogenous manures were found to do) would of necessity develop the special aim and products of the plant, and that in fact it was more natural to expect that the seed would under these circumstances be more *starchy* than that it would be more nitrogenous and less starchy. In growing *wheat-grain*, then, by means of *nitrogenous* manures the *percentage* of nitrogen in the produce was rather diminished than increased. The following results will show whether a similar effect is observed in the growth of turnip-bulbs:—

This is not the place to give any detailed account of our methods of analysis, but we may say that we think considerable confidence may be placed in the results, as a comparative series; and we believe them to be, moreover, not wide of the exact truth. If we had to give an opinion, however, as to the probable direction and extent of any error, we should suspect it to be in defect rather than in excess, and that if it exist it is pretty uniform throughout

PERCENTAGES of Nitrogen in Dry Turnip Bulbs, the produce of different Manures.

Plot Numbers.	Description of Drilled Manures.	Drilled Manures only.	Drilled Manures, and Top-dressing of Rape-cake.	Drilled Manures, and Top-dressing of Amm. Salt.	Drilled Manures, and Top-dressing of Rape-cake and Amm. Salt.
9	400 lbs. calcined bone-dust, hydrochloric acid = 268 lbs. sulphuric acid	1·46	1·93	2·82	2·22
22	11 cwts. superphosphate of lime	1·58	1·89	2·89	2·44
	Mean Results	1·52	1·91	2·86	2·33

the series; that its probable extent is 0·10, and its utmost range 0·20. Should such general deficiency pervade our results, it is dependent partly on the fact that succulent specimens cannot be fully dried in air at 212° without some loss of nitrogen, and in part also upon certain practical difficulties attending the conduct of the determination of nitrogen in substances in which the actual percentage is so small as in the instances before us. We may add that each of the results given in this paper is the mean of two determinations at least, and when there has been a difference of 0·10 a third has always been made.

Referring to the results of the table, and taking the columns separately, we see a very marked coincidence between the figures in each, and as marked a contrast between column and column; and if we call to mind the peculiarities of the several organic conditions of manuring, we shall see the influence of the nitrogenous supply to be exactly opposite to that observed in the case of wheat-grain, and in fact that the percentage of nitrogen in the turnip-bulb bears a direct instead of an inverse relation to the predominance of that substance in the manure.

Thus, in the instances quoted, the percentage of nitrogen in the dry substance of the produced bulb is by mineral manures alone 1·52; by the addition of rape-cake, which contains, besides a large amount of carbon, a considerable quantity of nitrogen, we have 1·91 per cent.; by ammoniacal salts, supplying abundance of nitrogen, but no carbon, 2·86 per cent.; and when to this exclusive nitrogenous supply rape-cake is superadded, we have 2·33 per cent. There is here seen, then, very evident connexion between the percentage of nitrogen in the substance of the bulb, and the supply of it in the manures employed. It is worthy of remark, however, that it is not the actual acreage quantity of nitrogen, but its proportion to other constituents that is so clearly indicated. Thus, in the third column, with an acreage supply of

about 60 lbs. of nitrogen by manure, we have a percentage of 2·86 in the dry matter of the produced bulb, whilst in the fourth column, with a supply of about 110 lbs. per acre, we have only 2·33 per cent.; but when we remember that in the latter case there was a large amount of carbon in the manure, and in the former none, we have a clear illustration of the close connexion between the provision by manure and the composition of the produce. To render our meaning more intelligible we may further explain that the nitrogen in the turnip, and indeed in food-products generally, exists in combination with carbon, hydrogen, and oxygen, itself comprising nearly one-sixth part of the thus constituted nitrogenous compound; the remainder of the dry matter consists of the compounds destitute of nitrogen, of which the chief constituent is carbon. Now in column 3 there was no carbon in the manure, but in column 4 a large amount was provided in the rape-cake, and notwithstanding that there was in this case not only the same amount of nitrogen supplied by ammonia salt as in column 3, but further, all that of the rape-cake, raising the total amount to nearly double, yet the supply at the same time of carbon, favouring the formation of non-nitrogenous compounds, gives a less proportion of those which are nitrogenous.

Again, if we compare the mean of these results with the mean percentage of dry matter under the four conditions of manuring, we find with the lowest percentage of nitrogen in the bulb the largest amount of dry matter, and with the highest percentage of nitrogen, the lowest amount of dry matter. There is then with the highest percentage of nitrogen more of circulating fluid and less of fixed deposited substance than with the lowest; and since there was, moreover, not only a less matured bulb, but a less acreage produce of it in a given time than where the nitrogenous supply was less, we are led to infer that the high percentage of nitrogen indicates a relative deficiency of carbonaceous substance, rather than a favourably increased amount of nitrogen. Indeed, these results will confirm the opinion already urged, namely, that turnip-bulb formation is very dependent on an abundant supply of *carbonaceous matter to the roots*, and that the more the nitrogenous condition of manuring prevails over the carbonaceous, the more will vascularity and the less will special deposition be enhanced. Thus the highly vascular seed-forming turnip-plant is to the less vascular bulb-forming one, as the well-conditioned breeding or working animal is to the stall-fed fattening one; a considerable amount of nitrogenous as well as carbonaceous food is essential to both of these; in the one case, however, exercise tends to consume what in the other increases the bulk of the animal: so that whilst the food taken may indeed in the two cases be very similar, yet the balance of it retained in the animal will be as different as, in the cases of the two plants, is attained by more directly varying the supply, and the peculiar habits of life and growth will be developed accordingly.

The following results further show how truly dependent is the composition of the turnip-bulb upon the provision by manure:—

Percentages of Nitrogen in the Dry Matter of Turnip Bulbs, the produce of different Manures.

Plot Numbers.	Conditions of Standard Manuring.	Standard Manures only.	Standard Manures, and Top-dressing of Rape-cake	Standard Manures, and Top-dressing of Amm. Salt.	Standard Manures, and Top-dressing of Rape-cake and Amm. Salt.
1	12 tons farm-yard dung	1·56	...	2·54	...
2	Unmanured	3·31	2·17	2·98	2·53
3	8 cwts. rape-cake	2·23	2·79	2·80	3·00

We see that the percentage of nitrogen by farm-yard dung is 1·56, which differs little from either the results obtained by mineral manures alone, when all the organic supply was derived from normal sources, or from the number observed by Boussingault, which was 1·70. The addition of sulphate of ammonia to the farm-yard dung, raises the percentage of nitrogen in the bulb from 1·56 to 2·54, or by two-thirds of the usually observed amount. Here, however, we have in the manure a large provision of carbonaceous matter, and, as before noticed, a coincidently less percentage of nitrogen than when there was ammoniacal salt alone.

In the second line of the table we have some most interesting results, consistent with what have gone before, and, further, affording a new and significant illustration of the office of the turnip as a *fallow-crop*.

It will be recollected that the average weight of the bulbs on the unmanured plot was, in this season of 1845, less than 2 oz., and that the entire produce was only 13½ cwts. per acre. We find, however, that these stunted bulbs give a percentage of nitrogen higher than any in our series, even than those which had an unusually excessive supply by manure, and twice as high as the amount supposed generally to exist in the cultivated bulb. We may reasonably infer that, under the influence of season and a soil reduced to the lowest conceivable state of exhaustion, as regards its fitness for the growth of the cultivated turnip, the natural supply of nitrogen was, in proportion to that of other constituents, abundantly available to the special accumulative powers of the plant. In the same line we find, in the second column,

that the supply of a top-dressing of rape-cake to this otherwise exhausted plot, raises the acreage produce of bulb from 13½ cwts. to 7½ tons, and the average weight of bulb from less than 2 to nearly 11 oz., and notwithstanding the nitrogenous supply of the rape-cake, we have, with its large provision of carbonaceous substance, the percentage of nitrogen reduced from 3·31 to 2·17. In the 3rd column, where there is added to the natural supplies of soil and season nitrogen, but *no* carbon, we had an evidently unhealthy condition; for the acreage produce, the size of bulb, and the number of plants, were all less than where there was no manure whatever. Again, with these unfavourable circumstances of growth we have a very large percentage of nitrogen; less, indeed, than in the unmanured bulbs, but considerably higher than when rape-cake alone was used. In the 4th column we have the same supply by manure of carbon and nitrogen as in column 2, with the addition, however, of the nitrogen as in column 3, and we find, as in other cases, that although the actual supply of nitrogen is greater than in column 3, it being proportionably less, the percentage in the bulb is reduced.

In the third line the standard manure is rape-cake, the extra dressings being, as usual, a further addition of rape-cake, of ammoniacal salt, or of both. Comparing the percentage of nitrogen by the drilled rape-cake, as in column 1, with that by farm-yard dung, we find that the rape-cake gives the highest, and we would suppose the proportion of nitrogen to carbon would be greater. In column 2 the amount of rape-cake being greater, the percentage of nitrogen is greater: the *supply* of nitrogen to that of carbon is not, however, greater than in column 1; but we have before seen that a full quantity of rape-cake, without extra mineral manure, is not conducive to the most healthy growth of the turnip-bulb; nor indeed would the carbon so supplied be so completely and rapidly available as the nitrogen. The addition of ammoniacal salt, in column 3, raises the percentage of nitrogen from 2·23 to 2·80, and in column 4, as compared with column 2, from 2·79 to 3·00.

We have made other determinations of nitrogen in turnip-bulb, with a view to some more special points, but as we cannot discuss them in this paper without extending our remarks to an undue length, we shall defer notice of them until a future occasion. The results already given are, moreover, we think, sufficient to aid our estimation of the characters of the turnip as a food and rotation crop.

An important fact elicited is, that within a certain range, which indeed is wider than has generally been supposed, the organic composition of the turnip bears a very direct relation to that of the manures by which it is grown. It is seen that the proportion of nitrogen usually found in the cultivated turnip-bulb may be nearly doubled by means of ammoniacal manures, and since we have stated that the feeding value of a crop may to some extent be measured by its percentage of nitrogen, it might be supposed that we should be led strongly to advocate the use of such manures in the growth of the turnip. Our field experiments have already shown, however, that this would be a one-sided inference from these departmental results; and when we come to make some general application of our varied evidence to practical and economic agriculture, the true position and bearing of the different branches of the question will be indicated.

We regret that we have not as yet a sufficient number of determinations of nitrogen in the turnip leaf to enable us to decide satisfactorily whether the percentage be as clearly dependent upon the supply by manure as in the case of the bulb; the vigorous leaf being, however, highly vascular, and containing much of the still circulating unassimilated food derived from the soil, we might anticipate it would be so; but on the other hand, if we look at the bulb as a reservoir of matters which are in excess so far as the natural seed-forming tendencies are concerned, we might expect the less artificial organs, the leaves, would be more constant in their composition. The following results will not assist us much in deciding these questions; they are, however, not without interest:—

PERCENTAGE of Nitrogen in the Dry Matter of Norfolk White Turnip Leaf.

Plot Numbers.	Description of Manures.	Dried at 212°.	Specimen dried below 200°, and Nitrogen calculated upon fully dried Substance.
1	Farm-yard dung ...	3·24	3·60
2	Unmanured ...	4·22	4·35

Here are given the results obtained from specimens of leaf, in one instance dried fully at 212° in the water bath, and in another dried much below that temperature; the percentage of nitrogen in this case being calculated upon the fully desiccated substance. The fact before alluded to, that succulent specimens frequently lose nitrogen at 212°, is thus illustrated; in one instance there is a defect of 0·36, and in the other of 0·13. We have met with a similar result with other succulent substances.

It will be remembered that the turnip-leaf was found to contain a proportion of dry matter more than half as large again as the bulb; and it is seen that in the case of the dung specimen the dry

matter of the leaf has a percentage of nitrogen twice as high as that of the bulb. A given weight of the fresh leaf would therefore contain more than three times as much nitrogen as an equal amount of bulb. Since, however, the bulk of the leaves at the time the turnip crop is gathered or consumed are past the condition in which our picked specimens were taken for analysis, it would be unsafe to employ these results for purposes of acreage calculation; yet they are in other respects to be relied upon.

Comparing the characters of the cultivated with those of the uncultivated plants, as shown by the analyses which have been given, we observe the decrease by cultivation in the percentage of nitrogen in the dry matter is in the leaf only ·75, but in the bulb 1·75; from which, again, we may perhaps gather that the cultivated bulb is the result of a continued accumulation of *secreted* matters, formed in quantity beyond the essential requirements of the plant as such: the leaf, on the other hand, containing, besides its own special structures and products, little more than those substances derived from *immediate* supply,—has, therefore, a composition in a less degree varying according to the constant circumstances of growth, but comprising a larger proportion of unsecreted matter.

The fact that, notwithstanding the large nitrogenous contents of turnip-leaves, they should only be to a small extent valued as food, doubtless arises from the large amount of matters which they contain only brought within the range of the organism, themselves as yet unorganised, and existing as saline and other changeable fluids, to which we may readily attribute a medicinal and purgative, rather than a direct nutritive effect; elaboration to some extent being, as we are aware, an important element in the condition of food for animals. The low degree of stability in some of the nitrogenous contents of succulent substances, as indicated in the drying process, as well as our conceptions of the offices and physiological position of the different parts of a plant, bespeak, indeed, that where an active circulation is still proceeding, there will be found not only the actual and fixed but also the prospectively possible constituents, the latter as yet only in a vehicular condition, and little influenced by the selective and appropriate powers of the organism. It is true that the varying character of the vital apparatus of different animals adapts them to the use of vegetable food in varying degrees and states of elaboration; but there seems to be a point in this degree of elaboration below which constituents lose their food-qualities; or even, it may be doubted whether, in such cases, the matters are not really as little truly vegetable as would be the watery extract of the soil as it is taken up by the rootlets, and from the condition of which little deviation has hitherto resulted from the vital actions of the plant.

Such substances, indeed, may perhaps be considered as still belonging to the mineral kingdom, upon which animal life cannot be sustained.

Referring to the more special lesson of the experimental results last given, we notice, that whilst the leaf grown by farm-yard dung contains 3·60 per cent. of nitrogen in its dry matter, that grown without manure of any kind in a turnip-bulb exhausted soil has 4·35 per cent.; and it will be remembered the bulbs corresponding to these specimens of leaf give respectively 1·56 and 3·31 per cent. We have, then, in the leaf as well as in the bulb, a larger proportion of nitrogen in the more natural but agriculturally useless turnip than in the cultivated one; and if we are right in considering that, within certain limits, the composition of a succulent imperfectly elaborated vegetable will bear some direct relation to the supplies of food within its reach, we must conceive that there was, independently of art, a resource of nitrogen available to the uncultivated plants far beyond that of other necessary constituents. If, then, the powers of reliance upon normal supplies of nitrogen here observed are to be fully developed and turned to economical account, it is more especially by means of an artificial provision of the other constituents that this object will be attained.

We think that in these facts we have a beautiful illustration of some of the physical and physiological characters upon which depend, materially at least, the economic value of the turnip in rotation with corn. The true *economy* of alternate cropping, whilst, however, it is intimately associated with functional differences, such as we have shown to exist in the selected plants, yet depends much also upon the destination and uses of the produce, independently of which, the peculiar accumulative tendencies of the different crops could not be rendered profitably subservient. We shall not, however, consider the connexion between the various sources of the economy of a rotation of crops, until, having detailed all the evidence which it is our intention to bring forward, we come to sum up and apply our departmental results to the practice of agriculture.

We shall now give some account of the mineral substances found in the turnip. Our experimental results referring to this branch of the question are very numerous, and it was our wish to have considered them somewhat fully; but as our permitted space is already nearly exhausted, we must defer doing so until a future opportunity, and confine our remarks on this occasion to some explanation of the nature of the subject, and to indicating the general bearing of our evidence upon the conclusions which have been arrived at in the foregoing pages.

The knowledge which we at present possess of the amount, the composition, and the office of the mineral matter found in combination with the various definite organic compounds of which the solid and fixed substance of a plant is made up, is very limited; yet it is such as by no means leads us to assign to all the constituents of the ash of a crude vegetable product an essential position in the constitution either of the parts already elaborated, or of those which would result from the continued growth of the plant. It is obvious that an examination into the nature and constancy of the circumstances of growth, with which variations in the quantity and composition of plant-ashes are connected, cannot alone provide an explanation of the uses and importance of the mineral substances in the plant; it is, however, an essential step in the inquiry, and the results attained by it must materially direct and aid any collateral course of investigation.

In entering at once upon this part of our evidence, we may again state that we did not determine the amount of dry matter in the produce of the first two seasons' experiments; we are unable, therefore, to give the percentage of ash in the dry matter in the specimens of those two seasons, and it will afterwards be seen that this particular is more significant than that of the percentage in the fresh produce. On this account, and as we wish to compress our matter as much as possible, we shall not give any statement of the results of those two years, but only remark that a close examination of them affords like conclusions to those to which the third season's experiments lead us.

The percentage of ash in the fresh bulbs, the mean of the produce of each of the four conditions of manuring, frequently referred to before, are given below.

General Description of Manuring.	Percentage of Ash in Fresh Substance of "Norfolk White" Turnip Bulb.
Season 1845.—Mean of 13 experiments by purely mineral manures	0·58
Season 1845.—Mean of 13 experiments by mineral manures and rape-cake added	0·57
Season 1845.—Mean of 13 experiments by mineral manures and ammoniacal salt	0·61
Season 1845.—Mean of 13 experiments by mineral manures, and both ammoniacal salt and rape-cake	0·60

These results are the actually found percentages of ash, without any deduction for adventitious substances, such as siliceous matter and charcoal. The figures exhibit very slight differences, such as could not justify any important conclusions, were these buted to the bulb, notwithstanding its large amount of water, in some respects a higher condition of elaboration, or fixedness in its solid constituents, than to the leaf. We have, indeed, supposed that bulb formation, in the degree in which it is developed for feeding purposes, is a deposition of matter existing in quantity beyond what is *essential* to the health of the natural plant, much as depositions are known to take place in animals under somewhat analogous circumstances.

The following comparative statement of the proportion of ash in the dry matter of the leaf, the bulb, and the seed of the Norfolk White turnip, will favour the view that the composition of the bulb implies a more advanced selective process than that of leaf:—

	Leaf.	Bulb.	Seed.
Percentage of ash in the dry matter of	9·5	6·9	4·5

There is then, comparing one organ with another, as well as different specimens of the same organ, a diminution in the proportion of the mineral to the organic constituents of the plant the further we advance towards the matured results of the vital process. It is true that even in the seed the amount of mineral substances is greater than our conceptions regarding the composition of the definite compounds of which it is made up would alone have led us to anticipate; but numerous experiments with wheat grain show that, however small may be the differences exhibited in a series of specimens which can be compared with each other in this respect, yet they will indicate the less percentage of ash in the dry matter the higher the percentage of the dry matter itself—that is to say, the more completely ripening processes have been developed. An *excess* of mineral matter in any such case may to some extent therefore be owing to an increased proportion of vascular contents to perfectly elaborated substance.

Admitting that the mineral substances found in the leaves of the turnip and of other plants are such in variety and in amount that we cannot suppose them to be all destined to enter into combination, and actually to constitute a portion of the fixed and essential formations of the plants, yet their presence within it is not on that account quite inexplicable. The experiments of De Saussure and others show that the rootlets of a plant take up the dissolved substances presented to them, exercising but little of selective power, whilst such as they have is rather of a mechanical than of a more purely vital kind. It is not to be wondered at, then, that the composition of the ash of highly vascular vegetable substances should exhibit a wide range of difference, according to climate, manuring, and soil. In such cases a large proportion of

the mineral matters are distributed, not as constituents of the organised substance of the plant, but in its vessels and fluids, owing their quantity and character, to a great extent, to the external influences just referred to, but little, comparatively, to the selective processes of the organism.

The following mean results of analysis seem to show that the more the truly vital processes have been exercised, the more *special* does the composition of the mineral matter become:—

	Leaf Ash. Mean of 24 Analyses by Mr. D. Campbell.	Bulb Ash. Mean of 24 Analyses by Dr. Gilbert.
Potass	22·05	44·84
Chloride of potassium ...	4·84	0·34
Soda	0·19	1·79
Chloride of sodium	6·15	6·86
Lime	30·53	11·40
Magnesia	0·82	1·46
Phosphoric acid *	5·05	7·89
Sulphuric acid	12·55	10·63
Carbonic acid	17·82	14·79
	100·00	100·00

These results being the mean of so many analyses as twenty-four in each case, the general character of the distinctions they exhibit may be fully relied upon. It is to be regretted that we have not an actual analysis of the ash of the seed of the Norfolk White, to place by the side of those of the leaf and of the bulb. We know, however, that phosphoric acid, potass, and magnesia are eminently seed-ash constituents, and that the existence of the vehicular element, chlorine, in a *perfectly ripened* seed is doubtful. The increase in the percentage of the more special, and decrease in that of the less special constituents, is clearly shown in the results given above, as we proceed from the earlier formation to the later one, the composition of which is more influenced by the peculiar elaborative action of the organism. Of the soda salts, indeed, the actual amount is somewhat larger in the bulb than in the leaf, but their proportion to the potass ones is much less.

It has been observed that the ash analyses of green crops seem to afford confirmation of the much discussed theory of the substitution of potass by soda in plants, but that those of grain crops, on the other hand, do not serve the same purpose. It seems to us, however, that if in green and succulent substances, in which

* In the analysis of the leaf and bulb ash, the phosphoric acid is calculated from the bone-earth precipitate, taking no account of the small quantity of iron salt usually present.

there exists a considerable amount of matter admitted by the roots, with but little of special selective power, the proportions of potass and soda may vary according to the variations in the soluble contents of the soil, but the further we advance towards the ultimate results of the organism, the larger is the proportion of potass to soda; there is in such a fact evidence against the supposition that the vegetable organism can substitute the one alkali for the other, for in the case assumed soda would seem to be present only *before* the *vital* selective processes had been exercised upon the matters brought within their sphere of influence. If, then, the theory referred to suppose a replacement of potass by soda, as an actual constituent of vegetable products, we think that facts hitherto observed are such as should tend to disprove rather than to prove its validity. On the other hand, we may well believe that the large amount of mineral matters admitted into a plant, beyond that which is likely to become fixed and combined with its structures or deposits, has, nevertheless, some office to perform. We know too little, however, of the means employed by the vital processes to enable us to assign special agencies to special substances; yet the presence of mineral matters not actually to take part as constituents, is by no means improbably of essential importance in determining the changes to which the circulating juices of the plant are subject; nor is it impossible that in such an office as this soda may substitute potass, and one acid another, that is to say, as *agents*, if not as constituents. It is, indeed, only by supposing some other requirement in the plant than that of mere provision of actual constituents, that we can in any degree account, either for the extraordinary effects which a large supply of mineral substances is in some cases found to produce, or for its possession of the power by virtue of which so large an amount of such substances is taken up by its roots and distributed throughout its living organs.

It was our intention to bring forward many more results, both of the field and laboratory, relating to the important subject of root-culture, had our space permitted it. We have still eighty analyses of ashes obtained from turnips, the history of the growth of which is detailed in this paper. It would also have been advantageous to give, in less technical language, a short summary of the results arrived at in the course of these experiments, for the convenience of those readers who are more conversant with practical than with scientific agriculture. Having, however, through the kindness of the Journal Committee, already extended our article to a length beyond what is usually allotted to contributors, we must conclude with a brief explanation of the means to be employed in the pro-

fitable cultivation of roots, and of the peculiar properties which they possess, and which constitute their value as fallow-crops.

A practical farmer, accustomed to consume his turnips upon his land every fourth or fifth year, might be inclined to doubt the correctness of any conclusions drawn from a set of experiments so artificial as the removal of five successive crops of turnips from the same field. It should, therefore, be distinctly understood that the object of these experiments is not to provide any examples for direct imitation in practice, but to enable us to ascertain the real characters of season, soil, and manuring required for the growth of the turnip, in order that, the principles of its culture being better understood, the practice of it may be more economically carried out.

In our experiments upon wheat, given in the last number of this Journal, we showed that the produce of grain, beyond that which the soil and season gave in successive years, was dependent upon the supply of nitrogen; that 100 lbs. of rape-cake, containing 5 lbs. of nitrogen and 80 to 90 lbs. of carbonaceous matter, gave no greater increase of corn than a salt of ammonia containing 5 lbs. of nitrogen and no carbonaceous matter; and that the produce from 14 tons of farm-yard dung upon the same space of ground year after year was invariably less than that which was obtained from 2 cwts. of ammoniacal salts. The farm-yard dung and rape-cake increased the produce of grain in proportion to the amount of nitrogen which they contained; but as the rape-cake contains only 5 per cent. of nitrogen, and dung, frequently not a ½ per cent., or one pound in 200, to what purpose can this bulk of carbonaceous matter be applied? As long as corn is cultivated, it is evidently of little use.

Our experiments upon turnips answer this question in a most satisfactory manner. They show distinctly that the production of turnip-bulb depends upon the supply of carbonaceous matter in the soil, and that the true office of the turnip and other root-crops consists in converting the otherwise useless refuse of our corn-crops (straw) into a succulent and nourishing food for animals. During the five years over which our turnip experiments have been carried, in only one instance has the acreage weight of bulbs reached 17 tons. We know that the mineral matter required by the turnip has not been deficient, and in many instances very large quantities of nitrogen have been supplied; but the essential substance, carbonaceous matter, required for bulb-formation, has been but moderately supplied in the form of rape-cake; in one instance, where it was supplied in a larger quantity by dung, the greatest produce was obtained. Having, therefore, shown that to obtain heavy crops of bulbs, large amounts of carbonaceous matters should be supplied to the soil, and that dung is the cheapest source of this substance, the question next arises, What are the best substitutes for it?

Dung is an article in which our farm-yards are very apt to be deficient. It might be supposed that if sufficient carbonaceous matter were once accumulated upon a farm exporting only corn and meat, the loss in these two products would not be greater than would be supplied in return by the atmosphere; but the experiments of Boussingault and Dr. R. D. Thomson show that the amount of such matter respired by an animal, and therefore lost to a farm, is very great; indeed we should not be far wrong if we said that in feeding a crop of turnips by stock one-half of the carbonaceous matter in it is lost to the farm. To restore the loss of organic matter most economically, various processes are recommended: some advocate the consumption of artificial food with the turnip; some the employment of ammoniacal manures in order to collect carbon from the atmosphere; and some maintain that if the mineral substances composing the ash of the turnip were restored to the soil, it could supply itself with organic matter.

To commence with the mineral manures:—Analysis has shown that a great portion of the ash of the turnip consists of the alkalies, potass and soda, and of magnesia—and these substances have been recommended in the formation of mineral manures; we think, however, that a careful examination of the position which the turnip-crop holds in a rotation, and the manner in which its organic and inorganic matters are applied in farm practice, will show that the artificial supply of alkalies can rarely, if ever, be advocated. A fair crop of turnips would contain in leaf and bulb about one ton and a-half of dry matter, of which 250 lbs. would consist of minerals. Omitting those minerals which are of less importance to consider here, we may take the composition of the crop as follows:—

Dry organic matter	3110
Potash	127
Phosphate of lime	50
Sulphate of lime	40

Of the organic matter, more than one-half of the carbon, but probably scarcely one-fourth of the nitrogen, is lost to the farm by the respiration and increase of the stock.* The amount of phosphate of lime removed would vary greatly with the nature of the stock consuming the turnips. A breeding flock or young growing animals abstract large quantities to be employed in the production of bone, while full-grown animals require very much less. Of the alkalies contained in the ash of the turnip the stock return to the soil nearly all they take up. Barley generally follows after turnips, the greater part of the corn being taken to market. A crop of 40 bushels carries off phosphoric acid equal to about 28 lbs. of phosphate of lime, and 9 lbs. of potash. The clover following the barley, being consumed by stock, causes a further loss to the farm of organic matter and phosphate of lime, but of little or no alkalies; while the wheat grain removes about 12 lbs. of potash and 30 lbs. of phosphates.

* This *retention upon the farm, of nitrogen specially*, demands more notice than our space permits.

We see, therefore, that much of the organic matter of the turnip is lost to the farm by respiration, and the phosphate of lime largely in the formation of bone; while the export of potash is so small that the quantity contained in one acre of turnips would not be entirely exported under twenty years. It is clear, then, that unless by actual waste, there is, under an ordinary course of farming, without the use of imported food, a comparatively small decrease in the amount of available alkalies in the soil; but when we consider the vast amount of alkalies existing in the soil itself, and set free by annual decomposition, and that in every well-cultivated farm there will be a considerable quantity imported in cattle food, there can be little doubt that, under ordinary circumstances, the available alkalies accumulate in the soil. It may be further remarked, that in our experiments the alkalies, in whatever form we applied them, were always injurious to the vigorous growth of the young plant. Although the export of phosphate of lime from a farm is very much larger than that of the alkalies, the continual use of it as a manure for the turnip-crop could not be advocated upon the ground of mere exhaustion; for it could be proved that where the supply of it to the turnip-crop during successive years has been much greater than what has been removed in produce, the effects of further applications were equally successful.

We are therefore inclined to limit the economical application of mineral manures to phosphate of lime alone, and even then in most cases it is employed, not as an element of which the soil generally is deficient, but as an agent for promoting to a remarkable degree the early and vigorous development of the young plant within a limited range, and carrying it with rapidity over those stages, any delay in which is attended with great injury, and often with the destruction of the whole crop.

The sources of phosphate of lime are guano, bones, and the compound of phosphates and sulphuric acid, called superphosphate of lime. The latter manure is the form which is found to produce the greatest effect upon the young plant, and especially upon the development of a large amount of fibrous roots. Although strongly acid, it may be drilled with the seed without the slightest injury to it.

It must, however, be clearly understood that the bulk of an agricultural crop of turnips depends materially upon the amount of organic matter contained in the soil, without which the development of the power of growth by means of the phosphate will be unavailing. The first application of a mineral phosphate is liable to produce heavier crops of turnips than those which follow, unless the carbonaceous matter taken from the soil by the turnips, and lost by the respiration of the stock consuming them, has been made up by imported cattle food. Rape-cake, as containing a large amount of organic matter, is an admirable manure for the turnip as a substitute for farm-yard dung; it may be employed in conjunction with superphosphate of lime—the former being sown broadcast, and the latter drilled with the seed.

Peruvian guano, which contains a large quantity of ammonia as well as phosphates, is found to be a much more certain manure for turnips in Scotland, where the fall of rain is large, than in those parts of England where it is much less. Indeed, the natural agencies of *season* are much more favourable to the growth of turnips in Scotland and the north and west of England than in the eastern counties, where the application of skill and capital, upon a soil well suited to the plant, has gained for them a high reputation. In the south of England, and wherever the comparatively small amount of rain that falls renders the production of the turnip-crop uncertain, the cultivation of the mangold-wurzel might be extended with considerable advantage: it can be sown sufficiently early in the spring to enable it to extend its roots deep in the soil before the dry weather sets in, it is not liable to injury from insects, and it is capable of producing a larger amount of solid food than any other crop in a rotation. The objection raised against it as an exhausting crop arises partly from the small amount of produce which it yields from a given weight of manure compared with turnips; but as the percentage of dry matter is greater, the objection may not be valid. The following table shows the amount of dry matter contained in various root-crops grown this season upon Rothamsted Farm under ordinary cultivation:—

Percentage of dry matter in	Long Red Mangold-wurzel ...	12·7
,, ,,	Yellow Globe ,, ...	11·34
,, ,,	Common Swede (name unknown)	12·2
,, ,,	Skirving's Swede, purple top ...	9·4
,, ,,	,, ,, green top ...	9·4
,, ,,	Green common Turnip	7·9
,, ,,	Norfolk White	7·83

We see by this table that 10 tons of mangold-wurzel contain as much dry matter as 15 tons of white turnips, and that the difference in bulk between a crop of Skirving's, compared with one of the older sorts of swedes, is due to the difference in the proportion of the water. That the soil on this farm, although not a turnip soil, is capable of producing good root-crops, *under a proper supply of manure*, may be inferred from the fact that this year, which is anything but a good turnip season, an acre of swedes was weighed, the bulbs of which gave 20 tons 10 cwts.; number of plants per acre, 20,120; average weight, 2 lbs. 3 oz. Ten of the largest were found to weigh 112 lbs.

We found in our experiments that the usual percentage of nitrogen could be nearly doubled by the use of ammoniacal manures; but we do not recommend the general *direct* use of such manures for turnips, notwithstanding that the value of our produce as food depends much upon the percentage of nitrogen it contains.

On some future occasion we shall endeavour to show that, excepting rape-cake, the manures in the market containing nitrogen are more advantageously employed for clover, and other crops of the like kind, than in any other place in the rotation.

If a proper quantity of imported food be consumed upon a farm, the direct supply of nitrogen to the turnip crop by means of artificial manures will certainly not be necessary. An *excess* of nitrogen in the soil produces too large a proportion of leaf, and too little tendency to form bulb. It is true that a crop of turnips having a large proportion of leaf will give a larger amount of manure to the land; but its yield of food will be comparatively small. But, since the manure obtained in such a case previously existed in the soil, the economy of the crop, even so far as its manuring influence is concerned may be doubted. In fact, so far as our experiments upon this subject enable us to judge, we believe that where the supply of nitrogen to the soil is very great, the amount of it collected from the atmosphere is less, and thus a part of the benefit of the crop would be lost. All the specimens in which we found a high percentage of nitrogen were those in which there was a great development of leaf with a comparatively small tendency to form bulb; and we believe that the high percentage was due to a deficient accumulation of carbon by the plant. Whilst, then, a high percentage of nitrogen may indicate an abundance of it in the soil, the growth of the plant has been in other respects defective. It is probable that the full-grown bulb of such a plant as has only a due proportion of leaf will seldom have a percentage of nitrogen much higher than that which has been usually observed; for with an increased supply of nitrogen there is an excessive production of leaf, and a bulb which, though richer in nitrogen, is not profitably developed. There is, however, a casual advantage in having a somewhat full supply of nitrogen in the soil for those of our turnips which are to be eaten late in the season; for the plants so grown, whilst they may have a less favourable proportion of bulb, yet, owing to the increased vitality and hardiness which result from the nitrogenous manure, the bulb is better fitted to stand the winter temperature without injury. A sufficient importation of food for stock will, however, render the purchase of nitrogenous manures for the turnip crop quite unnecessary; but where such manures are employed, rape-cake will be found to afford a sufficient, and in other respects the most advantageous, means of supply.

Lastly, it must not be forgotten that the tillage of the soil constitutes a most essential element in turnip culture; and that he who sows his turnip-seed upon a badly-cultivated soil is only throwing away his time and money. The naturally light and porous nature of a *turnip soil* points out what are the requirements of these plants; and when the necessary degree of tilth has been obtained, and the seed sown, the introduction of air beneath the surface of the soil by means of the horse and hand-hoe cannot be too frequent; for it is useless to place a large amount of dung in the soil to be converted into the substance of the turnip, unless the free action of the air is provided for at the same time, by which alone the decomposition of the dung can be effected.

J. B. Lawes.

Rothamsted, November, 1847.

Note.—In placing my name to this article, I must observe that whatever merit may be assigned to it is mainly due to the skill and talents of Dr. Gilbert, upon whom the responsibility attending the investigation has devolved. Those who have endeavoured to conduct with accuracy only a few experiments in agriculture will be capable of forming some estimate of the labour which so extensive a series requires.—J. B. L.

PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
LONDON