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XXII.—*On the Growth of Wheat by the Lois Weedon System, on the Rothamsted Soil.* By J. B. Lawes, F.R.S., F.C.S., and Dr. J. H. Gilbert, F.C.S.

In the year 1849, when wheat was selling at 5*s.* per bushel, and the "*Stout British Farmer*" was complaining of the badness of the times, and felt somewhat perplexed how to pay his rent and retain a little surplus, there appeared a pamphlet entitled '*A Word in Season*,' in which the author explained his method of growing wheat year after year without manure; and he promised to those who would adopt his system and follow his directions, a profit of 4*l.*, 5*l.*, or 6*l.* per acre. Of the numerous essays which have been published on agricultural subjects of late years, few have attracted more attention than this. Commencing its career in 1849 as a pamphlet of less than twenty pages, it has since gone through edition after edition, until now, in 1856, we find the subject much extended, and presented as a book of 120 pages.

In this little book, entitled '*Lois Weedon Husbandry*,' the author, the Rev. S. Smith, goes into considerable detail not before given, as to his mode of growing root and other green crops. But confining attention for the present to *wheat*, it may be observed, that although Mr. Smith has from time to time made various important alterations in the detail of the operations by which his system is to be carried out, he has in no way deviated from his original principle of growing this crop year after year in the same field; the land being subdivided into alternate strips of crop and fallow, the portion cropped one year being fallowed the next, and so on. A great number of intelligent agriculturists have visited the Lois Weedon farm, and, after an inspection of the crops growing on the plans there adopted, have generally been satisfied that the produce has been what the published accounts had stated it to be. Yet it is somewhat singular that those who have endeavoured to follow the directions given, on other soils, have generally been unsuccessful.

The object of the present paper is to give an account of some experiments which have been in progress for several seasons past, with a view of testing the applicability to the Rothamsted soil of the system described in '*A Word in Season*.' And besides discussing the experiments themselves, we propose to consider some points of interest which the principle of the Lois Weedon system involves; for although doubts may be entertained by practical men as to the possibility of cultivating large farms on such a plan, it must still be admitted that the results which have been obtained by the Rev. Mr. Smith himself, are calculated to impress upon us most important lessons regarding the rationale of admitted agricultural facts and practices. They teach us, too, how great, in certain kinds of soil, must be at once the inherent wealth and the power of accumulation and of yielding up to the growing crop the constituents upon which it feeds.

In the year 1851 about three acres were selected for our purpose, in a field adjoining that which has been devoted for so many years to the continuous growth of wheat with and without artificial or other manures. The soil of these fields is a heavy loam, with a subsoil of stiff reddish yellow clay, which rests upon chalk. The depth from the surface to the chalk is perhaps never less than six or seven feet, and frequently twice as much ; the natural drainage is, however, good. These soils, without being of high, are still of good average quality, and capable of growing good wheat crops. They are well suited, therefore, to test the degree of applicability to other soils, of plans proposed for extensive adoption in the cultivation of that crop. The field selected was under wheat in 1850, and was a bare fallow in 1851, prior to commencing the Lois Weedon operations in the autumn of that year. For the first crop the land was ploughed and harrowed in the ordinary way, and then set out in three feet strips ; of these, every other one was sown with three rows of wheat a foot apart, and the intermediate ones were left as *fallow spaces*, to be prepared for the second year's crop during the growth of the first. It will be seen, that, as each strip was three feet wide, and as the three rows at a foot apart would only occupy two feet, there were in fact *four*-feet fallow spaces, as is recommended by Mr. Smith in some cases, instead of only three, as adopted in his own practice.

The first sowing was in September 1851, and, not having the special implements since recommended for carrying out the plan on the large scale, the seed was *dibbled* in, at a distance of two to three inches apart in the rows. One portion of the experimental ground had a single seed dropped into each hole, thus conforming, as far as possible, to Mr. Smith's mode of sowing single seeds at two to three inches apart in lines made with his presser ; another and larger portion of the plot had two seeds in each hole. It was found that the *one-seed portion* took little more than half a peck of seed per acre, that is, half a peck to the moiety of the acre seeded at one time. The Rev. Mr. Smith, however, seems always to have calculated upon two pecks of seed being used, even though sown, as above described, in single grains, at two to three inches apart in the rows. And although, where we sowed two seeds in each hole, or twice as much as is recommended, we got on little more than a peck to the acre, yet it is but justice to Mr. Smith to state, that he now finds a more liberal seeding necessary for safety and security from blight, to which, as will afterwards be seen, our produce obtained on this plan was so subject.

It may here be further mentioned, that not having the special implements—the "*presser implement*," the *drill* "*to drop seed by seed into the hard channels*," the "*roller implement*," the "*horse-hoe implement*," and the "*scarifier and harrow implement*"—which are recommended in Mr. Smith's later editions for carrying out his plan on an extensive scale, we were obliged to adopt his *earlier* methods, by which, however, his records show, that he obtained as good, if not as economical results, as by his later ones.

Before the adaptation of special implements, Mr. Smith's plan comprised "one double digging," "two single diggings, with fork," "pressing, sowing, hoeing," &c.

The following is a concise statement of the operations carried out at Rothamsted, for each of the four crops respectively, which have been obtained in the course of this experiment. And it may here be premised, that one of the three acres was, for the sake of comparison, set apart for alternate wheat and summer fallow—the fallow being cultivated according to the common custom of the neighbourhood.

For First Crop, 1851-2:—

Wheat, harvest 1850; summer fallow 1851; ploughed, harrowed, &c., in the ordinary way, and sown with *one seed*, and *two seeds*, as above described, September 1851; hand-hoed twice, and weeded as other crops. Crop foul, poor, and much blighted; cut in August 1852.

Common fallow acre all sown autumn 1851; seed drilled at the rate of about two bushels per acre, in rows 9 inches apart; hoed and weeded as usual. Crop heavy, but somewhat blighted.

For Second Crop, 1852-3:—

The fallow intervals, which were not sown, trenched 14 to 15 inches in December 1851; forked in spring, and again before sowing; occasionally spudded, but became foul and crusted over during the summer. Seed sown as for first crop, October 1852; hoed twice, and weeded as usual. Crop not clean, poor, and blighted; cut September 1853.

Common fallow acre, all fallow in 1852-3.

For Third Crop, 1853-4:—

Stubble of harvest 1852, trenched 14 to 15 inches December 1852; forked in the spring; spudded occasionally, and again forked before sowing. Sown as above, October 1853; hoed twice, and weeded as usual. Crop pretty clean, but poor, and blighted; cut September 1854.

Common fallow acre all drilled, as before; hoed and weeded as usual. Crop very heavy, somewhat blighted.

For Fourth Crop, 1854-5:—

Stubble of harvest 1853, trenched 14 to 15 inches in winter

1853; forked in the spring; occasionally spudded, and scarified before sowing. Seed sown as usual, September 1854; twice hoed, and weeded as usual; moulded up with the plough in June. Crop clean, but poor, and blighted: cut September 1855.

Half only, of common fallow acre, drilled as usual for season 1854-5; hoed and weeded as usual. Crop small, but much less blighted than before.

In the following Table (I.) are given the results—

Of the four years' trial of the Lois Weedon plan; one portion with "*one seed*," and another with "*two seeds*," in each hole.

Of the "*common fallow*" acre, drilled with about two bushels of seed per acre.

And, for the sake of comparison, the produce in each of the four years, of the continuously unmanured and continuously cropped portion, in the adjoining experimental field.

This Table (I.) shows, that in each of the four years a larger crop was obtained where *two seeds* were sown in each hole than where *one* only was sown; and a reference to the weight per bushel, proportion of offal corn, and proportion of corn to straw, will show that the "*two-seed*" crop was also invariably somewhat better as to quality. As before observed, however, it is only due to the Rev. Mr. Smith to say, that "*for the sake of the sample and for safety sake*," he now recommends the seed to be sown thicker than he did formerly; though even in the later editions of the '*Word in Season*,' he still advised that the seed should be dropped singly, at two to three inches apart in the rows. But, even with the *two seeds*, the crop is in every case quite insignificant; and it should be noticed that it is only in the first year—that is, before the subsoil was brought up—that this thin dibbled crop was larger than the comparatively thickly drilled one on the continuously cropped and continuously unmanured plot in the adjoining field. Further, comparing the best of the two, namely the *two-seed* crop, with the drilled one after common fallow, we find that the latter in each year gives from twice to thrice the amount of produce of the former.

With regard to the drilled crop on the common fallow, it should be remarked that, in the first season (1851-2), the whole acre was sown; in the second season the whole acre was fallow; and in the third the whole was again sown. But, as this plan only gave a crop for comparison every other year, the plot was divided into two portions after the harvest of 1854, which were to be cropped or fallowed alternately. Comparing together the produce of this *common fallow portion*, with that of the *continuously unmanured plot* in the adjoining field, we see that, in 1852, the common fallow gives nearly three times the most produce; in 1854 it gives rather

TABLE I.—Results of Experiments on the Growth of Wheat at Rothamsted, on the Lois Weedon, compared with other Systems. Harvests 1852, 1853, 1854, and 1855.

Seasons.	Description of Plots, &c.		Particulars of Quantity.					Particulars of Quality.		
			Dressed Corn per acre in Bushels, Pecks, &c.	Dressed Corn per acre in lbs.	Offal Corn per acre in lbs.	Straw, Chaff, &c. per acre in lbs.	Total Produce per acre in lbs.	Weight per Bushel in lbs. and tenths.	Proportion of Offal Corn to Dressed as 100.	Proportion of Corn to 100 Straw.
1851-2.	1 First Year (after Common Fallow)	"One seed"	10 0½	515	135½	1866	2516	51·0	26·3	34·8
	2 First Year (after Common Fallow)	"Two seeds" ..	15 2½	795	175	2309	3279	51·0	22·6	42·1
	3 First Year (after Common Fallow)	Drilled	37 0	1901	187	4934	7022	53·0	9·8	42·3
	Adjoining Experimental Field	Continuously unmanured ..	13 3¼	782	77¾	1597	2457	56·6	9·9	53·9
1852-3.	1 Trenched, Forked, &c.	"One seed"	4 0¼	211	48½	796	1055	52·0	20·6	32·0
	2 Trenched, Forked, &c.	"Two seeds" ..	5 1	275	46¼	941	1262	52·6	17·5	34·5
	3 Common Fallow	(No crop)	..	..	..	..	..	..	..	..
	Adjoining Experimental Field	Continuously unmanured ..	5 3¼	266	93	1413	1772	45·9	35·0	25·4
1853-4.	1 Trenched, Forked, &c.	"One seed"	11 1	661	56	1078	1795	58·6	8·5	66·5
	2 Trenched, Forked, &c.	"Two seeds"	14 2¼	868	48	1368	2284	59·5	5·5	67·0
	3 Common Fallow	Drilled	42 0	2541	168	4545	7254	60·5	6·6	59·6
	Adjoining Experimental Field	Continuously unmanured ..	21 0¼	1277	82	2137	3496	60·6	6·4	63·6
1854-5.	1 Trenched, Forked, &c.	"One seed"	4 3¾	264	63¼	696	1023	53·0	23·9	47·1
	2 Trenched, Forked, &c.	"Two seeds"	6 1¾	350	69	803	1222	54·4	20·0	52·2
	3 After Wheat	Drilled	17 1½	1006	74½	1734	2814	57·8	7·4	62·3
	Adjoining Experimental Field	Continuously unmanured ..	17 0	1007	65¾	1787	2860	59·2	6·5	60·0

more than twice as much; and, as we shall see in the next Table, in 1856, it gave once and a half as much as the continuously cropped and continuously unmanured plot.

In contrast to these very marked effects of *fallow*, it is interesting to observe, that when in 1855 this common fallow plot grew wheat *after wheat*, the produce was, within half a bushel of corn and within half a hundredweight of straw, the same as was obtained on the continuously unmanured plot of the adjoining field in that same season, which was the twelfth in succession of wheat on that plot. So perfect an illustration could hardly have been expected, of the fact of the equal *wheat-growing condition* to which these two adjoining fields were reduced by the growth of the crop; or, what is the same thing, of the absolutely equal condition for practical purposes, to which these two soils were brought, in relation to the climatic resources of growth of one and the same season.

Lastly, in regard to these effects of *fallow*, it may be noticed that in no case is the amount of produce found to be equal simply to the sum of the continuous unmanured produce of the season of the fallow and of that of the succeeding crop. That is to say, the *produce after fallow* is not simply the produce of that particular season, taken together with that of the immediately preceding season. It is the result, not only of the unexpended resource of the fallow year, and of the resources (atmospheric and terrestrial) of the actual season of growth, but there is also an effect of the season of growth (whether for increase or decrease), reacting itself upon a two years' resource; and consequently, throughout the season, upon a different stage of progress and area of food collectors of the growing plant. Or, the difference between the actual produce after fallow and the simple sum of the produce of the two years may further depend upon the more or less favourable adaptation of season as regards the *healthy development* of the crop, as distinguished from the *mere amount* of the available resources of the soil and seasons.

But with this very marked increase of crop as the result of the common fallow, how is it that the more expensive processes of trenching and forking, with the thinner seeding, &c., which on the soil at Lois Weedon yielded such excellent results, have on the Rothamsted soil been so ineffective?

Undoubtedly the too thin seeding has been one cause of this. It is also certain that the same amount of labour expended upon the Rothamsted soil as upon the Lois Weedon one, was quite inefficient to get the same amount of staple and of exposure of surface to atmospheric influences. It may be here stated, however, that the trenching at Rothamsted cost on the average about once and a half as much as is estimated by Mr. Smith. It is granted too, that the more recent recommendation, namely, that of moulding up the growing crop in June, was only adopted in the last year of the experiment (1855), and then with little effect. But as the earlier recorded success at Lois Weedon was obtained without this—however great the improvement, as undoubtedly it is—it certainly was not an essential in the original plan.

With these unfavourable circumstances admitted then, we again ask, what is the rationale of the failure, which these circumstances have had their share in causing? Was the available mineral food for the crop deficient in this turned-up raw clay subsoil, with the good upper staple, weathered perhaps for centuries, now turned below for the descending roots to play in? Or, was it rather that the upper staple being now buried, or much intermixed with the subsoil, there was rendered available from its own, and from fresh atmospheric resources, less of the normally atmospheric food of the crop; and that the raw subsoil, but recently exposed to direct atmospheric influences, was able, so to speak, to prepare for the plant, and to accumulate for it in an available form, also less of the normally atmospheric food of plants?

On communicating our failure after four years' trial to the Rev. Mr. Smith, he suggested the probability that it was due to a want of a sufficient amount of the *mineral* constituents of the wheat-plant being rendered soluble and available; and that, in this case, the requisite supply of mineral matter should be made up by manure; believing that then, the soil having become pulverised and porous, there would be an abundant supply of *organic* substance provided by the atmosphere.

That the soil in question was not relatively deficient in soluble and available mineral food, and that, under certain circumstances, there was provided an abundant supply of organic food for a very much larger crop, was proved much more conclusively by the produce of the common fallow acre than any analysis of the soil could prove it. To test, however, in another way, what was the nature of the deficiency of the two-acre plot, trenched to a depth of 14 to 15 inches and afterwards forked, it was, after the harvest of 1855, divided into four portions, in such a manner that each of the four had an equal proportion of the trenched and forked fallow and of the stubble ground. The whole was then ploughed and prepared for sowing in the ordinary way: one portion was left unmanured, the second received mineral manure only, the third ammoniacal salts only, and the fourth both mineral constituents and ammoniacal salts. All four of the plots, together with half of the common fallow acre by their side, were then drilled with about two bushels of seed per acre in the ordinary way.

In the following table are given the results of this experiment, obtained in the season 1855-6 just passed. For the sake of comparison, there is first given, in the *upper portion* of the table, the average annual result for the four previous years, of the "*one seed*," of the "*two seed*," and of the "*drilled common fallow*" plots; and also the average for the same years, of the continuously unmanured plot in the adjoining field. And, in the *lower portion* of the table, is given the produce at the last harvest (1856), in the adjoining field (where wheat is grown year after year without or with similar manures successively), of the continuously unmanured plot, and of the plots having the same manures as those now applied to the Lois Weedon plots. The manuring of the plots was, per acre, as under:—

1. *Unmanured.*
2. *Mineral Manures only.*

    300 lbs. sulphate of potash.
    200 ,, ,, soda.
    100 ,, ,, magnesia.
    200 ,, calcined bone.
    150 ,, sulphuric acid (brown).

3. *Ammonia Salts only.*

    200 lbs. sulphate of ammonia.
    200 ,, muriate of ammonia.

4. *Minerals and Ammoniacal Salts.*

    300 lbs. sulphate of potash.
    200 ,, ,, soda.
    100 ,, ,, magnesia.
    200 ,, calcined bone.
    150 ,, sulphuric acid (brown).
    200 ,, sulphate of ammonia.
    200 ,, muriate of ammonia.

Looking at the *middle division* of the table, which shows the effects of manures, &c., on the trenched and forked land, and also the produce on the common fallow portion, it must be borne in mind that, in point of fact, rather more than half of the former was fallow, and less than half of it under crop, in the previous year; and that, moreover, smaller amounts of produce had been taken from this than from the common fallow portion during the four previous years. In comparing, therefore, the produce now obtained by thicker sowing, manure, &c., on this land with that on the common fallow plot, we must remember that the former was also in great part fallowed, and that the whole of it was less exhausted by previous cropping than the common fallow portion. Keeping this in mind, it is seen that the unmanured, trenched, and part-fallow portion, gave within a bushel as much corn, and actually a few pounds more straw and more total produce than the

TABLE II.

	Particulars of Quantity (per acre).					Particulars of Quality.		
	Dressed Corn; in Bushels, Pecks, &c.	Dressed Corn; in lbs.	Offal Corn; in lbs.	Straw, Chaff, &c.; in lbs.	Total Produce (Corn and Straw); in lbs.	Weight per Bushel; in lbs. and tenths.	Proportion of Offal Corn to Dressed as 100.	Proportion of Corn to 100 Straw.
Lois Weedon, Common Fallow, and continuously Unmanured Plots.—Average Annual Produce, 1852, 1853, 1854, and 1855.								
1. Trenched, Forked, &c. .. "One seed"	7 2¼	413	75¾	1109	1597	53·6	19·8	45·1
2. Trenched, Forked, &c. .. "Two seeds" ..	10 1¾	572	84½	1355	2012	54·4	16·4	48·9
3. Common Fallow .. Drilled	*19 3	*1110½	*88¾	*2369¾	*3569	56·2	8·0	50·6
4. Adjoining Field .. Continuously unmanured	14 1¾	833	79¾	1733	2646	55·9	14·5	50·7
Lois Weedon Plots; with Artificial Manures, and 2 bushels of Seed Drilled.—Harvest 1856.								
1. Unmanured	21 0	1251	129	2147	3527	59·6	10·3	64·3
2. Mineral Manures only	23 2	1434	100	2431	3965	61·0	7·0	63·1
3. Ammoniacal Salts only	35 1¼	2069	188¾	3842	6100	58·6	9·1	58·8
4. Minerals and Ammoniacal Salts	41 0½	2430	133¾	4904	7468	59·1	5·5	52·3
5. Common Fallow Plot—Unmanured	21 2¾	1302	86½	2113	3501	60·0	6.6	65·7
Adjoining Experimental Field; 13th Season of Wheat year after year.—Harvest 1856.								
1. Unmanured	14 2	789	103¼	1558	2450	54·3	13·1	57·3
2. Mineral Manures only	18 3¼	1062	104¾	2012	3179	56·4	9·9	58·0
3. Ammoniacal Salts only	24 0¾	1343	162½	2818	4323	55·5	12·1	53·4
4. Minerals and Ammoniacal Salts	37 1	2159	152¼	4560	6871	58·0	7·0	50·7

* This should be the average for the four years, of what the whole acre would yield, on the supposition that only half of it was cropped each year. It is obvious, however, that as the whole acre was cropped after fallow in the first and third years, instead of half only in each of the four years, no exact comparison can be drawn. In fact, the seasons of the 2 crops after fallow were more favourable than those of the other 2 years, and hence the averages in the Table will be relatively somewhat too high for the four years of the Lois-Weedon-plan produce; though it should be remembered on the other hand, that the 4 years' produce on the Lois Weedon plan had the benefit of the previous year's fallow, and hence was the result of 5 years' resource. The following is, however, an example of the method of calculation adopted as perhaps the best under the circumstances:—

"Total Produce" of whole acre .. .. 1852 = 7,022 lbs.
" " .. .. 1854 = 7,254 "
4) 14,276 "
3,569 "

common fallow. It is evident, therefore, that the less produce on the trenched portion in the previous years, was in greater measure due to the thin seeding on the comparatively poor and raw turned-up subsoil, than to any relative deficiency or want of available condition of the food of the plant within the soil—*provided only* that a sufficiently healthy early development, and a sufficiently wide distribution of the underground feeders of the crop, were but obtained.

Taking the produce of this unmanured portion thus explained, as the standard by which to compare the effects of manures on land in the same condition, we find that—

"*Mineral manures only*"—gave an increase of not quite 2½ bushels of total corn, and of only 284 lbs. of straw.

"*Ammoniacal salts only*"—gave an increase of about 15 bushels of total corn, and of 1695 lbs. of straw.

"*Minerals and ammoniacal salts*"—gave an increase of rather more than 20 bushels of corn, and of 2757 lbs. of straw.

These striking results can leave no doubt that the *mineral* supplies in the soil in question were far in excess over the available and assimilable nitrogen. A comparison, too, of the middle and the lowest divisions of the Table will show that, if we take into consideration the very different condition of the land in the two cases, the effects of these manures on the Lois Weedon or trenched plots, were perfectly consistent in kind (though of course not equal in degree) with those of the same manures in the adjoining field, where they have been applied, and the crop has been grown, for many years in succession.

Hundreds of other experiments, and the whole range of recorded agricultural experience, conspire to show, that in ordinarily cropped and cultivated soils, the available mineral supplies are generally in excess relatively to the available supply of nitrogen of the soil and season, in the case of the wheat crop : in fact that, excepting in cases of very special and unusual exhaustion of the mineral or soil-proper constituents, the direct supply of them by manure for wheat does not increase the crop in any practicable and agricultural degree, unless there be a liberal provision of *available and assimilable nitrogen within the soil.* The results given above are a remarkable illustration of this. Thus, when the mineral constituents alone were added to this part fallow and only part crop-exhausted land, they gave an increase of only 438 lbs. of total producè; but when the same mineral constituents are added to the same soil with *ammoniacal salts*, the increase over and above that by ammoniacal salts alone is 1368 lbs., instead of only 438 lbs. Here, too, is a sufficient incidental proof that the minerals were added in an *available form ;*—indeed, that they only required sufficient available nitrogen within the soil to yield a larger crop than would be obtained in the average of seasons on such soil by the ordinary means of farming.

But turning now from the effect of the *mineral* constituents to that of *assimilable nitrogen* in manures, we have in these simple experiments the best answer—namely, that of direct contrary fact—to those who would endeavour to persuade the farmer, that because the soil itself contains hundreds of times more nitrogen than the largest crop of wheat, therefore the comparatively small quantity which is added in an ordinary dressing of manure can have little or no effect. We shall recur to the subject of the nitrogen in soils further on, should our allotted time permit it. In the mean time let it be prominently noted, that whilst the *minerals* alone gave a total increase of only 438 lbs., the *ammoniacal salts* alone gave 2573 lbs. of increase! And again, whilst the addition of minerals to ammonia gave an increase of 1368 lbs., the addition of ammonia salts to minerals, on the other hand, gave an increase of 3503 lbs.!

There can now be little difficulty in deciding, that it was no deficiency of available mineral food merely, which prevented the plant for itself, or the soil in the first instance for it, from acquiring a sufficiency of available and assimilable organic constituents for the growth of a very much larger crop than was in fact obtained from this expensively cultivated land. It was, on the other hand, notwithstanding the "inexhaustible" supplies of the atmosphere, and notwithstanding the enormous amount of nitrogen in the soil in some form—it was, notwithstanding these —a deficiency of *available and assimilable nitrogen within the soil*, which restricted the full action of the obviously available minerals, and which hence restricted the produce also, to an amount below the average of farming. Whilst, only make up this deficiency of available nitrogen, and the produce is increased to once and a half or twice as much.

It appears, then, that the same means which afforded the Rev. Mr. Smith his early success on the soil at Lois Weedon, were quite incompetent to yield a similar result on the soil at Rothamsted. Nay, these same means, notwithstanding that in our case they were much more costly than either Mr. Smith had found them, or than the common fallow which we tried by their side, did not even attain, for the Rothamsted soil, those mechanical conditions, without which the necessary action between soil and atmosphere could not be expected to take place. We think it indeed very doubtful whether, even if all the more recent improvements in the plan could have been fully carried out at Rothamsted, a result would have been obtained there at all equal to that at Lois Weedon. Certain it is, that soils and subsoils, which may equally be included as "*clayey*" or "*heavy*" or "*loamy*," vary almost infinitely in degree, in physical character and texture, and in chemical qualities, under the influence of similar management and of equal climatic circumstances. We think, therefore, that considerable caution should be exercised in the application to various descriptions of land, of plans which peculiarly rely for their success on qualities of soil which are admittedly so variable in the degree of their activity.

Leaving the question of the field-experiments, let us now turn to a brief consideration of some points of great practical interest and importance, which a careful study of the relations of soil and atmosphere to produce, and of the success at Lois Weedon, cannot fail to suggest.

The main peculiarity of the Lois Weedon system of growing wheat is, that it develops to the utmost (chiefly by mechanical means), and relies exclusively upon, the resources of the soil and atmosphere, without the aid of manure: that is to say, it is sought, by the means employed, so to increase the depth of staple, and the area of distribution of the underground feeders of the crop, and so to increase the surface annually exposed to climatic influences, as to cause, not only a greater annual liberation of mineral constituents from the otherwise locked-up stores of them in the soil itself, but also a greater accumulation and elaboration, throughout its more porous and root-searching area, of the normally atmospheric food of plants, and particularly of nitrogen, in an available and assimilable form.

The principle of relying upon the stores of the soil alone, without return, for the mineral food of successive crops, is directly opposed to that laid down for the guidance of the agriculturist in the last number of this Journal by Baron Liebig. He says:—

> "Their heavy crops will perhaps not be rendered heavier by the restoration of all the mineral constituents, but they will at all events be rendered *permanent*. We shall never have a rational agriculture until, by such experiments, the law of the fertility of the soil, in reference to time, has been brought home to the minds of agriculturists."—*Journal*, p. 313.

The conclusion of the Rev. Mr. Smith, looking from the practical as well as the scientific side of the question, goes rather in a different direction. He says to his readers:—

> "The assertion is, that, on wheat land,—that is, on the great majority of clays and heavy loams,—no manure is required for wheat on this plan, since its food in abundance is there already."—*Lois Weedon Husbandry*, pp. 102-3.

And again (ibid. 103-4), referring to chemists, he says to his readers:—

"Ask them plainly, whether the soil and subsoil of clays and loams, generally though not universally, do or do not contain all that is wanted as *mineral food* for the wheat? Ask them, further, whether tillage, and pulverisation, and gradual exposure, and annual fallows, will not render soluble a sufficiency of these substances for your annual need? If they reply, 'Yes,' but demur to the plan, and add, that in time it will exhaust the capital of the land,—ask them once more, 'In how long a time?' And if they answer, 'Why, in some cases, in a thousand years or more, in others five hundred, and in some a hundred;' your rejoinder must be a smile; for you would surely feel, that even a hundred years' supply should satisfy living man."

Baron Liebig, in the article above referred to, also indignantly repudiates the notion that the cause of the efficacy of *fallow* is to be looked for in the increase of the amount of ammonia in the soil, or that any specially predominant influence was to be ascribed to the ammonia which the soil acquires in fallow. The Rev. Mr. Smith, on the other hand, speaking of the "*organic*" food—"carbonic and nitric acid and ammonia"—asks, "do not the pulverised intervals of the wheat, in the annual fallow, absorb and retain it for use?"

It is rather curious, that, with such vital inconsistencies of principle and opinion, the wheat-growing operations and success at Lois Weedon, and Mr. Smith's interpretation of them, should frequently have been brought forward in confirmation of the peculiar views of Baron Liebig. The means by which Mr. Smith obtains his large crops of *roots* also, have recently been adduced * as refutation of the views on such points emanating from Rothamsted. But the writer in question appears, as the rule, to misstate the extent and bearing of every conclusion, and even fact, which may happen to come from Rothamsted. For our own part, careful observation and inquiry on more than one visit to the spot, as well as the perusal of Mr. Smith's publications, lead us to say, that we know of no experience more calculated to confirm the opinions we have held in this Journal regarding the requirements of growth of full crops of wheat on the one hand, and of roots on the other, than that at Lois Weedon.

But to return. The question is of vital importance to practical agriculture, however little it may interest or affect the researches of "chemists and men of science,"—what is the characteristic nature of the exhaustion induced by the growth of the most important crop of the farm? And, we may add,—whether or not soils generally, or soils of any particular class, are competent, without injury, to sustain an annual extraction of mineral constituents, and to liberate, or (either by themselves or by the plants growing on them) newly to acquire from the atmos-

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* Journal of Agriculture of the Highland and Agricultural Society of Scotland, July 1856.

phere, a sufficiency of nitrogen for full crops, in an available and assimilable form?

Certainly, if we were to rely upon the mean results of the 42 analyses referred to by Baron Liebig (in the last Number of this Journal) in illustration of the amount of nitrogen contained in soils, we should be led to conclude that many soils, at least, had enough of the mineral constituents of our crops for thousands of years, under the ordinary practices of *rotation*, and for hundreds of years of the growth of wheat on the Lois Weedon system. Almost all other published analyses of soils would lead to a similar conclusion; in fact, we know of scarcely any that would not. It must be freely confessed, however, that the methods by which soils have hitherto generally been analysed, have proved themselves, in their results, to be little fitted to afford the information for which the analyses were undertaken. Nevertheless, judging from the whole of the evidence of this kind at command, it may perhaps safely be concluded that, excepting the one constituent phosphoric acid, the greater proportion of soils which are termed "*heavy*," "*clayey*," or "*loamy*," do *contain*, within a workable depth, a sufficiency of mineral constituents for thousands, or hundreds, of years, as above supposed. It is, however, by no means so clear, that many of them would not fall short rather in *annual liberation in available form*, than in *actual percentage amount* of the necessary mineral constituents. Indeed, there is evidence enough in agricultural experience to show that, although the ordinary practice of rotation leaves, in most soils, a balance of *available* mineral constituents, and therefore demands a supply of nitrogen from without, yet, with this supply *alone*, the point of the requirement of more immediately available mineral constituents for full and healthy crops is in its turn frequently soon arrived at. In fact, it is the "*condition*," both as regards mineral and nitrogenous supplies, rather than the *actually existing* amount of them in the soil, that becomes defective. And in the lighter soils more especially it is, that the *condition* as regards the mineral constituents of our crops, or the *floating capital* so to speak, both bears a much larger proportion to the available stores of the soil itself, and is more dependent on restoration or supply from without.

In Mr. Smith's "*heavy land*," with its clayey subsoil intermixed, disintegrated, and well weathered (and perhaps even in his "*light* land," with its dressing of marl), it is quite clear, from the continued good results, that the annually available mineral supply, or the mineral *condition*, is not at present impaired; nor, so far as existing knowledge of such matters can be relied upon at all, need Mr. Smith be alarmed lest the dormant stores, at least of his heavy soil, should not last the century which, he says, should satisfy living man. And it should be borne in mind, that the resources of the soil are not to be spoken of, as some are wont to do, as sufficient for—say fifty or a hundred crops, and to be cleared off to the *zero point* at pleasure, in half or double the number, accordingly as the soil is supplied with other elements of growth. Whatever the actual stores of the soil, they are only little by little available ; and it is not easy to suppose that a heavy soil, yielding, under proper management, annually enough for large crops over a continuous series of years, does not contain a correspondingly enormous store in the dormant state. Whether, however, the same soil would annually yield an equal supply of available minerals if its surface were less exposed to weathering influences, and the required nitrogen for full crops were provided by manure, is quite another question.

But now let us turn, as briefly as possible, to a consideration of the nature of the evidence which analysis affords, of the amount of nitrogen contained in soils, and then, equally briefly, to a review of some of the circumstances which seem to have their share in the production of the large annual crops of wheat, without manure, at Lois Weedon.

As is well known, in 1843 Baron Liebig laid more stress than formerly on the sufficiency of the assimilable supplies of nitrogen in the atmosphere ; and a few years later, after having before him the analyses of a number of soils made in his laboratory by Dr. Krocker, he superadded to the argument of the inexhaustibility of the supplies of the atmosphere, that of the large amount of nitrogen contained in soils themselves, to show that little or no effect could be attributed to the small proportion which is added in an ordinary dressing of manure ; and to this he now adds, still more emphatically, in reference to fallow, that the accumulation of ammonia in the soil in one year has no influence on the crop in the succeeding year. With regard to the amount of nitrogen in the soil, we, in 1847, alluded to this point, and gave the percentage obtained by analysis of the surface-soil of the field upon which our experiments on wheat were being conducted. The necessary distinction to be drawn between the immediately available and the actually existing contents of the soil, as above referred to, was, however, too obvious to allow a moment's scepticism as to the influence of the small proportions of available nitrogen which, in our experiments, we superadded in manure. On this point, however, as it is very important to the farmer that he should be satisfied respecting it, we cannot do better than quote the replies to this argument of Baron Liebig by M. Boussingault, and by M. Kuhlmann ; to the latter of whom Baron Liebig dedicates the fuller version of his paper in the last number of this Journal, which is published as an independent work in Germany.

M. Boussingault says,—

"Latterly, M. Liebig has sought to establish that the mineral matters, the alkaline salts, are the only efficacious agents of manures, supporting this assertion by analyses which indicate in arable land, even when unmanured, a considerable proportion of ammonia; from which it has been concluded that, as the soil always contains a more than sufficient amount of nitrogenized matters, there is no necessity to supply them to it.*"

And further,—

"This alkali was determined by calcining the soil with a mixture of soda and lime. We know that, by this method, the nitrogenized substances are transformed into ammonia; but the process does not enable us to decide whether this ammonia was entirely formed in the matter examined. In fact, a soil might furnish by analysis a very large proportion of the volatile alkali, and yet we might not be justified in affirming that it contains, I will not say this alkali already formed, but even putrescible nitrogenized substances, that is to say those which are efficacious in vegetation. Thus we might extract from a soil abounding in peaty débris, from a bituminous schist, large quantities of ammonia, without, on that account, being sure of obtaining advantageous crops from such soils.

"However, it is according to the determinations of nitrogen, that M. Liebig states that a hectare of arable land, taken to a depth of 25 centimètres, contains, not the elements of ammonia, but 2000 to 10,000 kilogrammes of ammonia itself; a result presented as an objection against the necessity of the employment of nitrogenized manures. M. Kulhmann has remarked, with reason, that there is an answer to this objection in the facts themselves, and it is, that a hectare of land may contain enough of nitrogen held in stable combinations to represent as much as 10,000 kilogrammes of ammonia, and nevertheless give meagre crops, whilst, if dressed with 250 kilogrammes of ammonia in the form of manure, it will yield, after cultivation, a satisfactory produce."†

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* "Dans ces derniers temps, M. Liebig a cherché à établir que les matières minérales, les sels alcalins, sont les seuls agents efficaces des engrais, en appuyant cette assertion sur des analyses qui indiqueraient dans la terre arable, alors même qu'elle n'est pas fumée, une forte proportion d'ammoniaque; d'où l'on a conclu que le sol contenant toujours une dose plus que suffisante de matériaux azotés, il n'y a pas lieu de lui en fournir."—*Economie Rurale*, tome ii. p. 77.

† "On a dosé cet alcali en calcinant la terre avec un mélange de soude et de chaux. On sait que, par cette méthode, les substances azotées sont transformées en ammoniaque; mais le procédé ne permet pas de décider si cette ammoniaque était toute formée dans la matière examinée. En effet, une terre pourrait fournir à l'analyse une très-forte proportion d'alcali volatil, sans que pour cela on fût en droit d'affirmer qu'elle contient, je ne veux pas dire cet alcali tout constitué, mais même des substances azotées putrescibles, c'est-à-dire, efficaces dans la végétation. Ainsi, on extrairait d'un sol abondant en débris tourbeux, d'un schiste bitumineux, de fortes quantités d'ammoniaque, sans que, pour cela, on soit assuré de retirer de semblables terrains des récoltes avantageuses.

"Cependant, c'est d'après des dosages d'azote, que M. Liebig trouve qu'un hectare de terre arable, sur une profondeur de 25 centimètres, contient, non pas les élémens de l'ammoniaque, mais 2000 à 10,000 kilog. d'ammoniaque en nature, résultat présenté comme une objection contre la nécessité de l'intervention des engrais azotés. M. Kulhmann a fait remarquer, avec raison, qu'il y a à cette objection une réponse dans les faits mêmes, et c'est qu'un hectare de terre peut

M. Kuhlmann himself says,—

"Neither must the nitrogen be held in too stable combinations, as it exists in coal, the direct employment of which does not conduce to the fertilisation of the soil, but which by distillation yields a very fertilising ammoniacal liquid. Do not the same reflections apply to an objection raised against the necessity of the employment of nitrogenized manures; namely, that a hectare of land to the depth of 20 to 25 centimètres contains ammonia in quantities infinitely greater than those by means of which we seek to provide it with the elements of fertility? In my opinion, it is not sufficient that distillation should enable us to separate ammonia from the soil; it is necessary that this ammonia should be accessible to the plant without the aid of fire or of other energetic agents.

"There is moreover a reply to the objections stated above in the facts themselves; a hectare of land may contain enough of nitrogen held in stable combinations to produce 5000 or even 10,000 kilogrammes of ammonia, and yet give poor crops. If we apply to the same land 250 kilogrammes of ammonia, in the form either of ordinary manure or of pure ammoniacal salt, the fertility will be doubled.

"Agriculture is, above all, a science of facts; it is in experience that it must seek the basis of its theoretical laws." *

These, then, are the opinions of chemists as well known by their investigations in the field as by their researches in the laboratory.

Having now to record some recent determinations of nitrogen in soils made at Rothamsted, it may be well first to dwell for a moment on some of the previously published data of this kind which have been quoted by Baron Liebig. With regard to the determination of nitrogen in soils, made by Dr. Krocker in 1846, in the Giessen laboratory, it appears, by reference to the original paper (Annalen der Chemie und Pharmacie, Band 58, pp. 381-8), that he only made a single determination on each of

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contenir assez d'azote engagé dans des combinaisons stables, pour représenter jusqu'à 10,000 kilog. d'ammoniaque, et donner néanmoins des récoltes chétives, tandis que, fumé avec 250 kilog. d'ammoniaque à l'état d'engrais, il rendra, par la culture, des produits satisfaisants."—*Ibid.* p. 78.

* "Il ne faut pas non plus que l'azote soit engagé dans des combinaisons trop stables, comme cela existe pour la houille, dont l'emploi direct ne donne pas lieu à la fertilisation du sol, mais dont la distillation déplace un liquide ammoniacal très-fertilisant. Les mêmes réflexions ne s'appliquent-elles pas à une objection produite contre la nécessité de l'emploi des engrais azotés; à savoir qu'un hectare de terre à 20 ou 25 centimètres de profondeur contient des quantités d'ammoniaque infiniment supérieures à celles au moyen desquelles on cherche à lui donner des éléments de fertilité? Dans ma pensée, il ne suffit pas que la distillation permette de déplacer de l'ammoniaque de la terre, il faut que sans le secours du feu ou d'agents énergiques cette ammoniaque puisse être offerte à la plante.

"Il y a d'ailleurs à l'objection présentée ci-dessus une réponse dans les faits même. Un hectare de terre peut contenir assez d'azote engagé dans des combinaisons stables pour produire 5000 et même 10,000 kilogrammes d'ammoniaque et donner cependant des récoltes chétives. Si l'on fume cette terre avec 250 kilogrammes d'ammoniaque à l'état d'engrais ordinaire ou de sel ammoniacal pur, la fertilité sera doublée.

"L'agriculture est, avant tout, une science de faits, c'est dans l'expérience qu'elle doit chercher la base de ses lois théoriques."—*Annales de Chimie et de Physique*, vol. xx., 1847, p. 271.

the soils. We are therefore (though without calling them in question) unable to form any such judgment from the results themselves of the probable limit of error arising from manipulation and other causes, as duplicate analyses would have enabled us to do. And when it is borne in mind, that most of the published analyses show an amount of nitrogen in soils only amounting to from one-tenth to one-quarter of 1 per cent., it will easily be seen that slight errors of analysis, such as in most subjects of investigation would be quite immaterial, are here of the utmost consequence—if, at least, we should wish to discuss, by the aid of such analyses, such differences between soil and soil, or between the same soil in the conditions in which it would yield respectively a given amount of crop below a usual average, or a full one, equal to twice as much as the former. In illustration of this, we need only say that 100 lbs. of ammonia, added to an acre of soil weighing 4,000,000 lbs. (and which every intelligent farmer knows would, on most soils, increase his crop enormously), would, if well mixed with the bulk of soil, only raise its ammonia by 0·0025 *per cent.*—or 1 part in 40,000. This fact should not be lost sight of in the consideration of the figures which will shortly follow.

Next to the determinations of nitrogen in soils by Dr. Krocker, as referred to above, the most extensive series quoted by Baron Liebig is that made at the instance of the Royal College of Rural Economy in Berlin. Baron Liebig introduces these results as follows (and the italics in the second paragraph are his own):—

> "The fact of the presence of this enormous amount of nitrogen in the soil has been confirmed by the researches made at the instance of the Royal College of Rural Economy in Berlin ('Annalen der Landwirthschaft,' vol. xiv., p. 2). The College of Rural Economy caused land of apparently uniform quality to be selected in fourteen different localities in Prussia for these experiments. At ten or twelve different points of each of these fields an equal quantity of earth was taken by the spade from the entire depth of the arable soil; these portions, in each case, were thoroughly mixed, and from the mass samples were taken.
>
> "In each sample the amount of nitrogen was determined *by three different chemists separately*, and from their results have been calculated for one acre of land, to the depth of 1 foot (the specific gravity of the soil being taken at 1·5), the following quantities of nitrogen, expressed however in pounds of *ammonia* (17 lbs. of ammonia contain 14 lbs. of nitrogen)."—*Jour. Roy. Ag. Soc. Eng.*, vol. xvii., part 1, p. 285.

As these determinations are introduced to the reader by so high an authority in the matter of chemical analysis, as being made "*by three different chemists separately*," and as Baron Liebig arranges the soils in the order of their richness in nitrogen, according to the *mean* of the three experiments for each soil, it may be interesting to examine what was the sort of agreement between the results of the three experimenters on each of the fourteen soils. Accordingly there is given the following Table:—

In the upper portion, the percentages of nitrogen in each soil, as found by each of the three chemists, and calculated upon the soil dried at 100° C. (210° F.), are given. And—

In the lower portion of the Table, the calculated lbs. of ammonia per acre of 4,000,000 lbs.* of dry soil, according to the determinations of each separate experimenter, and also according to the mean of the three, are given. And in the last column are given, the lbs. per acre of ammonia for each soil as calculated by Baron Liebig.

So discrepant are the determinations of the three separate experimenters on the same soil in almost every case, that the results must be considered quite inapplicable as a means of arranging the soils according to their probable relative amounts of nitrogen. So great, indeed, is the discrepancy, that we find frequently once and a half or twice as much, and in several instances even ten times as much, recorded by one chemist as by another, for one and the same soil. In fact, in applying each of the separate analyses instead of the mean of the three, to estimate the amount of nitrogen or ammonia per acre, we find that one or two of the soils could be put both at the top and nearly at the bottom of Baron Liebig's list, accordingly as we select the determination of one or another of the experimenters; whilst in the same way, several others might be separated from one another by half the items in the list. It may even be a question, how far a judgment can be formed from such results, of the probable average or range of amount of nitrogen in the soils.

It is, however, only due to Professor Magnus, the able and conscientious reporter to the Royal College of Rural Economy in Berlin, of the analyses in which these nitrogen determinations are but items, to say that he called particular attention to the little agreement between the results of the different experimenters. In fact, his chief conclusion was, that as twenty-one of the best chemists in Germany, or of those working under the superintendence of the most distinguished chemists, had been selected, and as there could therefore be no want of technical knowledge devoted to the subject, it was obvious that in the existing state of science little was to be expected from the analysis of soils.

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* The estimate of 4,000,000 lbs. of dry soil per acre, taken to the depth of one foot, is higher than we have been accustomed to take it; but we adopt it here, not only because it is a convenient round number, but because it obviously agrees very closely with the amount supposed by Baron Liebig, with whose estimates we are comparing our own figures. It is obvious that the cubic contents, and the weight of *available* soil on an acre, must vary extremely; so that any figure adopted in an estimate of this kind must be to a great extent arbitrary.

TABLE III.—Showing the Percentage of Nitrogen, and the supposed Ammonia per Acre calculated therefrom, in 14 Soils, each Analysed by three Chemists separately.

Nitrogen per Cent. in the Soils.

	By 1st Experimenter	By 2nd Experimenter	By 3rd Experimenter	Mean.
1. Havixbec	0·591	0·081	0·400	0·357
2. Burg Wegeleben	0·432	..	0·270	0·351
3. Turgaitschen ..	0·240	0·350	0·280	0·290
4. Wollup	0·200	0·298	0·271	0·256
5. Beesdau	0·137	0·249	0·108	0·165
6. Turwe	0·140	0·130	0·173	0·148
7. Dalheim	1·609	0·150	..	0·879
8. Laasan	0·112	0·113	0·138	0·121
9. Eldena	0·090 0·120	0·120	0·113	0·111
10. Burg Bornheim	0·102	0·114	0·113	0·110
11. Neuensund ..	0·147	0·103	0·010	0·087
12. Frankenfelde ..	0·079	..	0·093	0·086
13. Neuhof	0·130	0·154	0·011	0·098
14. Cartlow	0·076	0·106	0·005	0·062

Nitrogen calculated as lbs. of Ammonia per Acre of 4,000,000 lbs. of Dry Soil.

	By 1st Experimenter	By 2nd Experimenter	By 3rd Experimenter	Mean.	Ammonia in lbs. per Acre 1 foot deep, as given by Liebig.
1. Havixbec	28,704	3,932	19,428	17,352	18,040
2. Burg Wegeleben	20,980	..	13,112	17,048	17,200
3. Turgaitschen ..	11,660	17,000	13,600	14,084	14,350
4. Wollup	9,712	14,472	13,160	12,448	13,120
5. Beesdau	6,652	12,092	5,244	7,999	7,790
6. Turwe	6,800	6,312	8,400	7,172	7,380
7. Dalheim	78,151	7,284	..	42,716	6,970
8. Laasan	5,440	5,488	6,702	5,877	5,740
9. Eldena	4,371 5,828	5,828	5,488	5,377	5,330
10. Burg Bornheim	4,954	5,537	5,488	5,328	5,330
11. Neuensund ..	7,140	5,002	485	4,211	4,510
12. Frankenfelde ..	3,837	..	4,517	4,120	4,100
13. Neuhof	6,312	7,480	534	4,774	4,920
14. Cartlow	3,691	5,148	243	3,026	2,870

Concurring fully with Professor Magnus on this point, and believing that little advance will be made without previous special investigation and adaptation of methods of analysis to this particular subject, it is only with the reservation which such a conviction implies, that we would now record or apply the determinations of nitrogen in soils recently made at Rothamsted by the current methods. We may say, however, that every precaution has been taken to secure as much of accuracy as those methods are capable of. Nor are we wanting in evidence in the results themselves, that within certain limits, and for the discussion of some points of comparately broad distinction, they are sufficiently conclusive.

In the following Table (IV.) are given the results of determinations of nitrogen—in the soil and subsoil of the plot devoted at Rothamsted to the experiments on the Lois Weedon system—in the soil of the continously unmanured plot, of the continuously mineral-manured plot, of the continuously ammonia-manured plot, and of the continuously mineral and ammonia-manured plot, in the adjoining experimental wheat-field. There are also given, the determinations of nitrogen in specimens of soil and subsoil, &c., from the Rev. Mr. Smith's experimental fields at Lois Weedon. And, for the sake of comparison with the figures in Table III. last discussed, there is given in the lower portion of the Table (IV.), the amounts of *nitrogen* (in lbs.) that would be contained in 4,000,000 lbs. (= an acre about a foot deep) of the specimens analysed—both according to the individual analyses, and to the mean result for each specimen. In the last column, the mean acreage amount of nitrogen is represented in its equivalent amount of ammonia. It is obvious, however, that no actual fact is represented by thus applying the analyses of soils and subsoils indiscriminately, to a supposed equal acreage weight of soil in each case. The figures are only useful as conveying a very general comparative idea, of about how much ammonia, or its equivalent of nitrogen, would exist in a layer of one acre area, and about a foot thick, of soils or subsoils containing a given percentage amount.

It must be remarked, too, that whilst the specimens of surface-soils at Rothamsted were each taken at eight different places, and as nearly as possible to a depth of nine inches and an area of a foot square, the whole being then well mixed and re-sampled, those at Lois Weedon were each taken at one spot only; a good spit of depth being the only condition attended to. The soils at both places were collected during the present year (1856); those at Lois Weedon in August, and most of those at Rothamsted in September.

In all cases the soils were broken up and turned over and the large stones picked out; they were then further reduced and separated from smaller stones. Finally, they were rubbed to fine powder and passed through a fine sieve, in which state they were submitted to analysis. In these processes of preparation the soils were never submitted to a temperature above 60° to 70° F., and when so prepared they generally retained less, or little

Table IV.—Showing the amounts of Nitrogen (exclusive of Nitric Acid) in Rothamsted and Lois Weedon Soils and Subsoils.

Nitrogen per Cent. in the Soils, calculated as Dry.

		Experiment 1.	Experiment 2.	Experiment 3.	Experiment 4.	Mean.
Rothamsted	Lois - Weedon - Plot Surface Soil	0·1416	0·1418	..	..	0·1417
	Lois - Weedon - Plot Subsoil	0·0730	0·0763	..	..	0·0746
Rothamsted Surface Soils, adjoining Experimental Field	Unmanured	0·1560	0·1450	0·1560	..	0·1523
	Mineral Manure ..	0·1430	0·1529	0·1420	..	0·1459
	Ammoniacal Salts ..	0·1530	0·1694	0·1620	0·1505	0·1587
	Minerals and Ammoniacal Salts ..	0·1520	0·1593	0·1545	0·1567	0·1556
Lois Weedon	Heavy Land Stubble	0·1640	0·1590	0·1670	0·1666	0·1641
	Heavy Land Fallow	0·2020	0·1940	0·2000	0·2090	0·2012
	Light Land Fallow	0·1630	0·1520	0·1510	0·1540	0·1550
	Heavy Land Subsoil	0·0661	0·0670	0·0667	0·0610	0·0652
	Light Land Subsoil	0·0840	0·0770	0·0760	0·0760	0·0782
	Marl Pit .. .. .. Light Land Field ..	0·0920	0·0890	..	..	0·0905
	Rye - grass Subsoil, with Liquid Manure Heavy Land Field	0·0790	0·0790	..	..	0·0790

Nitrogen per Acre about 1 foot deep—taken at 4,000,000 lbs. Dry Soil.

		Experiment 1.	Experiment 2.	Experiment 3.	Experiment 4.	Mean.	Lbs. *Ammonia* in 4,000,000 lbs. Dry Soil.
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Rothamsted	Lois - Weedon - Plot Surface Soil	5,664	5,672	..	..	5,668	6,882
	Lois - Weedon - Plot Subsoil	2,920	3,052	..	..	2,984	3,623
Rothamsted Surface Soils, adjoining Experimental Field	Unmanured	6,240	5,800	6,240	..	6,092	7,397
	Mineral Manure ..	5,720	6,116	5,680	..	5,836	7,086
	Ammoniacal Salts ..	6,120	6,776	6,480	6,020	6,348	7,708
	Minerals and Ammoniacal Salts ..	6,080	6,372	6,180	6,268	6,224	7,557
Lois Weedon	Heavy Land Stubble	6,560	6,360	6,680	6,664	6,564	7,970
	Heavy Land Fallow	8,080	7,760	8,000	8,360	8,048	9,772
	Light Land Fallow	6,520	6,080	6,040	6,160	6,200	7,528
	Heavy Land Subsoil	2,644	2,680	2,668	2,440	2,608	3,168
	Light Land Subsoil	3,360	3,080	3,040	3,040	3,128	3,798
	Marl Pit .. .. .. Light Land Field ..	3,680	3,560	..	..	3,620	4,396
	Rye - grass Subsoil, with Liquid Manure Heavy Land Field	3,160	3,160	..	..	3,160	3,836

more, than 5 per cent. of water separable by further drying at 212°. For convenience and uniformity, the determinations in the Table are all given as calculated upon the soil so dried at 212°; though separate portions were always employed for the determination of the moisture in this way, and those of the nitrogen were always made upon the partially and only air-dried substance.

The nitrogen determinations were made by burning with soda-lime, collecting the ammonia in hydrochloric acid, and estimating as platinum salt in the usual way. It is obvious that this method does not give that portion of nitrogen which may exist as nitric acid. But from the interesting results of Professor Way, on the power of soils to absorb ammonia and nitric acid respectively, and on the general relation of these two substances in drainage-water, it may perhaps safely be concluded that, in most ordinary soils, but a very small proportion of their contents of nitrogen will be retained as nitric acid.

The two, three, or more determinations upon each soil, were in only one or two cases made by the same analyst; two persons being employed upon the series, each, as a rule, making two determinations upon the same specimen. In this way it was hoped to eliminate any prevailing tendency to high or to low results which might attach to the work of either operator. It is probable it would be the opinion of most chemists, that the discrepancies in the percentage amounts of nitrogen which the Table exhibits, are neither greater nor more numerous than were to be expected in the manipulation of the process employed, by two operators on such a series. When, however, it is remembered that, as already pointed out, the large dressing of a hundred pounds of nitrogen per acre, distributed through the soil to the depth of 1 foot, would only raise its percentage of nitrogen by 0·0025, equal $\frac{1}{40000}$th of its weight, it would at once be seen, that the separate determinations on the same soil frequently, nay, generally, differ much more from each other, than would the actual soil before and after such a potent manuring. It is clear then from this simple illustration, that such methods of estimating the nitrogen in soils are quite inapplicable to determine the difference in this respect between a soil yielding 16 bushels of wheat without manure, or twice, or twice and a half the amount, with it. That is to say, such methods are quite incompetent adequately to treat the question of the mere *temporary* "*condition*" of soils.

Exercising then all due caution, on the score both of the difficulty of fairly and uniformly sampling soils for analysis, and of that of accurately determining the nitrogen by current methods, let us see what are some of the more general indications of the

Table. For this purpose we take of course the *mean* results instead of the separate determinations; which latter, however, although disagreeing with each other sufficiently to show that the figures could not be relied upon to treat of the nice question of the effect of a single even heavy dressing of manure, have still so much of agreement, as to give some confidence at least in the *direction*, and in any marked distinctions, which the mean results would indicate as between soil and soil.

It is seen that the subsoils contain from one-half to one-third only as much nitrogen as the surface soils. From this it is obvious that an inch or two of variation in depth, in sampling a surface soil, might make a comparatively important difference in the percentage of nitrogen obtained. The effect of the admixture of more or less of subsoil, in a sample of professedly surface soil, is seen in the difference between the mean percentage in the Rothamsted soil which had been cultivated on the Lois Weedon plan, and that of a similar description in the adjoining field, which had grown wheat for several successive years, but without its subsoil being disturbed. Thus the trenched plot at Rothamsted gives a mean percentage of only 0·1417 of nitrogen, whilst the plot in the adjoining field, notwithstanding it has grown wheat for many years successively without manure, gives 0·1523 per cent.

Before proceeding to compare with one another the Rothamsted and the Lois Weedon soils, we may here, in passing, call attention to the fact that, slight as they are, and whether accidental or not, the differences which the mean results would show between the plots devoted to the continuous growth of wheat at Rothamsted, under different conditions of manuring, are really, at least in direction, such as those manuring conditions would lead us to expect. Without laying too much stress on the actual figures, it is seen, then, that whilst the continuously unmanured plot gives 0·1523 per cent. of nitrogen, that which has received for a series of years mineral manure only (which would tend to the extraction of more nitrogen from the soil than where no manure was employed) gives 0·1459 per cent., or rather less than the former. The plot which has received annually ammoniacal salts (as the results showed somewhat in excess of the available minerals), indicates 0·1587 per cent. of nitrogen; or rather more than either the continuously unmanured or the continuously mineral-manured plot. And again, quite conformably with the above, the plot which has received continuously both mineral manure and an excess of ammoniacal salts, shows a slightly lower percentage (0·1556) than where the ammoniacal salts were employed without minerals; though with this excess of ammoniacal salts, a slightly higher one than the unmanured plot.

Thus in both instances where a liberal supply of minerals has been used, the effect of which would be to use up, so to speak, more of the available nitrogen within the soil, the mean percentage of nitrogen indicated was rather lower than in the cases comparable with them on this point. It is freely granted, that some of the individual determinations are not quite consistent with the conditions here supposed; yet, with three or four experiments in each case, agreeing as most of them do pretty nearly, it is really of interest to observe, that the mean results appear to bear some relation to the known history of the plots.

Turning now to the Lois Weedon soils, it is seen that both specimens taken from the heavy-land field show a higher percentage of nitrogen than any of the Rothamsted plots, and particularly higher than the specially comparable instance at Rothamsted; namely, that where the land had been trenched and some of the subsoil intermixed with the surface soil. The Lois Weedon light land even, gives a slightly, but very slightly, higher percentage of nitrogen than the surface-soil of the continuously unmanured plot at Rothamsted. The difference, however, in favour of the Lois Weedon light land, notwithstanding it had been intermixed with subsoil and with marl, each containing only about half as much nitrogen, is more marked when it is compared with the trenched, that is, the Lois-Weedon-subsoiled plot at Rothamsted. To go to figures, we find that whilst the mean of four analyses gives for the Lois Weedon heavy-land *stubble* 0·1646 per cent. of nitrogen, the mean, also of four analyses, gives for the heavy-land *fallow* 0·2012 per cent. We cannot at all suppose that the whole of this large difference, amounting, as it would do, to from 1000 lbs. to 1500 lbs. per acre, if reckoned at 1 foot deep, is due solely to the joint influence of the exhaustion of the just removed crop in the one case, and to the accumulation by the tilled bare fallow in the other; though it is obvious, that the effect of the accumulation by fallow would not extend uniformly to the depth of 1 foot; and consequently the assumption of a gain of 1000 lbs. or 1500 lbs. of nitrogen per acre is very much higher than the figures really imply, even supposing the samples were really taken to exactly corresponding depths in the two cases. The more probable supposition is, however, that the sample taken from the stubble did in fact represent a somewhat greater depth of the staple, or more of intermixed subsoil, than that taken from the fallow interval.

Turning for a moment to the subsoils and marl, the Rothamsted unexposed subsoil indicates a rather higher percentage of nitrogen than the Lois Weedon heavy-land subsoil—the former giving 0·0746 and the latter 0·0652 per cent. It is seen, on the other hand, that the subsoil and marl of the Lois Weedon light-land field, with which the surface-soil is intermixed, both give a higher percentage than either the Rothamsted or the Lois Weedon heavy-land subsoil—that of the light-land subsoil being 0·0782, and that of the marl 0·0905 per cent. Lastly on this point, whilst the subsoil of the Lois Weedon heavy-land unmanured wheat-plot gives 0·0652 per cent., the subsoil of the plot devoted to rye-grass, with liquid manure, in the same field, gives 0·0790 per cent.

To resume—the comparison of the percentage of nitrogen in the Lois Weedon and the Rothamsted soils submitted to Mr. Smith's methods of growing wheat, the one with so much success, and the other with such signal failure, shows that the former contain a higher percentage of nitrogen than the latter. Thus, whilst the mean percentage in the trenched plot at Rothamsted is 0·1417, that in the light land at Lois Weedon is 0·1550 per cent., and in the heavy land at Lois Weedon (taking the mean of the eight determinations on both stubble and fallow plots) is 0·1827. Independently, then, of mere physical condition of soil, of mineral richness, or of other circumstances affecting the relations of the plant to the soil, we have here an intelligible chemical difference, perfectly consistent with what all other experience regarding the requirements for the vigorous growth of the wheat-crop would lead us to anticipate.

The questions still remain, however, whether the Lois Weedon soils, in all probability, have a greater power to acquire nitrogenous plant-food from atmospheric sources, or are likely more lightly to retain, or more easily to give up to the plant in an assimilable form, their previously existing or newly-accumulated stores of nitrogen?

With a view of getting such indications on these points as limited time would permit, the following experiments were made. Rather more than one thousand grains, in a finely-powdered state, of each of the soils enumerated in the Table (V.) given below (whose nitrogen had previously been determined), were put into a water-bath for about six hours, in order to secure an equal state of dryness. Exactly one thousand grains of each were then weighed, and respectively placed in small but equal-sized basins. Each of these was then mounted upon a small porcelain pot an inch and a half in height, and so placed in a large glass basin containing water to the depth of about an inch. The large basin was then covered with another such, and the whole left for three days at a temperature of 100° or more; by which from 1½ to nearly 4 per cent. only of water was absorbed by the different soils. The water in the large basin was then replaced by pretty strong ammonia-water; and the whole, covered as before, was left for four days in a warm room, the temperature being main-

TABLE V.—Results of Experiments on the Comparative Absorptive Power, for Water and Ammonia, of different Soils.

		Water, per cent.					Nitrogen per cent. in dry Soil.				Per cent. gain of Nitrogen by absorption.	
		After 3 days in closed moist warm atmosphere.	After 4 days' Ammonia-water vapour at 70°.	Added Nov. 26.	Added Nov. 30.	Retained after 18 hours' exposure at 70°.	After absorption of Ammonia.			Before absorption of Ammonia.	On Dry Soil.	On previously existing Nitrogen.
							Experiment 1.	Experiment 2.	Mean.	Mean.		
Rothamsted Soil	Continuously unmanured	1·80	2·78	5·0	10·0	1·65	0·2880	0·2779	0·2829	0·1523	0·1306	85·7
Lois Weedon Soil	Heavy Land	2·53	3·35	5·0	10·0	2·48	0·3970	0·3905	0·3937	0·2012	0·1925	95·7
	Light Land	1·41	2·35			1·60	0·2547	0·2529	0·2538	0·1550	0·0988	63·7
	Heavy Land Subsoil	3·88	4·95			2·51	0·2930	0·2959	0·2944	0·0652	0·2292	351·5
	Light Land Subsoil	2·00	2·80			1·57	0·1870	0·1912	0·1891	0·0782	0·1109	141·8

tained at about 70°. Even now none of the soils had gained quite 5 per cent. of water; and as it was thought that the absorption of ammonia would be facilitated thereby, 5 per cent. was now added to each of them; and after another four days' exposure to the moist ammoniacal atmosphere, a further 10 per cent. of water was added. In four days more the little basins were removed from the ammoniacal atmosphere, and by this time the soils smelt very strongly of ammonia. In order to expel all that was not retained in a comparatively stable condition, the little basins and their contents, uncovered, were exposed for eighteen hours in the warm room at about 70°; by which, as will be seen in the Table, the amount of moisture was reduced in all cases to below 3, and in some to below 2 per cent. In this state the percentage of nitrogen was again determined in the soils by the soda-lime and platinum-salt process; and in the Table are given the results of these determinations; and by their side, the mean percentage of nitrogen in the respective soils *before* they were submitted to the ammoniacal vapours. The percentages of water in the specimens at the different stages, as above described, and the percentage *gain* of nitrogen by absorption, calculated both upon the dry soils and upon the previously existing nitrogen in them, are also given; the former to the left, and the latter to the right of the nitrogen determinations.

A glance at the Table shows that there is some general though not numerically exact connexion between the capacity of the different soils for the absorption and retention of water on the one hand, and of ammonia on the other. It is seen that the Lois Weedon heavy land and its subsoil absorbed and retained a very much larger proportion both of water and ammonia than either the Rothamsted soil, or the Lois Weedon light land, or light-land subsoil. Thus the nitrogen in the Lois Weedon heavy land, which was before the highest in the series, has been raised by the absorption experiment by 0·1925 per cent.; whilst that in the Rothamsted soil is raised by only 0·1306. The Lois Weedon light land has, however, absorbed, or at least retained, less of ammonia than the Rothamsted soil, the increased amount of nitrogen in its case being 0·0988 per cent. It is further seen that both of the Lois Weedon subsoils have absorbed more than their corresponding surface soils; the increased percentage of nitrogen by absorption of ammonia being in the heavy-land subsoil 0·2292, and in the light-land subsoil 0·1109 per cent.

It was our intention, had time permitted, to have completed other experiments of this kind for the purposes of this paper; and we may possibly yet be able before concluding to append the results of some such which are now in progress. In defect of these, however, we cannot fail to observe as a significant fact, that the Lois Weedon heavy land, which has yielded Mr. Smith his best results, both contained more nitrogen in its original state, and absorbed and retained, under equal circumstances, both more water and more ammonia than the Rothamsted soil. The Lois Weedon light land, however, although containing slightly more nitrogen in its natural state than the soil at Rothamsted, absorbed and retained, in the experiment above described, rather less both of water and of ammonia than the Rothamsted soil. In drawing any conclusion from the results of an experiment of this kind, in regard to the probable comparative qualities of the soils in their natural state and position, we must first carefully consider what are the circumstances, in a necessarily artificial experiment, which might vitiate a strict comparison of the figures. It is to be borne in mind then, that the soils, when submitted to the absorption experiments, were in an equally finely divided state, and they would, therefore, expose nearly equal surfaces to the watery and ammoniacal vapours. The results should, therefore, show the comparative absorptive powers of equal surfaces of the respective soils. And this being so, of the three surface soils the Lois Weedon heavy land has the highest, the Rothamsted soil the next, and the Lois Weedon light land the least absorbent power in relation to a given surface exposed. But in its natural state and position the Lois Weedon light land would undoubtedly expose a much greater surface of atmospheric influences than the Rothamsted soil. Hence probably the reason that the Lois Weedon light land, though it did not absorb more ammonia in the experiment cited, yet in its natural state contained a higher percentage of nitrogen than the Rothamsted soil. Hence probably also, this Lois Weedon light land would both absorb or otherwise accumulate more nitrogen in an available form, under equal climatic circumstances, and yield it up more readily to the plant, than the soil at Rothamsted.

Since the above was in type, the additional experiments referred to have been concluded, and we give here a short statement of the results. In this second series of absorption experiments, the object was to include the surface and subsoil of the land devoted to the Lois Weedon experiments at Rothamsted; and also to submit the soils in a rather moister state to the ammoniacal vapours. 800 grains, in an equal state of dryness, of each of the soils enumerated in the Table below, had 25 septems, or about 23 per cent., of water added to them. In this state they were submitted, in the same manner as in the previous experiment, to moist ammoniacal vapours at a temperature of about 70°; though in this case for only 3 days instead of 12 as formerly. At the conclusion of the absorption period each little basin of soil was exposed for 24 hours in the open warm room at 60° to 70°. In this condition the specimens were put into closed bottles; from each of which one portion was taken for the determination of the moisture separable at 212°, and separate portions for that of the nitrogen, the duplicate being in each case made by a second experimenter. The following are the results:—

TABLE VI.—Results of further Experiments on the comparative Absorptive Power, for Water and Ammonia, of different Soils.

Description of the Soils.		Per cent. Water retained after absorption and 24 hours' exposure at 70°.	Nitrogen per cent. in dry Soil.				Per cent. gain of Nitrogen by absorption.	
			After absorption of Ammonia.			Before absoption of Ammonia.	On dry Soil.	On previously existing Nitrogen.
			Experiment 1.	Experiment 2.	Mean.	Mean.		
Rothamsted Soils ..	Continuously unmanured	5·33	0·2498	0·2632	0·2565	0·1523	0·1042	68·4
	Lois-Weedon-Plot Surface Soil ..	5·19	0·2525	0·2462	0·2493	0·1417	0·1076	75·9
	Lois-Weedon-Plot Subsoil	5·45	0·2378	0·2239	0·2308	0·0746	0·1562	209·4
Lois Weedon Soils ..	Heavy Land Surface Soil	5·65	0·3445	0·3308	0·3376	0·2012	0·1364	67·8
	Light Land Surface Soil	4·69	0·2488	0·2425	0·2456	0·1550	0·0906	58·4

The soils being throughout this experiment in a moister state, it seems they did not become so dry by exposure in the warm room; nor were the differences in the retentive power under these circumstances so great as in the former instance. Nevertheless, conformably with the former results, the Lois Weedon heavy land retained more water than the light land, and more also than either of the Rothamsted soils. The Rothamsted subsoil, too, retains more than either of the Rothamsted surface soils, though the surface soil that had been trenched does not bear the same relation to the one which had not, in regard to retention of water, as might be expected, though we shall find it does so in regard to that of ammonia.

With regard to the absorption and retention of ammonia, the results of this second series of experiments are entirely consistent with those of the first. They may indeed be considered to be the more so, from the variation in the actual per cent. of absorption, since the circumstances of the two sets of experiments equally varied. We find, as before, that the Lois Weedon heavy land absorbed and retained more ammonia than the Rothamsted soils, and the latter more than the Lois Weedon light land. And, as was the case with the Lois Weedon soils and their respective subsoils, the Rothamsted subsoil absorbed and retained more ammonia than its surface soil; and conformably with the greater power in this respect of the subsoil, we find the trenched land at Rothamsted absorbed and retained rather more ammonia than the one which had not had any of its subsoil intermixed with it.

In fact the results of this second series of absorption experiments confirm so entirely the bearings of the former one on all essential points, that the arguments and conclusions already recorded do not require any modification or correction from this additional evidence.

The result of the comparative examination in the laboratory of the Lois Weedon and the Rothamsted soils clearly brings out the fact, that of the former, the heavy one at least, both contained more nitrogen in some form, and had the power of absorbing more ammonia under equal circumstances, than the latter; whilst the experiments in the field have shown, that a much greater porosity, and consequently a greater amount of surface for atmospheric influences, is attained in this more highly nitrogenous, and more powerfully absorbent heavy soil at Lois Weedon, than, by an equal expenditure of mechanical means, could be attained in the one at Rothamsted. The Lois Weedon light land too, certainly contained more nitrogen than the Rothamsted soil in its natural state; and, as we have seen, would in that same state, in all probability, acquire more under equal climatic circumstances, and yield up more in a given time to the growing crop.

It would be taking a very narrow view of the case to suppose, that no other circumstances than an increased supply of nitrogen within the soil have had their share in the success of the wheat crop at Lois Weedon. There is no doubt that the methods there adopted are well fitted to develop to the highest degree the healthy distribution of both the underground and above-ground feeders of the plant. Those methods favour also the liberation, the elaboration, and the distribution throughout the root-searching area of the plant, of the mineral food of the crop, in a manner that it would be impossible to emulate in the application of direct manures. This system moreover, independently of the mere *amount* of available nitrogen provided within the soil by its means, secures also, better than any other means could do, the perfect distribution of the assimilable nitrogenous, wherever there is a liberal supply of the assimilable mineral food. It so happens too, that it is just those soils which are known to possess generally the greatest absorptive and retentive powers, that have generally also the greatest stores of most of the necessary mineral constituents of our crops. It is not, however, all which possess these physical or chemical powers of surface, and these inherent mineral riches, that will allow, with equal ease, the exposure of an equal surface for the development and available activity of these powers and stores.

That the nitrogen shown to exist in soils by the methods of analysis which have generally been adopted, does not necessarily so exist in a form readily and within a limited period assimilable by plants, is easily demonstrable. Thus, with a view to this point, several of the soils which have been the subject of this paper were operated upon as follows. A given weight (100 grains) was put into a flask, 20 ounces of water added, and a little strong caustic potash ley. The flask was then connected by a tube with a Liebig's condenser, and heat applied so as to keep the mixture gently boiling. A series of smaller flasks, gauged and marked to hold exactly 4 ounces each, were then successively attached as receivers, until three separate fifths of the original bulk of fluid had been collected. It has been shown by Boussingault, that when very dilute solutions of ammonia or ammoniacal salt are distilled in this way, practically the whole of the ammonia will come over in the first two-fifths of the distillate. And it is obvious that boiling a soil in a fine state of division with dilute caustic potash for two or three hours, would liberate a very much larger proportion of its nitrogen in the form of ammonia than could be rendered soluble and available for plants in many years of the influence of air and moisture upon a soil in the very limited state of division in which it exists in cultivated land. Collecting, however, a distillate of three separate fifths, supersaturating each with a known quantity of a test acid, adding litmus, and then neutralising by a test alkaline solution, it was found that only a small proportion of the nitrogen existing in the soil (the quantity varying slightly with the rapidity of the distillation) was obtained in the distillates. And quite conformably with the point established by Boussingault, and confirmed in our own experiments in the case of rain-waters, the first fifth contained by far the larger proportion of the whole ammonia which came over; the third fifth, in fact, containing very little. It was, however, found, that a very much larger proportion of the total nitrogen distilled over as ammonia from the soils after they had been submitted to ammoniacal vapours as above described, than before they had been so treated.

Although, therefore, it may generally happen that a soil which contains the highest per cent. of nitrogen may have a greater aptitude, if well worked, both to acquire more and to yield up its accumulated stores, and hence, so far be more fertile, yet it is obviously quite inadmissible to suppose, that the addition of a comparatively small amount of nitrogen to the soil, in a form proved to be readily accessible, can be of no avail, simply because the soil itself already contains a much larger absolute amount;—though, from its distribution and state of combination, it may be but in very small proportion available within a single season. That soils are not *necessarily* more fertile because they contain a larger actual amount of nitrogen, is interestingly illustrated in the effects of burning clays. The burnt clay after some exposure, as has been shown by Professor Voelcker, contains a much less percentage of nitrogen than the unburnt. No doubt the increased supply of available mineral food, as well as the change of texture by which the roots of the plant, as well as the atmosphere, are enabled better to permeate the soil, have much to do with the result. That this is so, may indeed be judged, by a consideration of the descriptions of crop grown with most advantage after the burning process. There can be little doubt, however, that the smaller amount of combined nitrogen, newly acquired by the porous burnt soil, will be much more accessible to the plant than the larger amount locked up in the unburnt clay; and to this circumstance, in all probability, a fair share of the beneficial effects of burning should be attributed. In fact, this smaller amount of accessible nitrogen in the exposed burnt clay, has a much greater proportional effect as compared with that in the unburnt, just as the smaller amount added in manure in an available form has a striking effect in an ordinary soil, notwithstanding that the latter may contain an enormously larger amount, but in a less accessible condition.

It is further, we think, very doubtful whether ordinary *agriculturally* cultivated soils, even *contain*, in any form, so large an amount of nitrogen as the uncritical reader might be led to suppose from the statements on this point given by Baron Liebig in the last number of this Journal. The percentages given in soils by Dr. Krocker, whose figures Baron Liebig does not quote in the Paper referred to, agree very closely in range with our own experience in such matters.* Of those which he has now brought more prominently forward, and which we have quoted in full at an earlier page, the range is in some cases so high, and the discrepancies between the individual analyses of the same soil, as already shown, so great, that we are disposed to place much more confidence in the medium amounts given in that Table. Then, again, neither the Russian black earth, nor the soils of gardens or woods (the latter being the only ones given by

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* Dr. Krocker's results will be found in the Appendix to Baron Liebig's 4th English Edition of his *Chemistry in its Applications to Agriculture and Physiology*, p. 275.

Baron Liebig as analysed by himself), can be taken as parallel with ordinary farming-land, under ordinary cultivation.

With regard to any estimates that might be made from our own determinations of nitrogen in the soils at Rothamsted and Lois Weedon, of the probable acreage amount within a given depth, it may be observed, that the result obtained and published ten years ago of the amount of nitrogen in the soil of our continuously unmanured wheat plot (0·2 p. c.), was considerably higher than that now recorded in Table IV. This was to a great extent due to the fact, that the earlier sample was taken to little more than half the depth of the recent one. By reference to the analysis book we also find that, for a substance containing so small an amount of nitrogen, much too small a quantity was submitted to analysis. There is also the consideration, whether or not part of the difference is due to the reduction of the condition of the land in regard to nitrogen, by the removal of ten more unmanured wheat crops. It is clear, however, that the determination of nitrogen made upon a sample taken to only half that depth, cannot be taken in estimating the probable acreage amount to the depth of one foot. Then, again, since the analyses now recorded were made upon samples taken to the depth of only nine inches, the calculated acreage amounts one foot deep, given in the lower part of Table IV. for comparison with Baron Liebig's adopted depth of one foot, must obviously be too high. With these explanations, then, as to the degree of applicability of our figures to any estimates of acreage amounts, the results are committed to the reader, as some additional data on the many points of interest which this question of the nitrogen in soils involves.

It was our hope and intention, had our time permitted it, to have included within the limits of this paper a short review of existing knowledge, and especially of the results and tendency of the investigations of recent times, bearing upon the sources of available nitrogen to cultivated plants, both within and without the soil. It is, indeed, remarkable how many are the independent researches, from experimenters both numerous and varied in their pursuit and object, which have come in upon this field of inquiry during the last few years. It is not less remarkable, that the subject of agricultural chemistry, perhaps more than any other, has demanded and successfully incited a rigid investigation of *methods* of research; and it has, both in this country, in Germany, and in France, led to improvement, and a much greater degree of accuracy, in some of the most difficult departments of chemical analysis. Besides the establishment of methods for the determination of quantities of ammonia and nitric acid, formerly far too minute to be made the subject of successful quantitative estimation, the analysis of gases, the peculiar influences of the sun's rays, meteorological phenomena generally, vegetable physiology in its various departments, structural and functional, not a little aided by the revelations of the microscope, are all now receiving their special study, and will find their special application in the elucidation of important agricultural questions. And, although we cannot fail to see that all will, sooner or later, conspire to give security to the next important step in these inquiries, it must be freely admitted, that as yet the difference of opinion is so great, and there really are so many points undetermined, that we may rest satisfied to delay for the present the summary we had intended to give, in the hope that, when the opportunity next occurs, we may have a less questioned advance to record.

In conclusion, the field results recorded in the foregoing pages have clearly shown that, from some cause or other, the endeavour, by given mechanical operations, to attain a deep and porous staple, with the admixture with the surface of a certain portion of the subsoil, was quite insufficient to secure in the Rothamsted soil, those conditions of texture and of other qualities incident to it, essential to the successful start, and healthy after development, especially of an early thinly-seeded wheat crop. The field experiments also afford conclusive evidence, that the defect, so far as it was chemical, was not connected with a deficiency of available mineral, relatively to available nitrogenous food. The concluding experiments showed, on the contrary, that an increased provision of nitrogen in the soil, by manure, gave a very much larger amount of increase on the now more thickly-seeded land, than an increased supply of the mineral constituents of the crop could do. That such should be the result on the land at Rothamsted, where the Lois Weedon plan had failed, was perfectly consistent with the limited degree of porosity for the exposure of surface to atmospheric influences, and for the permeation of the roots, which had been attained by the means employed. It is also perfectly consistent with those views as to the sources of the resultant effects of fallow, and as to the characteristic action of different constituents of manure on ordinarily cultivated land, upon which we have so often insisted.

The results in the laboratory again, have borne their consistent evidence on every point. Thus, bearing in mind at the same time the comparative character as to porosity of the Lois Weedon and the Rothamsted soils, it is found that, taking a given amount of each in its natural state, both of these more porous soils at Lois Weedon *contain* more nitrogen than those at Rothamsted. One of them again has, besides its greater exposed surface in the field, no doubt associated with a greater susceptibility to atmospheric influences generally, a greater power of absorption for ammonia in relation to a given surface. The other of these Lois Weedon soils, although absorbing a less amount of ammonia in relation to a given weight having an equal surface exposed, undoubtedly offers, under equal circumstances in the field, a much larger amount of surface for absorption than the soils at Rothamsted. Indeed, we can have little doubt, that to the difference between the respective soils in the degree of the conjoint influences of mechanical division, and of power of absorption and liberation (in part depending on it) of a sufficiency of available nitrogen relatively to the available mineral constituents, must in great measure be attributed the difference in the results obtained at Lois Weedon and at Rothamsted.

Further, in the results which have been recorded, whether in the field or in the laboratory, we find additional confirmation of the view :—

> "That the chemical effects of *fallow*, in increasing the growth of the cereal grains, are not measurable by the amount of the additional mineral food of plants liberated thereby; these being, under ordinary cultivation, in excess of the assimilable nitrogen existing in, or condensed within, the soil in the same period of time. The amount of the latter, therefore—(*i. e.*) the *available nitrogen*—is the measure of the increased produce of grain which will be obtained."

But the system adopted by the Rev. Mr. Smith, of growing wheat year after year on alternate strips of the same land, and as a general rule without any restoration, directly or indirectly, of the mineral constituents removed in the crops, certainly does not come within the definition of "*ordinary cultivation*," as referred to in the paragraph just quoted. Whilst, therefore, a soil not only rich in the absolute amount of the mineral constituents of the crop, but one capable of sufficient mechanical division, and susceptible to the liberating action of atmospheric influences, is absolutely essential to the success of the plan, yet all experience, practical and experimental, tends to show, that a large amount of inherent mineral stores, and their easy liberation, or available form for the use of the plant, will only suffice for the production of full crops of wheat, provided there be at the same time a liberal supply of *available* nitrogen *within the soil itself.*