REPORT

OF

EXPERIMENTS WITH DIFFERENT MANURES

ON

PERMANENT MEADOW LAND.

BY

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CONTENTS.

Part I.—Produce of Hay per Acre.

Part II.—Produce of Constituents per Acre.

Part III.—Description of Plants developed by different Manures.

PART IV.—CHEMICAL COMPOSITION OF THE HAY.

APPENDIX TABLES.

REPORT

EXPERIMENTS WITH DIFFERENT MANURES ON PERMANENT MEADOW LAND.

Part I.—Produce of Hay per Acre.

The extent of land in this country in Permanent Grass, and the importance of the crop, both as regards its yield of food for animals, and its relations, under existing circumstances, to the crops under tillage, establish for it a high claim to investigation, with a view to increased productiveness. In several of its aspects—and in some involving its most intricate relations—the subject has received the attention of investigators at once competent and laborious. The pages of the 'Journal of the Royal Agricultural Society of England' sufficiently bear out this statement. Among them are to be found valuable records of practical observation, and experience, as to the distribution, the adaptation, and the comparative utility, of the most important plants composing this heterogeneous crop, according to character of soil, climate, and other circumstances.* We have elaborate examinations by Professor Way, into the composition of the several plants, each grown under circumstances favourable to its development, and all taken as far as possible at an equal stage of growth.† And in Number xli. of the Journal will be found three Papers, each of distinctive value, bearing upon the practical management and manuring of the Grass crop.

As the title of the present Paper will indicate, its scope and objects are sufficiently distinct from those of the inquiries above alluded to. And, whilst the plan of the investigation which has been undertaken, and the character of the data which it has afforded, will necessarily lead to a somewhat special treatment of the subject, we shall endeavour, as far as circumstances will permit, to pay due regard to what appears to have been established hitherto.

An inquiry into the comparative effects of different manuring

* See 'Prize Report,' by Mr. John Bravender, Jour. Roy. Ag. Soc., vol. v.: also Papers by Professor Buckman, Jour. Roy. Ag. Soc., vol. xv. p. 462; vol. xvii. p. 162; and vol. xvii. p. 513.

† Jour. Roy. Ag. Soc., vol. xi. p. 530, and vol. xiv. p. 171.

substances upon permanent grass, has, however, other grounds of interest than such as relate merely to determining the best means of increasing the gross amount of its produce. There is perhaps no crop more influenced in its *character*, as well as its *quantity*, by the attention bestowed upon it. Our Grass-crop comprises, as is well known, not only a great number of genera and species belonging to the *Graminaceous* family — the Natural Grasses commonly so called—but also various members of other families of plants, among which, by far the most important is the *Leguminous*. It so happens, then, that in our Meadows and Pastures there are associated, members of those two families of plants that afford us the crops which are not only the most important among those which enter into our rotations, but which, as there grown separately, and in alternation with one another, exhibit very characteristically different degrees of dependence upon the direct artificial supply of some of their constituents; and coincidently with this, show very distinctive relationships to one another in the course of cropping.

Thus, Wheat, Barley, and Oats, are of the *Graminaceous* family, and have, therefore, so far, their points of close relationship with the so-called "Natural Grasses." Beans, Peas, and the cultivated Clovers, Lucerne, &c., of our rotations, are, on the other hand, of the *Leguminous* family; and hence their relationship to the clovers, and allied plants, of our Meadows and Pastures. It is true, that the circumstances of growth, and the treatment, of the plants composing the mixed herbage of our Pastures and Meadows, are widely different from those of the allied plants—especially of the seeding ones—in our arable fields. In the one case, too, the plants are chiefly perennial, and in the other chiefly annual. It might well be expected, therefore, that, notwithstanding their natural alliances, crops which differ so widely both in certain comparatively incidental conditions of growth, and in some intrinsic qualities, should, at the same time, manifest somewhat different manurial requirements. In so far, however, as the influence of the different conditions, does not outweigh that due to the natural grounds of alliance or distinction among our agricultural plants, the effects of special manures, on the development of the different plants in our Meadows and Pastures, should afford interesting points of coincidence with those observed in regard to the allied crops grown in our Rotations.

In fact, among the most interesting of the points incidentally brought out by the experiments which form the subject of the present Report, is the striking confirmation which the results afford of the (so to speak) special adaptation, in a course of practical agriculture, of certain constituents of manure, to the

growth of certain of the crops of our rotations, accordingly as they belong to the one or to the other of the two great families of plants above referred to. That is to say, the comparative action of different descriptions of manure, upon the development of the different plants of the mixed herbage of our Meadow, was found to accord with, and further to illustrate, points independently established regarding the manurial requirements, and the mutual relations, of the plants of our rotations to which they are botanically allied. At the same time, independently of the difference in other conditions of growth and management, the permanent and the alternating crops generally differ from each other so widely, both in regard to the amount of certain constituents which they respectively remove from the land, and to the proportion of these which will probably be in due course returned in the home manures, that the character of the supplementary manures required by even much allied crops, must obviously be somewhat different in the two cases.

To turn to the experiments themselves: The plan adopted was, to apply a number of different combinations of manuring substances, each, year after year, to the same plot of land. And in order to provide proper standards of comparison, two plots were left continuously unmanured, and another portion was annually manured with farm-yard manure.

The land selected comprised about 6 acres of the Park at Rothamsted, and it had been under permanent grass for certainly more than a century; indeed, for as long a period as is included in any record that can be found relating to it. The general mode of treatment for many years prior to 1851, was to manure occasionally with farm-yard dung, road scrapings, and the like; and sometimes with Guano, or other purchased manure. One crop of Hay was removed annually, amounting in weight to from $1\frac{1}{4}$ to 2 tons per acre; and the second crop was always eaten off by sheep. In the spring of 1851, and again in that of 1852, 4 separate acres of the allotted area were appropriated to the consumption by sheep of as many lots of differently manured turnips; 10 tons of the roots being eaten upon each acre. Neither the 4 acres so appropriated, nor the remaining 2, were manured in any other way in those two seasons (1851 and 1852); nor were they manured at all in the three succeeding ones prior to the commencement of these experiments in 1856. It should be mentioned too, that the consumption on the land of the different turnips did not in any case increase the produce over the 5 years, 1851–5 inclusive, by more than about 2 cwts. per acre annually. The land is a somewhat heavy loam, with a red clay subsoil resting upon chalk;

and although it is not artificially, it is very well naturally drained. The area selected was perfectly level. Lastly, no fresh seed of any kind has been sown either within the period of the experiments, or for many years before it.

Early in 1856, 9 plots, of half an acre each, were measured off for as many different combinations of so-called *artificial* manuring substances; 2 of a quarter of an acre each, to be continuously unmanured; and 2, also of a quarter of an acre each, to be manured annually with farm-yard dung. In 1858, 4 additional plots, of one-sixth of an acre each, were appropriated to trials with nitrate of soda; the land so selected having been unmanured for several preceding seasons. The description, and quantities per acre, of the different manures employed, are given in the Tables, by the side of the results they yielded; but it will be well to state them here, at one view, a little more fully than there is there room to do.

Plot 1. Unmanured.
Plot 2. Unmanured (duplicate plot at the further end of the series).
Plot 3. 2000 lbs. sawdust.
Plot 4. 200 lbs. each, sulphate and muriate ammonia (good samples of the salts so named in commerce).
Plot 5. 2000 lbs. sawdust, and 200 lbs. each sulphate and muriate ammonia.
Plot 6. 275 lbs. nitrate of soda.*
Plot 7. 550 lbs. nitrate of soda* (equal in nitrogen to the ammoniacal salts of plot 4).
Plot 8. Mixed mineral manure, composed of—

200 lbs. bone ash .. .. } superphosphate of lime.
150 lbs. sulphuric acid (sp. gr. 1·7 }
300 lbs. sulphate of potash.†
200 lbs. sulphate of soda.†
100 lbs. sulphate of magnesia.†

Plot 9. "Mixed mineral manure," as plot 8, and 2000 lbs. sawdust.
Plot 10. "Mixed mineral manure," as plot 8, and 200 lbs. each sulphate and muriate ammonia.
Plot 11. "Mixed mineral manure," as plot 8, 200 lbs. each sulphate and muriate ammonia, and 2000 lbs. sawdust.
Plot 12. "Mixed mineral manure," as plot 8, 200 lbs. each sulphate and muriate ammonia, and 2000 lbs. cut wheat-straw.

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* The experiments with nitrate of soda did not commence until the third season, 1858.

† The sulphates of potash and soda used, are the rough commercial articles; the sulphate of magnesia, Epsom salts.

Plot 13. "Mixed mineral manure," as plot 8, and 400 lbs. each sulphate and muriate ammonia.
Plot 14. "Mixed mineral manure," as plot 8, and 275 lbs. nitrate of soda.*
Plot 15. "Mixed mineral manure," as plot 8, and 550 lbs. nitrate of soda* (equal in nitrogen to the ammoniacal salts of plots 4, 10, &c.).
Plot 16. 14 tons farm-yard dung.
Plot 17. 14 tons farm-yard dung, and 100 lbs. each sulphate and muriate ammonia.

It would be desirable to have had some plots, with the superphosphate of lime, and the mixed alkali-salts, used separately; but it was considered, that to increase the number of the experiments, would be to extend the series beyond convenient practicable limits.

The artificial manures were, for the purpose of equal distribution, mixed with ashes prepared by burning soil with a portion of weeds and turf. They were sown broadcast. The date of sowing was, in 1856, the middle of February; in 1857, the 24th February; and in 1858, the 31st of March; excepting that the nitrate of soda (used in 1858 only) was not applied until the 8th of April. The farm-yard manure, and the sawdust, excepting in the first season, were put on in the previous November or December.

The first crop only, in each year, was mown; and the produce of each plot was weighed separately as *hay*, at the time of being carted to the rick. The second crop was eaten off by sheep having no other food; each plot, according to the bulk of its produce, having a given number penned upon a portion of it, the area being extended, day by day, as the feed was eaten down. To the further particulars of the feeding, and to the estimates made of the produce of the second crop, we shall recur presently.

The weight of hay (one cutting) taken from the different plots, in each of the 3 seasons, is given in Table I., p. 8.

Although the three seasons over which the experiments have extended differed widely one from another in climatic characters, the amounts of *gross produce*, under equal conditions of manuring, were upon the whole much the same in the three seasons. There was indeed a tendency to increase, from year to year, as the expe-

* The experiments with nitrate of soda did not commence until the third season, 1858.

Experiments with Different Manures on Permanent Meadow Land.

Table I.—Produce of Hay per Acre: tons, cwts., qrs., and lbs.

Plot, Nos.	MANURES. (Per Acre, per Annum).	ANNUAL PRODUCE. 1856. Cut June 25; carted July 1.	1857. Cut June 23; carted Ju. 26-27.	1858. Cut June 26; carted Ju. 29-30.	Average of 3 Years.	Average Annual Increase or Loss by Manure.
	Series 1.—Without Direct Mineral Manure.					
1	Unmanured	tns. cwt. qrs. lb. 1 2 1 23	tns. cwt. qrs. lb. 1 5 2 0	tns. cwt. qrs. lb. 1 2 0 8	tns. cwt. qrs. lb. 1 3 1 10	tns. cwt. qrs. lb. . .
2	Unmanured (duplicate plot	1 0 3 27	1 3 0 16	1 10 0 0	1 4 2 24	. .
	Mean, or Standard Unmanured	1 1 2 25	1 4 1 8	1 6 0 4	1 4 0 3	. .
3	2000 lbs. Sawdust	1 0 2 16	1 0 3 16	1 0 0 4	1 0 2 3	−0 3 2 0
4	200 lbs. each, Sulphate and Muriate Ammonia	1 15 3 24	1 13 2 22	1 15 2 6	1 15 0 8	0 11 0 5
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	1 15 1 5	1 13 0 14	1 17 0 22	1 15 0 14	0 11 0 11
6	275 lbs. Nitrate of Soda*	. .	. .	1 6 1 12	. .	0 2 1 9
7	550 lbs. Nitrate of Soda*	. .	. .	1 11 3 8	. .	0 7 3 5
	Series 2.—With Direct Mineral Manure.					
8	"Mixed Mineral Manure"†	1 10 2 13	1 12 2 26	1 16 1 22	1 13 1 2	0 9 0 27
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	1 13 0 15	1 15 2 18	1 19 0 8	1 15 3 23	0 11 3 20
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	2 16 3 7	2 17 1 10	3 4 0 4	2 19 1 16	1 15 1 13
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	2 16 3 13	2 17 1 16	3 1 2 4	2 18 2 11	1 14 2 8
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat Straw	2 8 1 8	2 14 0 2	3 0 1 4	2 14 0 23	1 10 0 20
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	3 2 0 26	3 1 3 24	3 7 0 4	3 3 2 27	1 19 2 24
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda*	. .	. .	1 17 3 8	. .	0 13 3 5
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda*	. .	. .	2 10 1 8	. .	1 6 1 15
	Series 3.—With Farmyard Manure.					
16	14 tons Farmyard Manure	1 15 3 26	2 7 2 8	1 17 0 20	2 0 0 27	0 16 0 24
17	14 tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate of Ammonia	2 4 2 25	2 13 2 16	2 7 2 0	2 8 2 14	1 4 2 11

* The experiments with Nitrate of Soda were not undertaken until the third year (1858), and the land devoted to it had been unmanured during several preceding seasons.
† For further description of this, and other manures, see page 6.

riments proceeded; but this tendency is the more apparent when the acreage amounts of *dry matter*, instead of gross produce of hay merely, are considered. Viewed in this way, the increase was moreover much greater in the second year as compared with the first, than in the third as compared with the second. It was too, perhaps upon the whole, the more marked where the most liberal manuring was employed, and the largest crops thereby obtained. On this point it should be remembered, that the manure from the sheep consuming the second crop, so far as it was due to the residual manures applied for the preceding first crop, would be so much addition to that supplied for the first crop of the succeeding season; and that the addition would be the greater, the more liberal had been the manuring, and the larger the amount of after-grass. It would too, with excess of manure, be somewhat cumulative, and relatively the more so, the more excessive the manuring, and the greater the produce of after-grass. The difference in the produce by the same manure, in one season compared with another—at any rate the increase in the amount of it in the second year of manuring over that in the first—cannot, therefore, be *wholly* attributed to differences in the characters of the seasons themselves.

With regard to the seasons themselves, a few general observations may nevertheless be made. The growing period of the first season, 1856, was generally much colder and wetter than that of either 1857 or 1858. Its rain was in April above the average, in May very large, and in the final month, June, but small. The moisture in the atmosphere, as indicated by the dew-point, was generally comparatively low; and with this, the range of temperature above that point was also low.

The grass season of 1857 ranged higher both in maximum and in minimum temperatures, and also in mean range, than that of 1856; and in that of 1858 higher numbers still were registered in regard to these several characters; but especially to that of the maximum temperature of the final month June, which in this third season, 1858, was very excessive. Both in amount and distribution of rain, April differed not very materially in the three seasons. May, as already mentioned, gave in 1856 a very large amount of rain, and also a large number of rainy days. In the same month of 1857, with at the same time much higher temperatures than in 1856, both the actual fall, and the distribution of rain, were very small. In May of 1858, again, with still higher temperatures than in the same month of 1856, both the actual amount and the distribution of rain were pretty full. In June, 1856, with again lower temperatures than in the other years, there was, after the very wet May, now but very little rain. In the warmer June of 1857 there was a fair amount of rain;

and in the still hotter June of 1858 there was, after a moderately wet May, but little rain.

The three seasons were therefore very different from one another, both in actual character as to heat and moisture, and in the mutual adaptations of these two qualities. As has been observed, however, the gross amount of the heterogeneous produce —*hay*—did not differ very widely in the three seasons; though the acreage amount of *dry matter*, and consequently of carbon assimilated, was nevertheless notably less in the first, and colder and wetter season 1856, than in either of the others. And, as will afterwards be seen, with the prevailing wet and cold of 1856, the percentage of dry matter in the produce was low, and that of the mineral matter, and of the nitrogen in that dry substance, high—characters which indicate comparatively backward conditions as to the stage of growth and the maturation of the plants. In a subsequent division of this Report we shall illustrate by pretty full detail on the point, the fact that the proportions of the different descriptions of herbage, as well as the character of the development of each, were very much affected, within equal periods of the season, according to the kind of manure employed. Had we equal means of deciding upon the varying character of the produce dependent on the varying character of the *seasons*, there can be little doubt, that the produce of these three very different seasons would show great differences, both as to the relative amounts of the various plants developed, and as to the character of the development of each.

Directing attention now to the comparative effects of the different *manures*, little more need be said as to the produce of the individual seasons. The results, as between one condition of manuring and another, will be both better and more easily traced by confining attention to the column showing the *average annual produce over the 3 years*, and to the concluding one of the Table (I.) showing the *average annual increase by manure*. These records relate, as will be remembered, to the produce of one cutting only. An estimate will be given further on, as to the actual and relative amounts of hay, to which the after-feed on the several plots was probably equivalent. At present it is only necessary to consider, how far the consumption of the after-grass upon the land, should influence the judgment to be formed of the effects of the different manures according to the weights of the produce of the first crop alone. On this point it may be remarked, that the knowledge we possess as to the average proportion of the nitrogen, and of the mineral matter, of the food consumed by stock, which they probably finally *store up* in their

bodies (and in the case of nitrogen exhale), is such as to lead to the conclusion, that the land would lose comparatively little of these manuring substances by the consumption upon it of the after-grass by sheep. By far the larger proportion of these contained in the second crop of one year would, therefore, remain towards the produce of the first crop in the succeeding year. Taken over a series of years, the annual produce yielded in the first crop, will thus pretty closely represent the average annual result of the manure on any particular plot; at any rate sufficiently so for a general comparison of the effects of one manure with that of another.

On one of the unmanured plots the average annual produce of hay was 1 ton 3 cwts. 1 qr. 10 lbs.; and it varied but little from year to year. The duplicate unmanured plot was somewhat shaded from the afternoon sun. It gave in the first two years about 2 cwts. less of hay annually per acre than the other, but in the third year as much as 8 cwts. of hay more. The fact was, as the result of the after-feeding showed, that this second plot, though it gave less mown hay in the first two years than the first plot, gave, on the other hand, more aftergrass in those years. Hence, there was less removal from the land in the first two years; and, compared with the other plot, some accumulation of manuring matter for the first crop of the third season. The average annual yield of mown hay on the duplicate plot was, however, only $1\frac{3}{8}$ cwts. more than on the other. The mean result of the two plots may therefore be fairly taken as the average annual yield of the land and seasons in question. This amounted to 1 ton 4 cwts. and 3 lbs. of hay, as the *standard unmanured produce* of the experimental meadow-land.

Sawdust contains very little of either nitrogen or mineral matter; but, upon high authority, it has been stated to produce great effects as manure, by virtue of the solvent action of the carbonic acid which it yields in its decomposition, upon the mineral constituents of the soil. The plot where there were employed per acre annually 2000 lbs. of sawdust (containing 4 to 5 lbs. of nitrogen), yielded, however, an average annual produce of about $3\frac{1}{2}$ cwts. *less* hay than the unmanured land. Where 2000 lbs. of sawdust were employed *with ammoniacal salts* (Plot 5), there were only 6 lbs. per acre per annum more produce than where the same description and amount of ammoniacal salts were used alone (Plot 4). When the same amount of sawdust was added with a liberal mineral manure (Plot 9), the mixture gave annually about $2\frac{5}{8}$ cwts. more hay than when the same mineral manure (Plot 8) was used alone. Lastly, when the sawdust was employed in admixture with both the ammoniacal salts and the

mineral manure (Plot 11), the produce per acre per annum was about ¾ cwt. less than when the same ammoniacal salts and mineral manure (Plot 10) were used without the sawdust. The nearly a ton per acre per annum of organic matter rich in carbon, in the form of sawdust, was then practically of no avail.

As the previous enumeration (p. 6) and the Table (p. 8) show, the ammoniacal salts employed, consisted of an equal mixture of the sulphate and the muriate of ammonia of commerce. This mixture is reckoned to contain about 25 per cent. of ammonia, which is equal to about 20·5 per cent. of nitrogen. The 400 lbs. of ammoniacal salts per acre per annum, as used on several of the plots, would therefore bring annually on to the land about 100 lbs. of ammonia.

Where the 400 lbs. of ammoniacal salts were used alone (Plot 4), they gave an average annual *increase* of 11 cwts. of hay. The average annual *produce* by the ammoniacal salts was 1 ton 15 cwts. of hay.

The "*mixed mineral manure*" alone (Plot 8), which contained an ample supply of acid—phosphate, and sulphate of lime, and of potash, soda, and magnesia, in the form of sulphates, but which did not afford, in a direct manner, an increased supply of available silica, gave an average annual increase of about 9¼ cwts. of hay per acre.

The ammoniacal salts alone, it has been seen, gave an annual increase of 11 cwts. of hay; only 1¾ cwt. more, therefore, than purely mineral manures. It will be shown, however, in some detail in a subsequent section, that the description of the increase differed extremely in the two cases. In fact, where the ammoniacal salts were employed, the increase was exclusively due to the increased growth of *Graminaceous plants*—the so-called *Natural Grasses*—there being scarcely a *Leguminous* plant to be found upon the plot. Where the purely mineral manures were used, on the other hand, the *Grasses*, properly so called, were observed scarcely to have increased at all; whilst the whole plot was thickly covered with Perennial Red Clover (*Trifolium pratense perenne*) and some other Leguminous plants. Such a result is perfectly consistent with what has been before established regarding the (so to speak) characteristic adaptation of mineral and nitrogenous manures respectively, to those crops of the respective families which are grown in our rotations.

Mineral manures alone have then much increased the growth of the *Leguminous* plants on the meadow land. They enabled the *Graminaceous* ones, on the other hand, to assimilate but little more of nitrogen or carbon from natural sources, than did the normal supply of available mineral constituents in the unmanured

land. Very different was the action of mineral manures upon the growth of the Graminaceous plants of the Meadow, when those manures were associated with a liberal artificial supply of *available nitrogen.* In the case of experiments both upon Wheat and upon Barley, too, it has been shown that the land experimented upon was competent, for a series of years, to yield up annually enough of mineral constituents for a considerably larger crop than could be grown under the influence of the annually available natural supplies of nitrogen alone. The annually available mineral constituents were, however, not sufficient for such full crops as the seasons would yield, *when there was a liberal artificial supply of available nitrogen.* There appear to be obvious reasons, why this should be expected to hold good to a greater extent with Meadow Grass than with these Graminaceous corn crops. In land of pretty equal original characters, the amount of mineral matter taken annually from a given area in Grass (mown for hay) is, under the same annual climatic circumstances, much greater than that taken off in the corn and in the straw of the seeding crop. The mechanical operations, and the exposure to the atmosphere, in the case of the arable land, would appear to indicate a greater annual disintegration and liberation of total mineral constituents over a given area, though not perhaps more within the limits of the immediately superficial layers. In the case of Meadow Grass, therefore, the original characters of the soil, and the seasons, being equal, both the annual demand for mineral constituents would be greater, and the total annual yield of them from the soil would be less, than in the case of the cereal crop.

Consistently with the foregoing considerations, it was found, that although the ammoniacal salts when used alone gave an annual increase of only 11 cwts. of hay, the same amount of ammoniacal salts, when in conjunction with the "*mixed mineral manure*" (Plot 10), gave an annual increase of 1 ton 15⅜ cwts. of hay. Thus, the combination of ammoniacal salts and the mixed mineral manure gave more than three times as much increase as the ammoniacal salts alone, and four times as much as the mineral manure alone. The average annual produce, by the mixture of the ammoniacal salts and mineral manure, amounted in fact to within less than a hundredweight of 3 tons of hay per acre, by the side of 1 ton 4 cwts. per acre on the continuously unmanured land.

Now, this produce, by the mixed mineral manure and ammoniacal salts (Plot 10), consisted almost exclusively of *Graminaceous* plants. There was scarcely a clover, or any other *Leguminous* plant, to be found upon the plot. The action of the

mineral manures, in this conjunction with ammoniacal salts, was *not* therefore to yield increase by aiding the development of Leguminous plants, as was the case when the same mineral manures were used alone. The mineral manure has now acted by supplying, within the reach of the plants, a sufficiency of certain mineral constituents, to enable the Graminaceous plants to appropriate, and turn to the account of growth, a much larger portion of the *artificially supplied nitrogen* than they could do when the ammoniacal salts were used alone. In fact, there were 1 ton 4¼ cwts. per acre per annum more *Graminaceous* hay grown, when the artificial supply of nitrogen was accompanied by a liberal artificial supply of certain mineral constituents, than when it was not so accompanied.

It has been shown, that the mineral manures had little or no effect in increasing the assimilation of nitrogen by the Meadow *Grasses*, when that constituent *was not artificially supplied.* On the other hand, they very considerably aided that assimilation, when available nitrogen *was artificially supplied.* It has also been shown, that the addition to the mixed mineral and nitrogenous manure of a large quantity of sawdust—a substance rich in carbon—did not further increase the produce. In fact, neither did the sawdust (whether alone or in admixture) seem to aid the solution of mineral constituents by the evolution of carbonic acid; nor did this possible source to the plant of carbonic acid itself seem to have been of any avail. The addition to the mixed mineral and ammoniacal manure, of an equal weight of cut wheat-straw instead of sawdust (Plot 12), was equally without effect with that of the latter substance. Indeed, notwithstanding the large amount of mineral constituents, and especially of silicious compounds, contained in the cut wheat-straw, as compared with the sawdust, there was, whether compared with the produce by the mixed mineral and nitrogenous manure, or with that by the mixed mineral and nitrogenous manure and sawdust, an average annual deficit of 4 to 5 cwts. of first-crop hay, where the cut wheat-straw was employed. The plot with the cut wheat-straw, like the duplicate unmanured one, was, however, somewhat shaded; and like the latter, though it gave a somewhat deficient first crop, gave at the same time rather more after-grass than the plots most comparable with it. It remains to be seen, therefore, whether the less exhaustion by the first crop hitherto, and the greater return of constituents as manure in the consumption of the second crop, will not, before long, tell upon the amount of produce of the first crop. And, how far the inefficiency of both sawdust and cut wheat-straw was due to the slowness of their decomposition, will perhaps be apparent in the course of years.

The mixed mineral manures in conjunction with 400 lbs. per acre, per annum, of ammoniacal salts, gave an annual *produce* of more than 2 tons 19 cwts., and an annual *increase* (over the unmanured) of 1 ton 15⅜ cwts. of strictly *Graminaceous* hay. The same mineral manures, together with double the above amount of ammoniacal salts, gave even more produce and increase still. The mineral manures and the double supply of ammoniacal salts gave, on the average, 3 tons 3¾ cwts. of annual *produce*, and 1 ton 19¾ cwts. of annual *increase*, of *Graminaceous* hay.

When we bear in mind the fact, that the mixed mineral manure alone scarcely increased the Graminaceous produce at all, it would appear that the increase of such produce, upon the super-addition of the 400 lbs., or of the 800 lbs. of ammoniacal salts, was (so far as its nitrogen was concerned) at any rate mainly due to that which was thus *artificially supplied.* Assuming this to have been the case, it would result that the first increment of 400 lbs. of ammoniacal salts (= 100 lbs. ammonia) yielded an increase of 1 ton 15⅜ cwts. of hay, but that the second increment of the same amount gave a further increase of only 4⅜ cwts. The two together, as above stated, gave 1 ton 19¾ cwts. of increase. As the nitrogenous supply was increased, the effect of a given amount of it was therefore very greatly diminished. Nor is this result to be attributed to a deficiency of mineral constituents where the larger amount of ammoniacal salts was employed. The produce on the addition to the mineral manure of the *smaller* amount of ammoniacal salts, was indeed quite as heavy, if not heavier, than the soil and seasons were suited to mature advantageously. Further evidence on the point will be adduced in a subsequent section of the Report. But it may be here stated in passing, that the crop grown by the *larger* amount of ammoniacal salts—supplying as it did the enormous quantity of 200 lbs. of ammonia per acre per annum—was so over-luxuriant, as to be much laid, matted together, and dead at the bottom, some time before the bulk was ready for cutting.

It has been already stated that the trials with *nitrate of soda* were not commenced until the last of the three seasons, over which the other experiments extended. The nitrate too, was sown about a week later than the other manures. The result of this single season's trial with the nitrate was, that a given amount of nitrogen so supplied, did not increase the produce of hay equally with the same amount in the form of ammoniacal salts. Still the influence of artificial nitrogenous supply upon the Grass crop is here again illustrated.

Nitrate of soda, in amount supplying nitrogen equal to about 50 lbs. of ammonia per acre (Plot 6), gave scarcely any increase

whatever over the *mean* unmanured produce of the same season.* Double this amount of nitrate of soda (Plot 7), containing nitrogen equal to the ammoniacal salts of Plot 4, gave about $3\frac{3}{4}$ cwts. less increase of hay per acre than the equivalent amount of ammoniacal salts. When the smaller amount of nitrate of soda was used in conjunction with the "mixed mineral manure," the produce amounted to 1 ton $17\frac{3}{4}$ cwts. of hay, or to $11\frac{1}{2}$ cwts. more than when the same amount of nitrate was used alone. Lastly, with the larger amount of nitrate of soda (= in nitrogen to the 400 lbs. of ammoniacal salts), together with the "mixed mineral manure" (Plot 15), there were 2 tons $10\frac{3}{8}$ cwts. of produce instead of 1 ton $11\frac{1}{4}$ cwts. by the same amount of nitrate of soda without the mineral constituents. This increased produce by the nitrate of soda and mineral constituents was, however, considerably less than either the average annual yield, or that of the third season taken alone, by an equal amount of nitrogen in ammoniacal salts, with the mineral manure in addition. So far, however, as the action of the manures applied in such full quantity is cumulative from year to year, it will of course to that extent be illegitimate to draw any strict comparison between the produce of one manure in its third season, and that of another in its first season of application. The character of nitrate of soda as an efficient Grass manure, and as acting, both on this and other crops, by virtue of the nitrogen it contains, is too well established by other experiments—indeed by common experience also—to admit of doubt. It remains to be seen, what will be the comparative effects of a given amount of nitrogen supplied in nitrate of soda and in ammoniacal salts respectively, when the trials have been continued over numerous and various seasons.

Before leaving the results with the nitrate of soda, it should be stated that it had the same effects as the ammoniacal salts, in discouraging the growth of the Leguminous herbage, and in encouraging that of the Graminaceous plants, or Grasses. The increase of action when the mineral constituents were added to the nitrogen in the form of the nitrate, was, therefore, as in the case of their addition to the ammoniacal salts, *not* to be attributed to their enabling Graminaceous plants to take up more nitrogen *from natural or unaided sources*, but to their supplying, within a limited range of the soil, the mineral constituents requisite for the efficient action upon the collective and assimilative processes

* It will be remembered, however, that in this third season the duplicate unmanured plot gave an obviously somewhat excessive produce of hay; it having given smaller *mown* crops than the other in the preceding seasons, but more after-feed, and hence the condition of the land on the duplicate plot would be relatively somewhat too high for the third mown crop.

of the plants, of the *nitrogen artificially supplied.* It will be shown, on a future occasion, that the *percentage* of nitrogen in the dry substance of the hay, grown both by ammoniacal salts alone, and by nitrate of soda alone, was comparatively very high—in fact, considerably higher than when the mineral manures were also employed, whereby the Graminaceous produce was much increased. So far then as there was an excessive amount of nitrogen, in the form of elaborated nitrogenous vegetable compounds, where the supplied nitrogen was liberal—the mineral constituents in defect—and the growth restricted thereby—it was that there is a relative deficiency in the formation of the *non*-nitrogenous vegetable substances.

Attention has now been called to the annual amount of hay obtained both without manure, and by the use of certain individual, or classified constituents of manure. In this way, some information has been acquired as to the manurial requirements for the growth of a heavy produce of the crop in question. Let us now examine—what were the effects upon the hay crop of that complex substance—*Farmyard manure?* And, bearing in mind the facts already brought to view, in regard to the action of certain individual manures, let us endeavour to form a judgment as to which of the constituents, or classes of constituents, of farmyard manure, its effects upon the hay crop are mainly, or at any rate characteristically, due.

The annual application of 14 tons of *farmyard manure* per acre, gave, over the three years, an average annual produce of 2 tons $\frac{1}{4}$ cwt. of hay, $= 16\frac{1}{4}$ cwts. per acre per annum more than the unmanured plot. This increase by farmyard manure is greater than that by either the mixed mineral manure alone, or the ammoniacal salts alone; but it is less than half the increase obtained when these two descriptions of manure were used conjointly. This increase of $16\frac{1}{4}$ cwts. of hay per annum, by the use of 14 tons of dung is, it will be seen, little more than 1 cwt. of hay for every ton of the manure employed.

It has been seen that *carbonaceous substance*, whether applied in the form of sawdust or of cut wheat-straw, had little or no effect upon the hay crop. It is probable that the carbonaceous substance of the dung would yield up its carbon in the form of carbonic acid, or of other products of decomposition, more readily than that of either of the substances just mentioned. But the farmyard manure contained, besides carbonaceous substance, a large amount of both mineral constituents, and of ammonia, or nitrogen in some form. It has been seen, too, that these latter substances, when used without carbonaceous matter, gave greatly increased crops of hay. Under these circumstances, we can hardly hesitate to attribute the main effects of the farmyard

manure upon the hay crop, rather to the conjoint action of its mineral and nitrogenous constituents than to its enormous bulk of carbonaceous substance.

That the *mineral* constituents of the dung had their share of effect, would appear from the facts, that the *Leguminous* herbage was moderately luxuriant on the dung plot, and that those of the *Grasses* were the most developed, which were increased in their proportion to the rest by the artificial mineral manures. And again, that the *nitrogen* also of the dung was effective, may be judged, not only from the general development of the Graminaceous plants under its use, but from the fact of a like fullness in the proportion of the Grasses *in flowering and seeding stem*, as where ammoniacal salts were employed in conjunction with the mixed mineral manure. It would appear, however, that a much less proportion of the whole nitrogen supplied to the land was active, when it was provided in the form of farmyard manure, than when in that of ammoniacal salts. There would, in fact, be considerably more of nitrogen applied per acre in the 14 tons of farmyard manure, than in the 400 lbs. of the mixed ammoniacal salts. Nevertheless, the encouragement of the Leguminous plants was much greater, and that of the Graminaceous ones much less, where the farmyard manure was employed, than where the 400 lbs. of ammoniacal salts, together with the mixed mineral manure, were used.

That the less produce by the farmyard manure, than by the mixed mineral manure and 400 lbs. of ammoniacal salts, was due to a deficiency of *available* nitrogen, notwithstanding the large actual *amount* of it in the dung, would appear from the fact, that on the employment of 200 lbs. of ammoniacal salts *in addition* to the farmyard manure (Plot 17), there was a further average annual increase of $8\frac{3}{8}$ cwts. of hay per acre. Still, even with this addition, there was about $\frac{1}{4}$ a ton less of hay annually than where the "mixed mineral manure" and the 400 lbs. of ammoniacal salts were applied.

The evidence regarding the action of the *farmyard manure* goes to show, that, though it is doubtless a very complete and important restorer of both the mineral constituents and the nitrogen required to repair the exhaustion of this most greedy crop, yet, the amount of these constituents supplied by its means is proportionally much less active within a given time than that provided in the artificial combinations. As, however, permanent meadow-land, especially when attached to an arable farm, does not, as practice goes, so much as a matter of course, come in for a due periodic supply of farmyard manure as does the land under rotation, it becomes far more necessary in its case to bestow special consideration that the mineral constituents be not exhausted

TABLE II.—SHOWING the Number of SHEEP fed by the AFTER-GRASS, and the quantity of HAY to which it is estimated to be equivalent

Plot, Nos.	MANURES (Per Acre, per Annum).	Area of Plots.	ACTUAL PARTICULARS OF THE FEEDING. 1856. Sheep put on, Oct. 10. Number of Sheep.	1856. Number of Days Feeding.	1857. Sheep put on, Sept. 23. Number of Sheep.	1857. Number of Days Feeding.	1858. Sheep put on, Oct. 18. Number of Sheep.	1858. Number of Days Feeding.	CALCULATED RESULTS. Number of Sheep kept for One Week per Acre. 1856.	1857.	1858.	Average Annual.	Estimated Average Amount of Hay per Acre, per Ann. in the After-grass.* lbs.
SERIES 1.—Without Direct Mineral Manure.													
1	Unmanured	Acre. ¼	10	13	8	13	10	12	74·3	59·4	68·6	67·4	1078
2	Unmanured (duplicate plot)	¼	10	17	10	13	†9½	12	97·4	74·3	65·2	79·0	1264
	Mean, or Standard Unmanured		10	15	9	13	†9¾	12	85·8	66·8	66·9	73·2	1171
3	2000 lbs. Sawdust	½	20	13	16	13	16	12	74·2	59·4	54·8	62·8	1005
4	200 lbs. each, Sulphate and Muriate Ammonia	½	20	14	20	13	20	12	80·0	74·2	68·6	74·3	1189
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	½	20	14	20	13	20	12	80·0	74·2	68·6	74·3	1189
6	275 lbs. Nitrate of Soda	1/6	. .	. .	. .	. .	60	1	. .	. .	102·8	102·8	1645
7	550 lbs. Nitrate of Soda	1/6	. .	. .	. .	. .	60	1	. .	. .	102·8	102·8	1645
SERIES 2.—With Direct Mineral Manure.													
8	"Mixed Mineral Manure"	½	20	14	25	13	25	12	80·0	92·8	85·8	86·2	1379
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	½	20	14	25	13	25	12	80·0	92·8	85·8	86·2	1379
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	½	30	11	30	12	30	12	94·2	102·8	102·8	99·9	1598
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat Straw	½	30	11	30	12	30	12	94·2	102·8	102·8	99·9	1598
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	½	30	17	30	13	30	12	145·6	111·4	102·8	119·9	1918
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	½	40	11	40	12	40	12	125·8	137·2	137·2	133·4	2134
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	1/6	. .	. .	. .	. .	60	1	. .	. .	102·8	102·8	1645
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	1/6	. .	. .	. .	. .	60	1	. .	. .	102·8	102·8	1645
SERIES 3.—With Farmyard Manure.													
16	14 Tons Farmyard Manure	¼	10	13	12	13	11	12	74·2	89·2	75·6	79·7	1275
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	¼	10	13	12	13	11	12	74·2	89·2	75·6	79·7	1275

* The calculation is made on the assumption that each Sheep would eat grass = 16 lbs. of Hay per week.
† One Sheep was taken from this plot to be killed when it had been only half the period feeding.

exhausted, than in that of rotation crops under ordinary good management. In fact, the grass-land of the arable farm is but too frequently looked upon as the legitimate sphere for robbery for the other crops. Indeed, considering the nature of the exhaustion of permanent grass-land generally, when mown for hay, and at the same time bearing in mind the character of the artificial manures, which are, in point of economy, at the command of the farmer, it would seem that the *permanent* condition of such land should be kept up by farmyard manure, stable dung, town manures, and the like, and the *active growth* aided, year by year, by the so-called artificial, nitrogenous—or, better still, nitrogenous and phosphatic—manures. Where hay is grown for the supply of a neighbouring town, the (in the above sense) permanent condition of the land is very generally maintained by town manures of some kind brought by the return carriage. But where hay is grown on an arable farm, and is mown for consumption by the stock (or, still worse, for sale), the return is but too often by no means so complete. The question of keeping up the fertility of grass-land by sewage, or other irrigation, is one of course of entirely separate consideration from that now before the reader.

Before giving a summary enumeration of the results and conclusions thus far indicated, it will be well to direct attention to the relative, and, as far as they can be estimated, the *actual* amounts of *after-grass* yielded, on the differently manured plots.

In TABLE II. are given:—

In the 1st Division—the actual number of sheep that were put upon each plot of after-grass, and the actual number of days they were fed upon it, in each of the three seasons of the experiments;

In the 2nd Division—the number of sheep calculated to be kept per acre, on each plot for one week, in each of the individual seasons, and on the average of the three seasons; and

In the last column of the Table—the estimated average annual amount of hay per acre, to which the after-grass consumed would be equivalent, reckoning the sheep to eat grass equal in amount to 16 lbs. of hay per head, per week.

Calculating the after-grass into its assumed equivalent of hay, as above described, the result is, of course, only an approximation to the truth. Looked upon as such, it is not without its value and interest. The so-estimated amounts of after-feed on the respective plots show, as compared one with another, relations very coincident, in general direction, with those indicated by the mown first-crops of hay.

It has already been noticed that the produce of first-crop hay on Plot 2 (the duplicate unmanured plot) was less in the first two seasons, and more in the third, than on Plot 1, the other unmanured one. Table II. shows, on the other hand, that there was rather more after-feed in the two first seasons on the duplicate unmanured plot than on the other. Taking the mean of the two plots, the unmanured land shows an average annual yield of after-grass = 578 lbs. of hay. The sawdusted plot, as in the first crop, so again in the second, gives rather less produce than the unmanured one. The ammoniacal salts alone gave rather more after-feed than the unmanured plot; and the ammoniacal salts and sawdust gave the same amount as the ammoniacal salts alone. The Plot with the "mixed mineral manure" alone, with its luxuriant Leguminous herbage, gave more after-feed than the one with ammoniacal salts alone. The addition of the sawdust to the "mixed mineral manure" gave no further increase. The Plot with both the "mixed mineral manure" and the 400 lbs. of ammoniacal salts, as in the first crop, so now in the second, gave more produce than either of the plots where the respective manures were used separately. The addition of sawdust to the mixture of the two manures gave no further increase. The addition of cut wheat-straw, instead of sawdust, showed some advantage in the second crop, the produce in the first crop being somewhat deficient. The combination of the "mixed mineral manure," and the double amount (= 800 lbs. per acre) of ammoniacal salts, gave the largest amount of first-crop hay, and now again the largest amount of after-grass, of any manure in the series.

1171

The nitrate of soda, which was used only in the third season, and then yielded less of first-crop hay than an amount of ammoniacal salts equal to it in contents of nitrogen, appears, according to the figures in the Table, to have given, on the other hand, a larger amount of after-grass. As, however, a large and equal number of sheep was put upon each of the nitrate plots, and *for one day only*, not even the relative amounts, still less the actual quantities recorded as estimated second-crop hay, can be much relied upon in these cases of experiment with the nitrate.

The farmyard manure plots gave of second crop, as they did of first, a produce intermediate between that without manure, and that by the "mixed mineral manure" and 400 lbs. of ammoniacal salts.

Were these estimated amounts of hay in the second crop of the respective plots, to be added to those actually removed in the first crop, the *comparative* action of the different manures as it

would be then represented, would not appear to differ in any material point from that indicated by the amounts of hay actually taken off in the first crop. Independently of this, however, by far the larger proportion of both the mineral constituents and the nitrogen of the second crop would, as before stated, be returned to the land by the sheep feeding upon it. It would, therefore, obviously be a further deviation from the true representation of the actual facts, to take into account the estimated second crop as a part of the removed produce of the manures employed, than to omit it from the calculation altogether. These estimated amounts of second crop, varying as they do in the proportion of from 1 to 2, according to the manure employed, are, nevertheless, interesting of themselves, as showing great differences in vegetative activity after removal of the first crops, depending, of course, on the varying character and amount of the residual or unused manure. They are, moreover, useful aids in forming a judgment respecting the comparative cumulative effects, from year to year, of the different manures. But when, in a subsequent Part of this Report, we come to consider the debtor and creditor account of certain constituents on the several plots—the relation of the amounts removed in the produce to those supplied in manure—we shall assume the amounts taken off in the increase of the first crop only, as the most nearly representing the gain due to the supply in the manure employed.

It is proposed, in a subsequent section—to show the acreage amounts of certain constituents removed in the produce from the different plots, and the relation of these in the increase, to those supplied in the manures—to consider in some detail the varying description of the herbage according to the manure employed—and to show the consequent variations in the chemical composition of the complex gross produce, or *hay*. In the mean time, founded upon the evidence thus far recorded, relating to the amount per acre, and the general character, of the hay obtained by the different manures, the following general results and conclusions may be enumerated:—

1. That the effect of a mixed, but purely *mineral manure*, upon the complex herbage of permanent meadow land, was chiefly to develop the growth of the *Leguminous* plants it contained; and scarcely at all to increase the produce of the *Graminaceous* plants, or commonly called *Natural Grasses*.

2. That the action of purely *nitrogenous manures*, upon the per-

manent meadow, was to discourage the growth of the *Leguminous* herbage, and to increase the produce of the *Graminaceous* hay.

3. That by the *combination of both nitrogenous and proper mineral manures*, the produce of *Graminaceous* hay was very much increased. In the particular soil and seasons in question, the increase obtained by the combination was far beyond the sum of the increase yielded by the two descriptions of manure, when each of them was used separately.

4. That *farmyard manure* gave a considerable increase of chiefly *Graminaceous* hay. In the soil and seasons in question, however, the artificial combination of nitrogenous and mixed mineral manure yielded a very much larger increase than an annual dressing of 14 tons of farmyard manure.

5. That peculiarly *carbonaceous manures* had little or no beneficial effect on the amount of produce of the hay. That the little effect (if any) which the carbonaceous manures did exhibit, seemed to be favoured by admixture with mineral manures; and then (as when the mineral manures were used alone) it appeared to be the Leguminous, rather than the Graminaceous herbage, that was encouraged.

6. That the beneficial action of *farmyard manure* upon the Grass crop, is to be attributed chiefly to its *mineral and nitrogenous constituents*, and comparatively little to its large amount of carbonaceous substance.

7. That the large increase of produce obtained by the *combination of nitrogenous and mixed mineral manure*, being almost entirely *Graminaceous*, the mineral manures, when in this combination, did not act as when used alone, in developing the highly nitrogenous *Leguminous* herbage. The great increase in the produce of hay obtained by the conjunction of the mineral with the nitrogenous manure, is to be attributed to the supply, within a limited range of the soil, of a sufficient amount of the necessary mineral constituents, to enable the *Graminaceous* plants to turn to the account of growth, *the nitrogen at the same time artificially supplied.*

8. The general result is, that the Leguminous plants in the *meadow*, like those grown in our *arable fields*, were much increased in growth, and assimilated more nitrogen from unaided sources over a given area, when they were liberally supplied with certain *mineral*, or *primarily soil-constituents*. At the same time, notwithstanding the high (both percentage and acreage) yield of nitrogen in Leguminous produce generally, the increased growth of the *Leguminous herbage of the meadow* was not favoured by the direct supply of nitrogenous manures—a result which is again very similar to that obtained with the *Leguminous*

crops of our rotations. On the other hand, the Graminaceous *hay plants*, like the Graminaceous *corn-crops of our rotations*, assimilated but little more nitrogen, from natural sources, under the influence of liberal supplies of purely mineral manure; they gave a largely increased growth, only when there was an artificial supply of *available nitrogen within the soil;* and when this was provided, the direct supply of mineral constituents was essential to its full effects.

The more practical conclusions may be very shortly stated. In order that the more temporary, or more rapidly acting means of increasing the produce of meadow land, may have their full effect, the more permanent means of amelioration that may be required—such as draining, marling, liming, and the like—must not be neglected. The application of bones is not recommended for general adoption. They appear to be chiefly adapted to the exhausted pastures of certain localities, and not to be generally applicable to meadow land which is mown for hay. The hay crop is a great exhauster of the mineral constituents of the soil; and these, owing to the high price of salts of potash, cannot, with profit, be fully restored in artificial manures. The return of the mineral constituents is better accomplished by means of farmyard manure, stable dung, night soil, and the like; which, at the same time, bring on to the land a more or less considerable quantity of available nitrogen. The best "*artificial*" manures for grass-land, are, Peruvian guano, which is rich in phosphates as well as nitrogen; and nitrate of soda, and sulphate of ammonia, which are rich in nitrogen, but contain, of course, no phosphates. Peruvian guano, when used alone, may be employed at the rate of from 1½ to 2½ cwts. per acre; nitrate of soda alone, or sulphate (or muriate) of ammonia, at the rate of 1½ to 2 cwts. per acre. The salts of ammonia are, however, relatively too expensive to be employed largely with profit; and both ammoniacal salts and nitrate of soda are more advantageously used in combination with guano. A very generally useful top-dressing for the hay crop may be made of 3 parts Peruvian guano, 1 part nitrate of soda, and 1 part sulphate of ammonia. Of this mixture, 2 to 2½ cwts. per acre may be employed. With this applied annually, and the application of 10 or 12 tons per acre of poor rotten dung once every four or five years, a good crop of hay may be taken off every year, without injury to the land. The best time of sowing the "artificial" manures is generally in January; and it should at any rate be seldom postponed beyond February.

Part II.—Produce of Constituents per Acre.

In order that the more directly practical conclusions to be drawn from the experiments might be brought out more prominently, attention was confined in the former section of our Report almost exclusively to the nature of the manures employed, and to the amounts of the gross produce or increase of hay obtained by their use. A few passing remarks only were made upon the variable character of the herbage, according to the description of manure employed. But there are other aspects of the subject than those hitherto considered, which are well worthy the attention of the intelligent farmer.

The permanent meadow land of a farm stands in a somewhat isolated position in regard to the crops under tillage. In the case of the *rotation* crops, the straw of the corn ones, the larger portion of the most important manurial constituents of the green crops, frequently the manure from the consumption of the hay of the meadow land itself, and perhaps that from imported cattle-food also, will, at least once in the course, find their way to the arable land. But the meadow land does not generally come in for a due share of restoration of constituents by the home manures. Hence it happens, that the amount of constituents actually carried from the land, year by year, in the hay crop, has generally a more direct influence on exhaustion, than that harvested in the rotation produce.

It is important to consider then—what amounts of the several constituents are taken from an acre of land in an ordinary crop of hay?—what is the drain of them, which the stores of the soil, or the supplies of other manures, are called upon to meet, when the produce is increased by means of active portable manures?—and further, what is the proportion of the active manurial constituent *nitrogen* supplied in such manures, that is recovered in the increase of crop obtained by its use?

It is also essential to a right appreciation of the action of different manures upon the grass-crop, carefully to ascertain their influence upon the development of the different plants of which the mixed herbage is made up, and at the same time to take into consideration the recognised comparative qualities of the different plants so developed.

Lastly, with a great variation in the proportion of the different plants developed, and in the degree of their maturity at any given time, according to season and the manure employed, it is obvious, that there must be corresponding variation in the per-centage composition of the complex produce—*hay*. The influence of the different manures upon the *chemical composition of the hay* constitutes, therefore, another important point of inquiry.

It would perhaps, in some points of view, be more in order to

give the results of the analyses, and with them to consider the *per-centage* composition of the hay, before treating of the *acreage* yield of the several constituents, calculated by means of those results; but it will, upon the whole, be more convenient to complete the subject of the *quantity* of produce before commencing upon that of *quality*.

Having, therefore, in Part I., considered the acreage amounts of the *gross produce*, or *hay*, attention will be directed in the present section (Part II.) to the acreage quantities of certain *constituents*, or *classes of constituents*, obtained by the different manures.

Part III. will be devoted to the discussion of one element of quality, namely, that of the description and proportion of the different plants developed.

Lastly, in Part IV., the *per-centage composition* of the complex produce—*hay*, will be considered.

The particulars relating to the amount of the several constituents, per acre, contained in the produce by the different manures, are given in a series of Tables, as follow:—

In Table III.—The produce of hay, per acre, calculated in lbs., as the basis of the succeeding Tables.

In Table IV.—The produce of total *dry substance*, per acre, in lbs.

In Table V.—The *mineral matter* (ash), per acre, in lbs.

In Table VI.—The *nitrogen* in the *total produce*, per acre, in lbs.

In Table VII.—The *nitrogen* in the *increase by manure*, per acre, in lbs.

In Table VIII.—The *proportion* of the *nitrogen recovered in increase, for* 100 *parts supplied in manure.*

1. *The Dry Matter per Acre.*

On the amounts of *dry matter*, per acre (Table IV.), a very few observations will suffice. Taking the average of the three years over which the experiments extended, the annual yield of dry matter was, *without manure*, almost exactly a ton per acre. This is slightly under the amount obtained, without manure, in *wheat* (corn and straw together), taking the average of fourteen years of the consecutive growth on the same land; and it is several hundredweights below that obtained in *barley*, without manure, taking the average of six years' consecutive growth on the same land.

By means of *manures*, the yield of dry matter, per acre, in the hay crop, was in several of the experiments considerably more than doubled. The increased produce of dry matter was thus great—indeed the greatest—where no carbonaceous manure whatever was employed. It may be reckoned that the dry substance of the hay would contain about 40 per cent. of carbon. Adopting this estimate, there would be about 900 lbs. of carbon assimilated per acre,

Table III.—Produce of Hay per Acre: lbs.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	ANNUAL PRODUCE. 1856.	1857.	1858.	Average of 3 Years.	Average Annual Increase by Manure.
	Series 1.—Without Direct Mineral Manure.					
1	Unmanured	2515	2856	2472	2614	..
2	Unmanured (duplicate plot)	2351	2592	3360	2768	..
	Mean, or Standard Unmanured	2433	2724	2916	2691	..
3	2000 lbs. Sawdust	2312	2340	2244	2299	−392
4	200 lbs. each, Sulphate and Muriate Ammonia	4028	3774	3982	3928	1237
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	3953	3710	4166	3943	1252
6	275 lbs. Nitrate of Soda	..	..	2952	..	261
7	550 lbs. Nitrate of Soda	..	..	3564	..	873
	Series 2.—With Direct Mineral Manure.					
8	"Mixed Mineral Manure"	3429	3666	4082	3726	1035
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	3711	3994	4376	4027	1336
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	6363	6422	7172	6652	3961
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	6369	6428	6892	6563	3872
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	5412	6050	6752	6071	3380
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	6970	6940	7508	7139	4448
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	..	..	4236	..	1545
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	..	..	5646	..	2955
	Series 3.—With Farmyard Manure.					
16	14 Tons Farmyard Manure	4030	5328	4164	4507	1816
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	5009	6008	5320	5446	2755

* For full description of the "*Mixed Mineral Manure*," see Part I. of this Paper.

Experiments with Different Manures on Permanent Meadow Land.

Table IV.—Produce of Total Dry Substance per Acre; lbs.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	ANNUAL PRODUCE. 1856.	1857.	1858.	Average of 3 Years.	Average Annual Increase by Manure.
	Series 1.—Without Direct Mineral Manure.					
1	Unmanured	2061½	2431¾	2124½	2205½	..
2	Unmanured (duplicate plot)	1885¾	2262¾	2872	2340	..
	Mean, or Standard Unmanured	1973½	2347¼	2498¼	2273	..
3	2000 lbs. Sawdust	1866¼	2052¼	1893½	1937½	−335¾
4	200 lbs. each, Sulphate and Muriate Ammonia	3222½	3272	3348	3280¾	1007¾
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	3148¼	3251½	3496	3298½	1025½
6	275 lbs. Nitrate of Soda	..	..	2503¼	..	230¼
7	550 lbs. Nitrate of Soda	..	..	3059¼	..	786¼
	Series 2.—With Direct Mineral Manure.					
8	"Mixed Mineral Manure"	2751½	3179¾	3493½	3141½	868½
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	2987½	3466¾	3679¼	3377⅛	1104½
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	5024¼	5591½	5889½	5501¾	3228¾
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	4924½	5606½	5778½	5436½	3163½
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	4286¾	5249½	5562¾	5033	2760
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	5445	5967	6057½	5823	3550
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	..	..	3660¼	..	1387¾
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	..	..	4811½	..	2538½
	Series 3.—With Farmyard Manure.					
16	14 Tons Farmyard Manure	3068½	4652½	3521	3747¼	1474¼
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	3985¼	5181¼	4400¾	4522½	2249½

Experiments with Different Manures on Permanent Meadow Land.

Table V.—Produce of Total Mineral Matter (Ash), per Acre: lbs.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	ANNUAL PRODUCE. 1856.	1857.	1858.	Average of 3 Years.	Average Annual Increase by Manure.
	Series 1.—Without Direct Mineral Manure.					
1	Unmanured	157·4	160·7	141·0	153·1	..
2	Unmanured (duplicate plot)	156·1	148·0	186·8	163·7	..
	Mean, or Standard Unmanured	156·8	154·4	163·9	158·4	..
3	2000 lbs. Sawdust	153·0	132·0	113·8	132·9	−25·4
4	200 lbs. each, Sulphate and Muriate Ammonia	259·4	206·8	204·5	223·6	65·2
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	237·5	206·5	222·1	222·0	63·6
6	275 lbs. Nitrate of Soda	..	..	169·1	..	10·7
7	550 lbs. Nitrate of Soda	..	..	191·7	..	33·3
	Series 2.—With Direct Mineral Manure.					
8	"Mixed Mineral Manure"	237·4	225·8	264·5	242·6	84·2
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	271·3	263·4	283·2	272·6	114·2
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	431·2	403·3	468·5	434·3	275·9
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	447·9	412·4	468·7	443·0	284·6
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	364·1	394·9	451·2	403·4	245·0
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	457·9	445·5	476·6	460·0	301·6
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	..	..	271·1	..	112·7
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	..	..	368·1	..	209·7
	Series 3.—With Farmyard Manure.					
16	14 Tons Farmyard Manure	293·9	346·7	279·8	306·8	148·4
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	376·5	387·6	358·4	374·2	215·8

Experiments with Different Manures on Permanent Meadow Land.

Table VI.—Produce of Nitrogen per Acre: lbs.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	ANNUAL PRODUCE. 1856.	1857.	1858.	Average of 3 years.	Average Annual Increase by Manure.
	Series 1.—Without Direct Mineral Manure.					
1	Unmanured	42·2	36·8	34·6	37·9	..
2	Unmanured (duplicate plot)	42·1	38·1	45·0	41·7	..
	Mean, or Standard Unmanured	42·2	37·4	39·8	39·8	..
3	2000 lbs. Sawdust	38·6	32·3	31·6	34·2	−5·6
4	200 lbs. each, Sulphate and Muriate Ammonia	63·2	58·5	65·7	62·5	22·7
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	62·8	55·3	65·0	61·0	21·2
6	275 lbs. Nitrate of Soda	..	..	49·6	..	9·8
7	550 lbs. Nitrate of Soda	..	..	60·9	..	21·1
	Series 2.—With Direct Mineral Manure.					
8	"Mixed Mineral Manure"	57·3	55·4	57·1	56·6	16·8
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	65·7	59·1	60·8	61·9	22·1
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	78·3	75·8	89·6	81·2	41·2
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	80·2	71·3	80·6	77·4	37·6
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	79·5	80·8	91·1	83·8	44·0
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	103·8	112·4	128·4	114·9	75·1
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	..	..	64·4	..	24·6
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	..	..	74·5	..	34·7
	Series 3.—With Farmyard Manure.					
16	14 Tons Farmyard Manure	54·4	69·8	49·1	57·8	18·0
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	81·1	64·9	67·6	71·2	31·4

Table VII.—Nitrogen per Acre in Increase where a Known Quantity was supplied in Manure: lbs.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Increase over the Produce without Manure.				Increase over the Produce by the "Mixed Mineral Manure."			
		1856.	1857.	1858.	Average of 3 Years.	1856.	1857.	1858.	Average of 3 Years.
	Series 1.—Without Direct Mineral Manure.								
4	200 lbs. each, Sulphate and Muriate Ammonia	21·1	21·0	25·9	22·7	..	..	..	..
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	20·7	17·8	25·2	21·2	..	..	..	..
6	275 lbs. Nitrate of Soda	..	..	9·8	..	..	..	..	..
7	550 lbs. Nitrate of Soda	..	..	21·1	..	..	..	..	..
	Series 2.—With Direct Mineral Manure.								
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	36·1	38·3	49·8	41·4	21·0	20·4	32·5	24·6
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	38·1	33·9	40·8	37·6	23·0	16·0	23·5	20·8
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw ..	37·4	43·4	51·3	44·0	22·3	25·5	34·0	27·2
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	61·7	75·0	88·6	75·1	46·6	57·1	71·2	58·3
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	..	..	24·6	..	..	..	7·2	..
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	..	..	34·7	..	..	..	17·4	..
	Series 3.—With Farmyard Manure.*								
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia*	26·7	−4·9	18·4	13·4	..	..	..	..

* The Increase is here taken over the produce by Farmyard Manure alone.

Experiments with Different Manures on Permanent Meadow Land.

Table VIII.—Nitrogen *recovered*, and *not recovered*, in Increase, for 100 supplied in Manure.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Increase taken over the Produce without Manure.					Increase taken over the Produce by the "Mixed Mineral Manure."				
		Per-cent. of supplied Nitrogen recovered in Increase.				Average Per-cent. of supplied Nitrogen not recovered in Increase.	Per-cent. of supplied Nitrogen recovered in Increase.				Average Per-cent. of supplied Nitrogen not recovered in Increase.
		1856.	1857.	1858.	Average of 3 Years.		1856.	1857.	1858.	Average of 3 Years.	
Series 1.—Without Direct Mineral Manure.											
4	200 lbs. each, Sulphate and Muriate Ammonia ..	25·7	25·7	31·6	27·7	72·3	..	..	..	..	..
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	23·9	20·6	29·1	24·5	75·5	..	..	..	..	..
6	275 lbs. Nitrate of Soda	..	..	23·8	..	..	..	..	..	..	..
7	550 lbs. Nitrate of Soda	..	..	25·8	..	..	..	..	..	..	..
	Mean	24·8	23·1	..	26·1	73·9	..	..	..	..	..
Series 2.—With Direct Mineral Manure.											
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	44·0	46·7	60·8	50·5	49·5	25·6	24·9	39·6	30·0	70·0
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust ..	44·0	39·2	47·2	43·5	56·5	26·6	18·5	27·2	24·1	75·9
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat Straw	39·5	45·8	54·2	46·5	53·5	23·6	26·9	35·9	28·8	71·2
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	37·6	45·7	54·0	45·8	54·2	28·4	34·8	43·4	35·5	64·5
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	..	..	59·9	..	..	..	..	17·7	..	..
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	..	..	42·3	..	..	..	..	21·2	..	..
	Mean	41·3	44·4	54·0	46·6	53·4	26·0	26·3	36·5	29·6	70·4
Series 3.—With Farmyard Manure.											
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia*	65·2	−12·0	44·9	32·7	67·3	..	..	..	..	..

* The Increase is here taken over the produce by Farmyard Manure alone.

acre, in the average annual produce of the unmanured land. Where an enormous amount of organic matter, rich in carbon, was supplied in the form of sawdust, little or no increased assimilation of carbon took place; where a still larger quantity was employed in the form of farm-yard manure (in admixture, therefore, with other active manurial matters), there was a considerable increase in the assimilation of carbon. But, under these circumstances, it is doubtful whether the farm-yard manure itself was the source of the increased amount of carbon fixed, or, at any rate, whether its supply of that substance (in the form of carbonic acid or otherwise), has been at all essential.

Thus, it was by means of mixtures of mineral manures and ammoniacal salts, without the direct supply of any carbon, that the greatest increased assimilation of that substance was obtained. For instance, on plots 10 and 13, there was an average of about 1½ tons of increase of dry substance per acre, per annum, by the use of the mixed mineral manure and ammoniacal salts. This amount of gross dry increase represents an increased assimilation of carbon, by about 12 cwts. per acre per annum, without the supply of any in the manure. To this enormous extent, therefore, have these *non*-carbon-yielding manures enabled the plants, either by their roots or their leaves, to draw that element, so essential for the maintenance of the respiration, and for the fattening of our animals, from the *atmosphere*:—into which, in the course of the ever-constant revolutions of organic nature, it had been emitted by the combustion or decomposition of the products of former vegetation, or by the respiration of animals fed on former crops:—and into which, it is destined to be returned by the same means, as the resource of future vegetable growth.

It was seen, how unavailing were *mineral manures alone* materially to increase the growth of the *Graminaceous* hay-plants. That is to say, by their supply alone, these plants were not enabled to assimilate an increased amount of either nitrogen or carbon from natural sources. Nor did the supply of one of these elements — *carbon* — enable the plants to draw from natural sources an increased amount of the other element—*nitrogen*. On the other hand, provided there were a sufficiency of the necessary mineral constituents, the supply of the element *nitrogen*, in an available form of combination, increased enormously the assimilation of the atmospheric constituent *carbon*. It may be remarked in passing, that a very similar result is observed when nitrogenous manures are employed for the *Graminaceous crops of our rotations*. Not that no other crops are found to assimilate an increased amount of carbon without its supply in manure, when they have a sufficiency of mineral constituents and available nitrogen within the soil. But compared with others, the

Graminaceous crops appear to be the most strikingly independent of any artificial carbonaceous supply.

2. *The Mineral Matter per Acre.*

The average annual yield per acre of *mineral matter* (Table V.) was, in the *unmanured hay-crop*, 158½ lbs. This, it may be observed, is about 1½ times as much as was contained in the annual *unmanured* produce of either *wheat* or *barley*.

By the use of *ammoniacal salts alone*, an average of 223½ lbs., or about 2 cwts. of mineral matter, was annually taken from the land in the hay-crop. This, again, is from 1⅓ to 1½ times as much as was removed in either wheat or barley when similarly manured—that is, by ammoniacal salts alone. By the *addition of mineral manures to the same amount of ammoniacal salts*, the quantity of mineral matter annually taken off the land in the hay-crop was increased to nearly 4 cwts. per acre. Against this amount, *farm-yard manure* gave an average of only 306¾ lbs. of mineral matter in its annual yield of hay, notwithstanding that it itself contained not only a very large amount of mineral constituents, but of nitrogen also, which is so essential to bring them into play. This comparatively defective action of the constituents of farm-yard manure is, doubtless, owing in great measure to the slow liberation of both the nitrogen and the mineral matter supplied in that form. When *ammoniacal salts* were used in *addition to the farm-yard manure*, still only 374¼ lbs of mineral matter were annually taken from the land; that is to say, still considerably less than when the whole of both the nitrogen and the mineral matter were provided in a more readily available condition.

It is more particularly in *potash*,* that the hay-crop is more exhausting than what might be called a corresponding produce of either wheat or barley. In relation to this point, attention should be called to the fact, that, as practice goes, almost as a matter of course, a notable proportion of the phosphoric acid, and of the magnesia, almost the whole of the silica, and by far the larger proportion of both the lime and the potash, taken from the land in the *wheat* and the *barley* crops, will, at some period of the rotation, be returned to it, in the home-manures to which the straw of these crops has contributed. But, in the case of *meadow-land* associated with land under tillage, it is by no means so probable,

* Independently of the fact that an ordinary hay-crop will contain more mineral matter than the corn and the straw of an ordinary wheat or barley crop, the ash of the *hay* contains about twice as high a per-centage of *potash*, as that of the gross produce (corn and straw) of *wheat* or *barley*. But further particulars will be given regarding the *individual mineral constituents* of the hay-crop, in Part IV. of our Paper.

that the mineral constituents of the hay will, in anything like a corresponding degree, find their way back from whence they came. It will be obvious, therefore, that, according to current practice, the meadow-land will be much more liable than the arable to become deficient in a due provision of the necessary mineral constituents. These considerations show that both the wheat and the barley-crops may, with comparative impunity, be kept up to a high point of productiveness by means of forcing portable manures, provided only that the crops of the course, as a whole, receive their due share of the home manures. It will, at the same time, be equally obvious, that similar means are not applicable for the production of full crops of hay, unless similar conditions be provided; that is to say, unless the meadow, in its turn, receive a due proportion of the home manures.

Where, however, grass is grown for hay by those holding little or no arable land, it is generally for the supply of a neighbouring town; and in such cases a liberal amount of stable and other town-manures is generally brought upon the land. Under these circumstances, the additional use of the more active portable manures, will not, as a rule, be advantageous.

3. *The Nitrogen per Acre.*

Attention must now be directed to the acreage yield in the hay of the important constituent *nitrogen*. In the experiments under consideration, the annual yield of nitrogen per acre, taking the average result of 3 years, was, *without manure*, 39·8 lbs. (see Table VI.). By the side of this amount it may be mentioned, that the average of 14 consecutive years of *unmanured wheat* gave 30·7 lbs.; and that of 6 consecutive years of *unmanured barley*, 26·5 lbs. of nitrogen.

From these figures it appears, that the hay-crop (so far as the experiment has yet extended) has given from one-third to one-half more nitrogen per acre per annum, without manure, than either wheat or barley. Part of this excess of nitrogen in the hay-crop, though probably not the whole of it, is due to the fact, that the *mixed herbage* of the hay comprised a number of *Leguminous* plants, which contain a higher per-centage of nitrogen, and have apparently greater powers of assimilating it from natural sources, than the *Graminaceous* ones. Indeed, where mineral manures alone were employed (Plot 8), under the influence of which the development of *Leguminous* plants was greater than on any of the other plots, there was an average of 56·6 lbs. per acre per annum of nitrogen, without the supply of it in manure, instead of only 39·8 lbs. without manure of any kind. Thus, without the addition of any nitrogenous manure, there was

here an average annual increase of 16·8 lbs. of nitrogen per acre. But this increased yield of nitrogen obtained by the use of mineral manures, it is to be observed, was not due to an increased development of the *Graminaceous*, but to that of the *Leguminous* portion of the herbage. In fact, the annual yield of nitrogen per acre in this case, where the *Leguminous* plants comparatively so much predominated, was nearly double that which has been obtained in the continuously unmanured cereal crops of the arable land.

The next point of consideration in regard to the *nitrogen-statistics* of the *hay-crop*, is one of great interest, both in a practical and scientific point of view; namely, that of the relation of the nitrogen in the *increase*, to that in the *manure* employed to produce it. Tables VII. and VIII. illustrate this part of the subject. Table VII. shows the *actual increase* of nitrogen in the produce (in lbs. per acre), where it was supplied in manure. Table VIII. shows the *proportion* of nitrogen recovered in the increase, for 100 of it supplied in manure. But in both Tables two sets of columns are given. The first of these relates to the increase of nitrogen over that in the *unmanured* produce, and the second to the increase over that in the produce by the "*mixed mineral manure.*" The reader has thus the facts put before him in two aspects. It appears to us, however, from a careful consideration of all the circumstances of the experiments, that the only legitimate mode of estimating the amount, or proportion, of nitrogen recovered in the increase of hay, for a given amount of it supplied in the manure, will be to assume the nitrogen of the *unmanured*, and *not* that of the *mineral manured produce*, as the standard or normal yield, upon which to calculate the increase obtained by the action of nitrogenous manure—whether this be used alone, or in addition to mineral manures.

Thus, it must be remembered, that the increase, both of gross produce and of nitrogen, was, when *mineral manures alone* were employed, due to an increased development of *Leguminous* plants. On the other hand, when nitrogenous manures were used, either alone or in combination with mineral manures, the increase was due to the increased development of the *Graminaceous* herbage only. Under these circumstances, it is obvious, that the whole increase by the combined action of both nitrogenous and mineral manures (it being almost entirely graminaceous), must be supposed to be due, *so far as the resources of nitrogen are concerned*, to that artificially supplied in the manure. That is to say, bearing in mind the difference in the *description* and *composition* of the herbage grown by mineral manures alone, and by mineral manures in admixture with nitrogenous ones, the influence of the

addition of the nitrogen is not represented simply by the difference between the prominently *Leguminous* produce by mineral manures alone, and the almost exclusively *Graminaceous* produce, when nitrogenous as well as mineral manures are employed. It will be obviously much nearer the truth to assume, that the artificially supplied nitrogen—whether employed alone or in conjunction with mineral manures—was engaged in the production of *at least* the whole amount of increase *above* the produce *without manure.*

In fact, it is not impossible that, in even this mode of estimate, the degree in which the artificially-supplied nitrogen has been involved in the amount and composition of the produce, is somewhat understated. For, even the *unmanured* produce contained more of the highly-nitrogenized *Leguminous* herbage, than did that grown by either ammoniacal salts alone, or by ammoniacal salts in conjunction with mineral manure. Hence, it might be concluded, that the point beyond which the artificially-supplied nitrogen became involved in the production of *Graminaceous* increase, would be even *below* that represented by the acreage yield of nitrogen *without manure.* For, that amount depended materially upon the quantity of the highly *Leguminous* herbage in the unmanured produce, which was at once diminished on the addition of nitrogenous manures.

For the above reasons, then, it is assumed that, at least the whole of the nitrogen in the produce by nitrogenous manures *beyond that yielded on the unmanured plot* may be calculated as due, in a certain sense, to that which was artificially supplied—whether or not the nitrogen was so supplied alone, or was aided in its action by conjunction with mineral manures. At the same time, it is freely granted, that the legitimacy of any estimates regarding the proportion of the nitrogen supplied by manure which is involved in the increase obtained by its use, must rest entirely on that of the assumption made as to the amount of the whole nitrogen of the produce, which is to be attributed to natural sources. It is not, indeed, possible, to obtain actual proof, that produce grown by nitrogenous manures has really assimilated *neither more nor less* of nitrogen from other sources, than that grown without them. It might be supposed that, with a ready supply of available nitrogen within a limited range of the soil, the plants would draw less upon the natural or unaided resources. On the other hand, it might be assumed that, with the increased vigour of growth due to nitrogenous manure, the feeders of the plant would be so extended, both above and under ground, as to increase its command over the natural resources of available nitrogen. It is obvious, therefore, that the best estimate to which our judgment can lead, cannot, after all, be looked upon

as representing with certainty, the exact proportions in which the nitrogen of the manured produce has, in point of fact, been obtained from the natural and the artificial sources respectively. These observations will sufficiently indicate the degree of reservation with which the figures in the Tables, and the arguments founded upon them, should be accepted.

In regard to the figures in Table VII., which show in lbs. the *actual increase of nitrogen per acre by its use in manure*, it should be explained, that, where 400 lbs. of ammoniacal salts, or 550 lbs. of nitrate of soda, were employed per acre, it is estimated that 82 lbs. of nitrogen were thereby supplied. The 275 lbs. of nitrate of soda is, of course, assumed to supply half, and the 800 lbs. of ammoniacal salts double that amount. The 2000 lbs. of sawdust, according to direct analysis, would contain only 4½ lbs. of nitrogen. It is, then, to these amounts of nitrogen *supplied*, that those recorded in the Table as *increase*, are to be respectively referred.

But it is in Table VIII., where the *increase* of nitrogen in the produce is, for each experiment, calculated in relation to 100 parts of it supplied in manure, that the *proportion* of the nitrogen assumed to be recovered, to that supplied, is brought to view the most clearly.

Where ammoniacal salts were used alone (see upper Division of Table VIII.), there was, taking the average of the three years, only 27·7 *per cent.* of the supplied nitrogen recovered in the increase. And where the ammoniacal salts and sawdust were used, there was somewhat less still recovered, namely, 24·5 per cent.

The nitrate of soda, which was employed in one season only, and then sown somewhat disadvantageously late, when it was used alone, returned in the increase of produce nearly the same proportion of its nitrogen as the ammoniacal salts (as just quoted)—namely, 23·8 per cent. when the smaller amount, and 25·8 when the larger amount of the salt was used. But in reference to this result, it should be mentioned, that the *percentage* of nitrogen in the hay grown by the nitrate, was notably higher than in that grown by the ammoniacal salts in the same season; in fact, the proportion of nitrogen in the former was somewhat abnormally high.

The result was, then, that where either ammoniacal salts or nitrate of soda were employed without the aid of the mineral manure, there was only about *one-fourth* of the supplied nitrogen recovered in the immediate increase of the hay-crop.

In connexion with the result just stated, attention may be called to the fact, that if, where both mineral and nitrogenous manures are employed (see lower Division of Table VIII.), the

increase of nitrogen in the produce by the use of it in manure is supposed to be represented by *so much only* as was over and above that yielded by the *mineral manures alone*, there would then appear to be only about the same proportion of the supplied nitrogen recovered as when the nitrogenous manures were used alone, and the increase of nitrogen then calculated over that in the *unmanured* crop. Thus, taking, as supposed, the yield of nitrogen by the *mineral manures alone* as the basis of the calculation, the increase obtained by the super-addition of the 400 lbs. of ammoniacal salts will have returned only 30 per cent.; that by the 400 lbs. of ammoniacal salts, and 2000 lbs. of sawdust, only 24·1 per cent.; that by the 400 lbs. of ammoniacal salts and 2000 lbs. of cut wheat-straw, only 28·8 per cent.; and that by the 800 lbs. of ammoniacal salts, 35·5 per cent., of the supplied nitrogen. In regard to the fact, that there appears to be a larger proportion of the supplied nitrogen recovered (35·5 per cent.) when the extravagant amount of 800 lbs. of ammoniacal salts per acre was employed, it may be stated that the result is due to an extremely *high percentage* of nitrogen in the produce, and not to a favourable proportion of increase. The larger return of the supplied nitrogen is, therefore, though an apparent, yet only a questionable advantage. Adopting the same mode of calculation as above, the addition of nitrate of soda to the mineral manures gave a less favourable result than that of ammoniacal salts. When 41 lbs. of nitrogen were employed in the form of nitrate, there were only 17·7 per cent.; and when 82 lbs. of nitrogen were so provided, there were only 21·2 per cent. of the supplied nitrogen recovered in the increase.

But, reckoning, as has been shown it would be more proper to do, that the whole of the nitrogen obtained by the conjoint action of the mineral and nitrogenous manures *beyond that yielded without manure*, has probably been due to that artificially supplied, the proportional return in the immediate increase then appears to be much greater. On this mode of estimation, the 400 lbs. of ammoniacal salts (with mineral manure) have returned in the increase 50·5 per cent.; the 400 lbs. of ammoniacal salts and 2000 lbs. of sawdust (with mineral manure) 43·5 per cent.; the 400 lbs. of ammoniacal salts and 2000 lbs. of cut wheat-straw (with mineral manure) 46·5 per cent.; the 800 lbs. of ammoniacal salts (with mineral manure) 45·8 per cent.; the 275 lbs. of nitrate of soda (with mineral manure) 59·9 per cent.; and the 550 lbs. of nitrate of soda (with mineral manure) 42·3 per cent, of the nitrogen supplied in the manure.

Taking the average of the results just quoted, there were about 48 per cent. of the supplied nitrogen recovered in the immediate increase of the hay-crop, when the nitrogenous manure was asso-

ciated with a liberal provision of the necessary mineral constituents. Such at any rate is the result, on the assumption that as much of the nitrogen of the produce as was *in excess of that obtained without manure*, is to be attributed to that which was *artificially supplied*. When, however, the same nitrogenous manures were employed without the aid of mineral manures, only about half as much of the supplied nitrogen appeared to be recovered in the immediate increase. There was, moreover, little more than half as much of the supplied nitrogen estimated as recovered, if, when mineral and nitrogenous manures were used together, the yield of nitrogen by the *mineral manures alone*, instead of that *without manure*, were assumed to represent the amount obtained from natural sources. But, even though the *larger* amount may more nearly represent the actual proportion of the supplied nitrogen which was recovered in the increase when mineral manures were also used, it will be, at the same time, obvious that, in a certain *practical* sense, the only *gain* of nitrogen in produce by the addition of it to mineral manures, is that amount beyond what would have been obtained by the *mineral manures alone*.

On other occasions it has been shown, that, in the growth of full crops of either *wheat* or *barley* by the direct application of nitrogenous manures, little more than 40 per cent. of the supplied nitrogen could be estimated as recovered in the immediate increase obtained. It might perhaps be anticipated, that the result would be different in the case of the *hay-crop*. Not only are but few of the plants composing it fully ripe at the time of being cut, but their roots have a much more complete possession of the whole area of the superficial layers of soil. So far as the experiments have yet extended, the *hay-crop* does not appear to return in its immediate increase, a larger proportion of the supplied nitrogen compared with *wheat* or *barley*, than might perhaps with reason be attributed to the more extended distribution of the feeders of the crop on a given area of land.

It appears, then, from the evidence as yet at command, that in the case of the *grass-crop*, as in that of the *ripened cereal grains*, a considerable proportion of the expensive constituent—*nitrogen*—which may be supplied in manure, has to be reckoned as *unrecovered* in either the immediate or the closely-succeeding increase of crop.

The possible explanations of this loss of nitrogen—real or apparent as the case may be—are numerous; but they are more or less within the reach of careful and extended experimental inquiry. It may be supposed—that a portion of the unrecovered amount of nitrogen is, in some form, drained away and lost?—that the supplied nitrogenous compound is transformed in the soil,

and nitrogen in some form evaporated?—that a portion remains in the soil in some fixed and unavailable state of combination?—that ammonia, or some other compound of nitrogen, or free nitrogen itself, is given off during the growth of the plant?—or, it may be, that the range of distribution of the supplied nitrogen, and its state of combination within the soil, are alone sufficient obstacles to its being taken up in larger proportion by the immediate crop? Should the last supposition afford a sufficient explanation of the facts observed, the assumed loss would be one but in appearance merely. The farmer might then still hope to reap the whole benefit of his costly nitrogenous manures, in the course of time, in succeeding crops. Be this as it may, the facts that have been recorded afford additional confirmation of the opinion so frequently insisted upon, that, in the case of the *Graminaceous* plants which we cultivate, a full crop is obtained only when there is a liberal provision of *available nitrogen within the soil;* and, further, that when this provision is made by means of direct nitrogenous manures, a large proportion of the so-supplied nitrogen will remain *unrecovered in the increase of crop*, at least for a considerable period of time.

The main facts elicited on a consideration of the *acreage yield* in the *hay-crop*, of some of its important *constituents*, or *classes of constituents*, according to the condition of manuring, may be summed up as follow:—

1. The average annual produce of *Total Dry Substance*, in the *unmanured meadow-hay-crop*, was about 1 ton per acre, which would contain about 900 lbs. of *carbon*. These amounts are somewhat less than were annually obtained *without manure* in either *wheat* or *barley*.

2. *Purely carbonaceous manures* did not appear to increase the assimilation by the *Graminaceous* herbage of either *carbon* or *nitrogen*.

3. *Purely mineral manures* induced little or no increased assimilation of either *carbon* or *nitrogen* by the *Graminaceous*, but a considerable amount by the *Leguminous* herbage.

4. *Specially nitrogenous manures*, such as ammoniacal salts, even when used alone, notably increased the assimilation of *carbon* and *nitrogen* by the *Graminaceous*, but not by the *Leguminous* herbage.

5. By means of manures supplying *both mineral constituents and nitrogen*, but no carbon, there was an annual increase of *Graminaceous* produce, equal to about 1½ ton of *dry substance* per acre, which would contain about 12 cwts. of *carbon*.

6. The annual yield of *mineral constituents* in the *unmanured*

hay-crop was nearly 1½ cwt. This amount is about one and a-half time as much as was contained in either *wheat* or *barley* when *unmanured.*

7. By means of *mineral manure alone*, or *ammoniacal salts alone*, the annual yield of *mineral matter* in the hay-crop was raised to about 2 cwts. per acre; and by *mineral and nitrogenous manure combined*, to about 4 cwts. per acre.

8. It is particularly in *potash*, that the *hay-crop* is more exhaustive of soil-constituents, than either *wheat* or *barley.*

9. Owing to the comparatively large amount of *mineral constituents* taken from the land in the *hay-crop*—to the less regular return of them by the *home manures*—and to the less exposure of the soil in the case of *meadow-land*—more special attention is required to prevent *its* practical exhaustion of soil-constituents, than in the case of *arable-rotation-land.*

10. The annual yield of *nitrogen* per acre was, in the *unmanured hay-crop*, nearly 40 lbs. This is from one-third to one-half *more* than was annually obtained in *unmanured wheat* or *barley.*

11. The hay grown by *mineral manures alone*, yielded considerably *more nitrogen per acre* than that grown *without manure.* The increased amount was due to an increased growth of the *Leguminous*, and not of the *Graminaceous* herbage.

12. *Nitrogenous manures alone* (ammoniacal salts and nitrate of soda) gave an *increase of nitrogen in the produce* equal to only about *one-fourth of that supplied in the manure.*

13. *Mineral and nitrogenous manures combined* gave an *increased produce of nitrogen* equal to from 45 to 50 per cent. of the *nitrogen supplied in the manure. Wheat* and *barley*, under similar circumstances, gave an increased produce of nitrogen equal to rather more than 40 per cent. of that supplied in the manure. The rather more favourable result with the *hay-crop* is not more than is probably attributable to the more complete distribution of the under-ground feeders of the crop.

14. In the case of the *meadow-grasses*, as in that of the *Graminaceous plants grown in rotation*, the growth was much increased by *direct nitrogenous manures;* and, in both cases, from 50 to 60 per cent. of the *supplied nitrogen* remained *unrecovered* in either the immediate, or the closely-succeeding increase of crop.

Part III.—Description of Plants developed by different Manures.

Perhaps the most remarkable and interesting of the effects of the different descriptions of manure, upon the complex herbage of which the experimental meadow was composed, was the very

varying degree in which they respectively developed the different kinds of plants.

Allusion has already frequently been made, in a cursory way, to the greater development of the *Leguminous* herbage by purely *mineral manures*, and to that of the *Graminaceous* plants, or natural grasses commonly so-called, by characteristically *nitrogenous manures*. In fact, the plots had each so distinctive a character in regard to the prevalence of different plants, that the experimental ground looked almost as much as if it were devoted to trials with different seeds as with different manures. So striking and characteristic, indeed, were the effects produced in this respect, that, in 1857 and 1858, the subject was thought of sufficient interest to induce us to request the examination of the plots by Professor Henfrey, to which he kindly assented.

An endeavour was also made in the second year, 1857, to separate, and determine, the proportion of the different plants in carefully averaged and weighed samples, taken from the several plots as soon as the grass was cut. Taking advantage of the experience gained in this first trial, the separations have been carried out more carefully in the case of the produce on some of the most important plots in the third season, 1858. The results of these separations are recorded in detail in Table IX., pp. 46-7, and in a summary form in Table X., p. 48; and it is the consideration of those results that will constitute the subject of this Third Part of our Report.

The mode of proceeding in making the separations and estimations may be shortly explained. As soon as the grass on a plot was cut down, samples were taken from many parts of it. These were carefully intermixed in such manner as to shake out as little seed as possible; and then, from the whole, a certain quantity was weighed out to be further operated upon. Characteristic specimens of each of the plants *in flower or seed*, or in other conditions in which they could be recognised, were then selected as types; and a number of boys were set to pick from the weighed sample, all they could find to correspond with these types. The remainder consisted chiefly of *detached foliage, and undeveloped stems*, which was then separated into four or five different lots, according to types selected to the best of our judgment. Each weighed sample was thus divided into from fifteen to twenty different descriptions of herbage. The weight of each of the selected portions was afterwards taken—all in an equal condition of dryness. The weights so obtained, of the respective grasses, or other plants, or parts of plants, in the original weighed sample from the plot, were then calculated into their percentage relation to the collective weight of the whole of the separated portions in their partially dried state. It is the results

so obtained that are recorded in the Tables. It should be mentioned, that we are indebted to Dr. Evan Pugh, of Pennsylvania, for the superintendence of the Botanical part of the inquiry.

It will be obvious, that absolute exactness in the determination of the proportions in which the different plants really occurred on the respective plots, would be extremely difficult to attain. If the bulk of the sample taken were so large as to exclude all possible doubt of its being a fair average of the whole produce, the labour of the separations would be so great as to be almost impracticable. There is, however, no doubt that the Tables do, in the main, very closely represent the facts. They do so, at any rate, quite sufficiently to bring very strikingly to view the most characteristic and important distinctions that were observed to be developed.

In the respective columns of the Table of detail (IX.) are given:—

1st. The Botanical names of the plants.
2nd. The Common or English names.
3rd. The *percentage proportions* of each plant, &c., on some of the most important of the experimental plots.
4th. Notes taken on a comparative examination of the specimens.

The plots selected for the Botanical analysis of their produce were:—

Plot 1. Unmanured.
Plot 4. With ammoniacal salts alone.
Plot 8. With the "mixed mineral manure" * alone.
Plot 10. With the "mixed mineral manure," and ammoniacal salts.
Plot 13. With the "mixed mineral manure" and the double quantity of ammoniacal salts.
Plot 16. With farmyard manure.
Plot 17. With farmyard manure and ammoniacal salts.

The separated plants are classified into:—

1st. Graminaceous herbage (Grasses commonly so called), in culm, bearing flower or seed.
2nd. Graminaceous herbage, detached leaf and undeveloped stem.
3rd. Leguminous herbage.
4th. Miscellaneous herbage, chiefly weeds.

Within each of these classes, the plants are enumerated in the Table, *in the order in which they respectively occurred in the largest*

* For full description of the "*Mixed Mineral Manure*," see Part I. of this Paper.

proportion on the unmanured plot. The comparison of the figures in the column relating to any particular *manured* plot, with those relating to the *unmanured*, thus shows at once, the deviation from the standard result which is induced by the manure in question, both as regards the *order* as to quantity, and the *actual numerical proportion*, in which the different descriptions of herbage were found to be developed.

In addition to the above explanation, it will be an useful further preliminary to the discussion of the effects of the different manures, to make a few remarks on the general character of the herbage of the experimental meadow.

In the third season (1858), to which our Table of separations refers, there was no *Dactylis glomerata* (Rough Cock's-foot), no *Poa pratensis* (Smooth-stalked Meadow-grass), no *Bromus mollis* (Soft Brome-grass), and no *Avena pratensis* (Meadow Oat-grass), detected in the produce of the *unmanured* plot. The Rough Cock's-foot and Smooth-stalked Meadow-grass occurred, however, on some of the manured plots; and each in large proportion under certain conditions of manuring. But the Soft Brome-grass, and Meadow Oat-grass, occurred in very few cases at all, and then in very small quantity. There was, too, a striking absence, on all the plots, of several esteemed permanent meadow-grasses. Thus *Alopecurus pratensis* (Meadow Foxtail), *Festuca pratense* (Meadow Fescue), *F. duriuscula* (Hard Fescue), *Phleum pratense* (Meadow Cat's-tail), and *Poa trivialis* (Rough-stalked Meadow-grass), were not found in our list at all in the third season, 1858. The Meadow Fox-tail, the Meadow Cat's-tail, and a Fescue-grass were, however, each observed on one or more of the plots in 1857.

Attention may now be directed to the comparative development of each of the plants according to the manure employed, taking each *seriatim*, in the order in which it predominated on the unmanured land. A short statement of the reputed characters of each, as to its adaptation to local conditions, and as to its recognised agricultural value, will, at the same time, be given.* The comparative development of the different *Graminaceous* plants will be first considered. The records relating to these are given in the two upper Divisions of the Table (IX.); those in the first refer to the plants *in culm*, and those in the second to the *leafy and indeterminate Graminaceous produce.*

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* See on these points, Lawson's 'Synopsis of Vegetable Products,' &c.; Bravender's 'Prize Report,' Journal of the Royal Agricultural Society of England, vol. v., part ii.; Professor Buckman's Papers, Journal of the Royal Agricultural Society of England, vol. xv., p. 462, vol. xvii., p. 162, and vol. xvii. p. 513; Donaldson 'On Manures and Grasses;' and Morton's 'Cyclopædia of Agriculture.'

EXPERIMENTS with DIFFERENT MANURES

TABLE IX.—Showing the Description and Proportions of the Different kinds of

DESCRIPTION OF THE HERBAGE.		PER-CENTAGE AMOUNTS OF EACH				
			Artificial Manures.			
Botanical Names.	Common Names.	Unmanured. (Plot 1.)	Ammoniacal Salts alone. (Plot 4.)	"Mixed Mineral Manure," (Plot 8.)	"Mixed Mineral Manure" and Ammoniacal Salts. (Plot 10.)	"Mixed Mineral Manure" and double quantity Ammoniacal Salts. (Plot 13.)
				1.—Graminaceous Herbage; Stems		
Lolium perenne	Common rye-grass	16·77	14·73	23·39	32·23	12·10
Holcus lanatus	Woolly soft-grass, or Yorkshire Fog.	14·02	14·43	6·94	32·64	26·37
Arrhænatherum avenaceum	Fibrous-rooted, tall oat-like grass	6·04	3·27	9·07	4·84	2·56
Anthoxanthum odoratum	Sweet-scented vernal grass	5·43	0·41	1·01	0·09	..
Agrostis vulgaris	Common or creeping-rooted bent-grass, also black switch, &c.	4·82	0·97	0·03	1·48	2·16
Briza media	Common quaking-grass	2·07	0·41	1·01	..	..
Cynosurus cristatus	Crested dog's-tail grass	1·10	0·05	0·39	..	0·05
Dactylis glomerata	Rough cock's-foot	..	1·64	..	1·38	20·17
Poa pratensis*	Smooth-stalked meadow grass*	..	..	..	..	..
Bromus mollis	Soft or downy brome-grass	..	..	..	..	0·10
Avena pratensis	Meadow oat-grass	..	..	0·34	..	1·57
	Total	50·25	35·91	42·18	72·66	65·08
				2.—Graminaceous Herbage; detached		
Leafy produce—from woolly soft-grass		3·41	12·28	5·46	4·06	15·35
Coarse leaf, &c.—some bent-grass; probably also cock's-foot, soft brome-grass, and others		8·78	11·46	1·79	6·64	3·93
Middling leaf—chiefly bent-grass; some meadow oat-grass, &c.		3·41	8·18	14·33	4·43	..
Fine leaf, &c.—unknown; possibly some Festuca bromoides, or barren fescue-grass		7·81	16·37	5·82	2·58	1·18
Dead leaves and stems		2·44	4·91	2·24	7·01	11·81
	Total	25·85	53·20	29·64	24·72	32·27
				3.—Leguminous		
Lathyrus pratensis	Yellow or meadow vetchling	2·07	2·20	4·53	..	..
Lotus corniculatus	Common bird's-foot trefoil	1·83	..	0·45	..	..
Trifolium pratense perenne†	Perennial red clover†	1·22	..	17·91	..	..
	Total	5·12	2·20	22·89	..	..
				4.—Miscellaneous Herbage,		
Plantago lanceolata	Rib-grass or plantain	10·79	0·41	..	0·09	..
Carum carui	Common caraway	1·71	..	0·78	0·28	..
Achillæa millefolium	Common milfoil or yarrow.	1·34	3·58	0·48	0·28	0·59
Rumex acetosa	Sheep's sorrel or dock	0·67	1·02	0·23	0·88	1·08
Silene	Catchfly	0·61	..	..	..	..
Ranunculus‡	Crow-foot	0·49	1·13	..	..	..
Lazula campestris	Field wood-rush	0·12	..	..	..	..
Veronica chamædrys	Germander speedwell	..	..	0·22	..	..
Galium verum	Common yellow-flowered bed-straw, or cheese rennet	..	..	..	0·32	..
	Total	15·73	6.14	1·71	1·85	1·67

* With some *Agrostis*. † With some *T. repens* on Plot 8.

on PERMANENT MEADOW LAND.

Herbage developed, according to the Manure employed. 3rd Season, 1858.

PLANT, &c.		NOTES.		
Farm-yard Manure.				
Alone. (Plot 16.)	With Ammoniacal Salts. (Plot 17.)	Order of Luxuriance.	Order of Ripeness.	General Condition.
bearing Flower or Seed.				
29·00	14·92	Plots 10, 16, 17, 8, 13; 1 and 4	Plots 8 and 4; 1; 13 and 16, nearly ripe; 17, unevenly ripe; 10, rather green	On all plots more or less shedded, remaining seeds not ripe.
10·75	19·87	Plots 10, 13, 17, 16 and 4; 1; and 8	Plots 8; 16 and 17, nearly ripe; 4 and 1, greenish; 10 and 13, green	Rather green, little difference, 10 and 13 affected by bulk and laying.
14·33	17·16	Plots 17, 16, 10, 1, 8 and 4; and 13	Plots 4, ripe; 1 and 8, pretty ripe; 17, part dead ripe; 13, nearly ripe; 10 and 16, part ripe	On every plot two distinct grades of ripeness: some dead ripe, some green.
0·34	0·66	Plots 1, 8, 4, and 10, 16 and 17	Plots 17, dead ripe; 8, 4, and 10, ripe; 1, mostly ripe; 16, nearly ripe	All dead ripe, chiefly shedded.
..	1·25	Plots 1, 10, and 13; 17, 4, and 8	Plots 10, dead ripe; 8 and 4, ripe; 13, unevenly ripe; 17, greenish; 1, green	
..	..	Plots 1, 8, and 4	Plots 8; 1 and 4, ripe	All nearly ripe.
0·45	0·26	Plots 1 and 16; 17, 8, and 4 and 13	Plots 8, 4 and 13, ripe; 16, tolerably ripe; 17, middling; 1, greenish	All in full head.
..	..	Plots 13, 10, and 4	Plot 4; 10, nearly ripe; 13, greenish	Seeds not quite ripe.
14·89	10·10	Plots 16 and 17	Plots 16; 17	Generally dead ripe.
..	..	. .	Ripe	Ripe.
..	0·40	. .	Plots 17, dead ripe; 8 and 13, ripe	Dead ripe and mostly shedded.
69·76	64·62			
Leaves and indeterminate Stems.				
2·24	5·55			
3·58	1·32			
4·03	..			
4·48	4·22			
3·58	3·96			
17·91	15·05			
Herbage.				
2·02	1·32	Plots 8, 1, 4 and 16; and 17	Plots 1, little seeded; 4, no ripe seed; 16, in flower; 8 and 17, green and in flower	All in flower.
..	..	Plots 1 and 8	Plots 8, in flower; 1, chiefly in flower, green	In flower, plants green.
1·68	0·46	Plots 8, 16, 1, and 17.	Plots 1; 17, scarcely ripe; 8, in full head; 16, some flowers, greenish	Green; chiefly in bloom; turning.
3·70	1·78			
chiefly Weeds.				
1·96	8·25	Plots 17, 1, 16, 4, and 10	Plots 4, pretty ripe; 10 and 17, nearly ripe; 16; 1, full head, not ripe	All in head, but seeds not ripe.
1·62	1·72	Plots 16 and 17, 1, 8 and 10	Plots 17; 1, seed shedding; 8, 10, and 16, ripe	All ripe.
0·22	1·78	Plots 4, 17, 1, 8, 10 and 13, and 16	Plots 13; 1 and 16, not in flower; 8 and 10, greenish; 4 and 17, green	None in flower; all green.
1·12	3·10	Plots 17, 10, 13 and 16, 1 and 4, and 8	Plots 1 and 8; 16, nearly ripe; 4 and 17, some seeded; 10 and 13, green	Some in bloom; some with ripe seeds.
..	..	. .	Ripe	Ripe.
2·02	1·58	Plots 16, 17, 4, and 1	Plots 17, seed ripe; 16, in seed; 1, in seed, leaves green; 4, flowers and seed	Stems bearing ripe seed, but having green radical leaves.
..	..	. .	Ripe; seeded	Ripe.
0·11	..	Plots 8 and 16	Plots 8 and 16, in flower	In flower.
..	..	. .	. .	Not yet in flower.
7·05	16·43			

‡ Various species.

TABLE X.—Summary of the facts given in more detail in Table IX.

	PER CENTAGE AMOUNTS OF EACH PLANT, &c.						
		Artificial Manures.				Farm-yard Manure.	
	Unmanured. (Plot 1.)	Ammoniacal Salts alone. (Plot 4.)	"Mixed Mineral Manure." (Plot 8.)	"Mixed Mineral Manure" and Ammoniacal Salts. (Plot 10.)	"Mixed Mineral Manure" and double quantity Ammoniacal Salts. (Plot 13.)	Alone. (Plot 16.)	With Ammoniacal Salts. (Plot 17.)
Total Grasses in flower or seed	50·25	35·91	42·18	72·66	65·08	69·76	64·62
Total Grasses in condition of detached leaves and indeterminate stems	25·85	53·20	29·64	24·72	32·27	17·91	15·05
Total Graminaceous herbage	76·10	89 11	71·82	97·38	97·35	87·67	79·67
Total Leguminous herbage	5·12	2·20	22·89	..	..	3·70	1·78
Total Miscellaneous herbage (chiefly weeds)	15·73	6·14	1·71	1·85	1·67	7·05	16·43
	96·95	97·45	96·42	99·23	99·02	98·42	97·88
Shedded seeds, &c., &c.	3·65	2·55	3·58	0·77	0·98	1·58	2·12
Total	100·00	100·00	100·00	100·00	100·00	100·00	100·00

I. GRAMINACEOUS HERBAGE.

1.—*Lolium perenne*—*Common Rye-Grass.*

This grass is reputed to be suitable to a great variety of soils, but to vary very much in character according to external conditions. It is easily propagated, is luxuriant and succulent, and yields an earlier feed than most other grasses. It is relished by stock, yields good hay, and is, in fact, one of the most generally useful of grasses. It flowers in June and July.

The grass having these reputed characters stands at the head of the list as to quantity *in culm*, not only on the unmanured plot, but on several of the others also. What proportion of the *detached leaf and undeveloped stem*, on the different plots, belonged to this grass, we were not able to determine. In the condition of flowering or seeding stem, the produce without manure contained 16·8 per cent. of it, that by purely mineral manures 23·4 per cent., that by ammoniacal salts alone 14·7 per cent., that by the "mixed mineral manure" and 400 lbs. of ammoniacal salts 32·2 per cent., and that by the "mixed mineral manure" and 800 lbs. of ammoniacal salts only 12·1 per cent. of it. Against these proportions of flowering and seeding Lolium, on the unmanured and artificially manured plots, the produce by the farm-yard manure contained 29 per cent. of it, and that by the farm-yard manure and ammoniacal salts only 14·9 per cent.

The general result in regard to the amount of Rye-grass in

flowering and seeding stem, according to manure, is as follows:—The proportion of it in the total produce was considerably increased by the "mixed mineral manures" alone, by the "mixed mineral manures" and the smaller amount of ammoniacal salts, and by the farm-yard manure alone. On the other hand, its proportion was diminished whenever the ammoniacal salts were used in relative excess; that is, when the ammoniacal salts were used alone, when they were used (with the mineral manures) in double quantity, and when they were employed in addition to the farm-yard manure. When the ammoniacal salts were used *alone*, the proportion of *Graminaceous leaf and undeveloped stem* was very high; when those salts were used in *excessive* amount with the mineral manures, the proportion of *two other grasses* (the Woolly soft-grass and the Rough Cock's-foot) predominated over that of the Rye-grass; and when the ammoniacal salts were used in addition to farm-yard manure, *three other plants* (Woolly soft-grass, Tall Oat-like grass, and Smooth-stalked Meadow-grass) seemed to gain upon the Rye-grass in degree of luxuriance.

Before passing to the next plant on the list, a few remarks may be appropriately made, which have a bearing not only on the interpretation of the results just given, but on that of those which have to follow. It must not be supposed, that figures which represent the proportion of *flowering and seeding stem* of a certain plant at one given period of the season, are at the same time accurate indications of the relative development of the *total plant* under the conditions in question. It must be borne in mind, that the numerous plants which constitute the complex herbage of our meadows, have each their natural period of flowering and seeding. This period will, however, be accelerated or postponed, as the case may be, by the external circumstances of soil, season, manure, and the association with other plants. General observation shows, that *nitrogenous* manures have a characteristic tendency to increase the development of *leaves and shoots* in our Graminaceous herbage. *Mineral* manures, on the other hand, induce much more the *seeding tendency*. With full supplies of mineral manures, therefore, we should expect (other conditions being favourable) that there would be a larger proportion of the growing plant in culm, at a given period, than when ammonia was supplied in relative excess. The general result was, indeed, that the proportion of the total Graminaceous plants which was *in culm*, was the greater where the mineral supplies predominated, and the proportion in leaf and undeveloped stem the greater when ammoniacal salts predominated. Hence, the effect of a manure on the development of the *total plant*, cannot be determined unconditionally by the proportion found in flowering and seeding stem.

The evidence is, nevertheless, sufficiently clear, that the bulky, luxuriant, and generally useful *Rye-grass*, was considerably developed by high artificial manuring, when this supplied a sufficiency of mineral constituents, and a pretty full, but not excessive, amount of nitrogen. But when ammoniacal salts were used in addition to farm-yard manure, the proportion of the Rye-grass appeared to be diminished. It will be afterwards seen, that this result was due to the fact, that two other grasses (Tall Oat-like grass, and Smooth-stalked Meadow-grass), which occurred either in comparatively small proportion, or not at all, on the other plots, were very considerably developed by the farm-yard manure.

2.—*Holcus lanatus*—*Woolly Soft-Grass, or Yorkshire Fog.*

This grass is said to be natural to damp and peaty soils; to give a considerable amount of after-math, but not to be liked by cattle either when green or in hay, being too soft, spongy, and insipid. In fact, some consider it as almost a weed. It is further said, to usurp the land in sandy soils, not to be reduced by cultivation, and to have the tendency to banish the artificial grasses. It flowers in July.

Such are the characters of the grass which was found second in amount among those in *culm*, on the unmanured land. It occurred, however, in larger proportion still on some of the manured plots. A considerable proportion of the *leafy* produce was also referred to this plant. The Woolly soft-grass, in the condition of flowering and seeding stem, constituted 14 per cent. of the produce without manure, 6·9 per cent. of that by mineral manures alone, 14·4 per cent. of that by ammoniacal salts alone, 32·6 per cent. of that by the mineral manures and 400 lbs. per acre of ammoniacal salts, and 26·4 per cent. of that by the mineral manures and the 800 lbs. of ammoniacal salts. Lastly, in the produce by farm-yard manure alone, the proportion was only 10·7 per cent., and in that by farm-yard manure and ammoniacal salts 19·9 per cent.

The general result was, that the proportion of the Woolly soft-grass was very much increased by nitrogenous manures. The effect was the more apparent when the leafy portion of the produce attributed to this plant was taken into the calculation. In fact, it is those artificial manures which developed the largest proportions of *total Graminaceous herbage*, that yielded the largest amounts of this grass. It amounted, culm and leaf together, to more than a quarter of the total produce when ammoniacal salts were used alone, to nearly 40 per cent. of it when the mineral manures and the 400 lbs. of ammoniacal salts were employed, and to more than 40 per cent. of the total produce when

the mineral manures and the 800 lbs. of ammoniacal salts were used. The proportion of the whole which was in the condition of leaf and undeveloped stem, was much the greatest where the ammoniacal salts were in relative excess; that is to say, when those salts were either used *alone*, or in the *double quantity with the mineral manures.* Where farm-yard manure was employed the Woolly soft-grass, like the Rye-grass, as mentioned above, appeared to be somewhat displaced in its proportion by the predominance of two other grasses (Oat-like grass, and Smooth-stalked meadow grass), to which further reference will be made presently. Still, by the addition of ammoniacal salts even to farm-yard manure, the proportion of the Woolly soft-grass was considerably increased.

This Woolly soft-grass, and the Rye-grass together, constituted about one-third of the total produce without manure; they together made up more than two-thirds of that by the mineral manures and the smaller amount of ammoniacal salts; and more than half of that by the mineral manures and double amount of ammoniacal salts.* Upon the whole, it appears that, although the Rye-grass is much increased by nitrogenous manures, the Woolly soft-grass is even more characteristically so; the latter, at the same time, seems less dependent on a coincidently liberal supply of mineral constituents. So far, therefore, as the relative development of these two plants is concerned, the character of the herbage would be the better when the supply of nitrogen in the manure was not excessive, and that of mineral constituents liberal.

It is quite consistent with the character given to the Woolly soft-grass—namely, that it tends to usurp the land and is not reduced by cultivation—that the manures which give the greatest increase in the produce of hay should give so large a proportion of this ill-reputed element. If, indeed, this grass be really so objectionable as it has been stated to be, it would appear to be very desirable carefully to exclude it from the seed in laying down grass-land; otherwise—soil and other circumstances being adapted to its growth—the higher the manuring, and the larger the crop, the greater will be the proportion in it of this ill-famed plant.

3.—*Arrhœnatherum avenaceum—Fibrous-rooted, tall Oat-like Grass.*

The reputed characters of this grass are, that it yields a considerable quantity of foliage on the culms, which affords a good

* Under this very excessive manuring, the Rye-grass appeared to be somewhat displaced in its proportion by the rough Cock's-foot, which on that plot, and on that alone, was very luxuriant.

deal of leafy feed in the spring. It is said to reproduce rapidly after cutting. Its taste is rather bitter, but it is not disliked by cattle. It does not grow abundantly except upon poor soils, and is upon the whole of somewhat questionable value; it is, however, much grown in France. Its time of flowering is May.

This grass (in culm, &c.) stood third in amount on the unmanured land; it there constituted, however, only 6 per cent. of the total produce. Purely mineral manures raised its proportion to 9 per cent. Ammoniacal salts, on the other hand, whether alone or in admixture with the mineral manures, seemed adverse to its predominance. Its proportion with such manures (see Plots 4, 10, and 13) was less than on the unmanured land. With farmyard manure, as with mineral manures, the proportion of the Oat-like grass was, as already alluded to, considerably increased. In fact, when the farmyard manure was used alone, the proportion of this grass in the total produce was more than double; and when with the addition of ammoniacal salts, about three times as great as it was on the unmanured plot.

The general conclusion to be drawn regarding the relative development of this grass, when grown in a mixed herbage, would seem to be, that, with high artificial manuring of the kind that meadow-land is most likely to receive, it would not by such means alone be increased, but more probably diminished in its proportion in the total produce. But when farmyard manure is liberally used, or the soil is comparatively rich in mineral constituents, its development would appear to be encouraged. The result may be due, either to the special adaptation of rich mineral manuring to the luxuriant development of this grass, or to the fact that, with highly nitrogenous manures, its growth is somewhat checked by the greater luxuriance of the freer-growing grasses.

4.—*Anthoxanthum odoratum*—*Sweet-scented Vernal Grass.*

It is to the presence of this grass that the peculiar fragrance of newly-made hay is due. Its foliage is broad and coarse, but the plant is a scanty grower, though most luxuriant on wet soils. It is not relished by cattle, but is not objected to in small proportion; it is said to be best adapted for sheep. Upon the whole this grass takes rank somewhat low in the scale of the better grasses for permanent purposes. It flowers early, namely, in April and May.

Our separations showed 5½ per cent. of the Sweet-scented Vernal-grass (in culm), in the produce of the unmanured land. There was only one other instance—namely, that where mineral manures were used alone—in which the proportion amounted to 1 per

cent. The highly nitrogenous artificial manures appeared to be very adverse to its growth, nor did it succeed much better with farm-yard manure. As, however, this grass is a very early one, it is possible that, at the time of cutting, some of it would be past the stage at which it would be recognised in our samples.

The general result was, that the growth of the Sweet-scented Vernal-grass was much discouraged by such manures as greatly increased the amount and proportion of the Graminaceous hay-plants as a whole. Whether this is of consequence in any other point of view than that of fragrance, and whether in this one it is of real practical importance, is, perhaps, a question.

5.—*Agrostis vulgaris—Common, or Creeping-rooted Bent-Grass, or Black-switch, &c.*

This grass is said to flourish most on dry soils, to be a troublesome weed on arable land, to be disliked by cattle, and also by sheep, excepting sometimes in winter. It is, in fact, reputed as useless, and is recommended to be discouraged as much as possible. The time of flowering is May.

This grass amounted, in culm, to nearly 5 per cent. in the produce without manure. The proportion was, however, very much reduced under every one of the manured conditions. This result is certainly not to be regretted, if the characters of the grass are fairly given, as above. However, the *detached leaf and undeveloped stem* set down in the Table as "middling," was supposed to consist chiefly, and that set down as "coarse" more or less, of Bent-grass; and if this estimate be correct, it would appear, that there was a considerable proportion of this grass in this undeveloped condition on most of the plots; though it would be least in amount where either the farm-yard manure or the mixtures of mineral manure and ammoniacal salts were employed. Fortunately, then, a grass having such a bad character as is attributed to the creeping-rooted Bent-grass seems to meet with the desired discouragement in those manures which develop more freely its more valuable congeners.

6.—*Briza media—Common Quaking-Grass.*

This grass is reputed to thrive best on poor soils, to afford a small yield, not to be liked by cattle, and to be discouraged by manuring. It flowers in June.

The Quaking-grass amounted to 2 per cent. in the sample of the produce from the unmanured land. It was only found in two cases in the manured produce, and then in even less proportion than in the unmanured. In the most highly-manured produce none whatever of it was to be found. The reduction or entire exclusion by manuring, is consistent with the character

of this grass as given above. It would seem, therefore, that it is not likely to be troublesome on good land, and that it is easy of expulsion by good manuring.

7.—*Cynosurus cristatus—Crested Dog's-tail Grass.*

This grass is said to have a wide range of soils, to grow on dry, damp, and even irrigated lands, and to vary in character accordingly. The opinions given respecting its value are somewhat conflicting. Some authorities consider its root-leaves, which are comparatively abundant, to be a favourable food for sheep, and that it is useful on soils and in seasons when other grasses are deficient. The stems seem, however, not to be eaten at all; and the more recent opinions, especially those of Professor Buckman, are quite against its utility. It is said, however, to be better for pasture than for hay; but as its character is to die out by improvement, its perhaps now established inferiority need not be much regretted. The time of flowering is June and July.

This crested Dog's-tail grass stood lowest of any among the grasses, in the scale of quantity on the unmanured land. It there amounted, in culm, to only 1 per cent. of the total produce. It was found in the manured produce in less proportion still, especially where ammoniacal salts were used. It would appear, therefore, that where such manuring is employed as greatly increases the produce of hay, there will be little or none of this doubtfully useful element.

8.—*Dactylis glomerata—Rough Cock's-Foot.*

The Rough Cock's-foot is said to be very abundant and productive on good soils, particularly on those of a clayey nature, and to be much improved by cultivation. It grows well in moist and shady places, has broad foliage, is tufty, and reproduces rapidly after cutting. All stock like it, but particularly sheep, early in the season, before it has become hard and coarse. Its time of flowering is June and July.

Of this grass, in the condition of flowering and seeding stem, none whatever was found in the sample taken from the unmanured plot; none in that from the mineral manured plot; and none in that from either of the plots manured with farm-yard manure. It would appear, however, from the notes made by Professor Henfrey on the growing crop of 1857, as well as from the results of the partial separations made by ourselves when the crop of that year was cut, that the Rough Cock's-foot was far more predominant in the second than in the third year of the experiment. The conditions of growth of the samples in which it was found in the third year, are consistent with its apparent exclusion under

the conditions mentioned above. It was found to the amount of less than 2 per cent. (in flowering and seeding stem) in the sample grown by ammoniacal salts alone, in less than 1½ per cent. in that by the same amount of ammoniacal salts with mineral manures in addition, but to the extent of 20 per cent. when the double or excessive amount of ammoniacal salts, together with the mineral manures, were employed. Where this very large proportion of Rough Cock's-foot was found in the produce of 1858, it was set down by Professor Henfrey in 1857, as "very fine," "abundant," and "ripe," and in the other cases as "backward." Consistently with this order of development of this plant according to manuring, we find a very small proportion of that leafy produce (the coarse) which was estimated to contain Cock's-foot, where the amount in flowering and seeding stem was so large, but more where the amount in flowering and seeding stem was only small. There was the most of it where the ammoniacal salts were used alone; and it was in the sample of "coarse" leafy produce grown by that manure, that Professor Henfrey concluded there was the most of the Cock's-foot.

It appears that characteristically nitrogenous manures are favourable to the predominance of the Rough Cock's-foot. Where the supply of nitrogen is only moderate, it would appear to be outgrown and overpowered by the Rye-grass and Woolly soft-grass. It, in its turn, appears to overpower, particularly the Rye-grass, when the nitrogenous manure is very abundant. And, under the same conditions, it seems to reduce, and almost to exclude, several of the grasses of less value, and of less free growth. Thus, when the Cock's-foot was so abundant, there was less of the Oat-like grass found than on any of the other plots, no Sweet-scented Vernal-grass, very little creeping Bent-grass, no Quaking-grass, and scarcely any crested Dog's-tail. The reputed characters of the Rough Cock's-foot given above, are consistent with this luxuriant growth under high manuring, and with this apparent tendency to push out other plants by its own active vegetation. The Cock's-foot also affords an example of a useful grass much developed by those manures which yield a great bulk of total produce.

9.—*Poa pratensis—Smooth-stalked Meadow Grass.*

The Poa pratensis is said to be rather particular in its choice of situation, not to relish damp soils, but to thrive well in good and rather dry ones. It grows tuftily, and is said to have the tendency to banish other grasses. Its character is to yield a good early feed, and a free-growing and hardy after-grass. It flowers in May and June.

This grass was found only in the samples of the produce

grown by farm-yard manure. In these, however, its proportion was very considerable, amounting to about 15 per cent. of the whole where the farm-yard manure was used alone, but to only 10 per cent. where the farm-yard manure and ammoniacal salts were used together. From our records relating to the produce of the second season, it appears that this Smooth-stalked Meadow-grass was detected on more of the plots in that season than in the third. Still, even then, it was found in very much larger proportion in the produce grown by farm-yard manure than in that by any of the other manures. This very marked development almost exclusively by farm-yard manure might lead to the conclusion, that part of the result was due to seed brought upon the land by the dung. But that the character of the manure, as such, had much to do with the effect, would seem from the fact, that the proportion of the Smooth-stalked Meadow-grass was considerably reduced when ammoniacal salts were used in addition to farm-yard manure.

It would appear that the Smooth-stalked Meadow-grass is particular in the choice of manure as well as situation, and that artificial nitrogenous manures are either directly obnoxious to it, or cause it to be pushed out by those grasses whose luxuriance is greatly stimulated by such manures. Nor was this Poa perceptibly favoured in its growth by purely mineral manures. It might be supposed, therefore, that the carbonaceous organic matter of the farm-yard manure had something to do with the greatly increased development of the plant under the influence of that manure. This greatly increased development of the Smooth-stalked Meadow-grass under the influence of farm-yard manure appeared to be chiefly at the cost of the Woolly soft-grass —an exchange not at all to be regretted. The Oat-like grass is another grass much more valuable than the Woolly soft-grass, the proportion of which was much increased by farm-yard manure. This manure was seen, therefore, to develop two better grasses at the expense of a worse one. But it is to be regretted, that so useful a grass as the Smooth-stalked Meadow-grass should appear to be so nearly excluded under the influence of those so-called artificial manures, which are practically the most useful in increasing the produce of Graminaceous hay.

10.—*Bromus mollis*—*Soft or Downy Brome-Grass.*

This grass is described as a common weed in grass-land, the seed of which should be carefully excluded when sowing down. It is said to be innutritious, and even injurious to some animals. It flowers early in the season, but, after cutting, often seeds in the after-grass. It is found most in poor exhausted pastures.

With such characters as are here given to this grass, it is not

to be regretted that it was found in only one of our samples, and there in very small proportion. Professor Henfrey was, however, of opinion that its leaf occurred in a few of the samples of the "coarse" leafy produce.

11.—*Avena pratensis—Meadow Oat-Grass.*

This grass is best adapted to dry heathy places. It is of doubtful feeding value, though conflicting opinions are given respecting it. But, as it is said to be soon got rid of by good cultivation, its qualities are perhaps not of much consequence. It is the last on our list of *flowering and seeding Graminaceous plants.* It was found in the samples from three only of the seven plots, and in those in but insignificant amount. The largest quantity was found in the sample grown by the mixture of mineral manure and the excessive amount of ammoniacal salts.

There are two other items to be briefly noticed before closing this *seriatim* account of the different descriptions of *Graminaceous* herbage found in the produce of the respective plots.

The proportion of the *leafy* produce set down in the Table as "*fine*," varied extremely according to the manuring. It was very large where the ammoniacal salts were used *alone;* and moderately so on the other plots where the total produce was not very large; but very small in the samples from the heaviest crops. We were quite unable to determine with any certainty to what plant or plants this "fine" leafy matter was to be referred. Professor Henfrey was, however, of opinion that some at least belonged to *Festuca Bromoides*, or Barren Fescue-grass.

"*Dead leaf and stem*" is the last item in the list of *Graminaceous* produce. Contrary to the fine leaf, this worthless dead matter occurred in very far the largest proportion where the artificial manuring was the highest, and the crops were the heaviest. Where the mineral manure and excessive amount of ammoniacal salts were employed, this damaged portion of the produce amounted to nearly 12 per cent. of the whole; and where the mineral manure and the more moderate amount of ammoniacal salts were supplied, to 7 per cent. Here, then, is experimental evidence showing a practical disadvantage in manuring so highly as to cause the crop to fall and die at the bottom before the bulk is fit for cutting.

II. Leguminous Herbage.

In the second season, 1857, four descriptions of Leguminous plant were distinguished on the experimental plots. These were *Lathyrus pratensis* (Yellow or Meadow Vetchling); *Lotus cornicu-*

latus (Common Bird's-foot Trefoil); *Trifolium pratense perenne* (Perennial Red Clover); and *Trifolium repens* (White or Dutch Clover). In the third season, 1858, very little of the last mentioned plant (Dutch clover) was observed on any of the plots; and the three other Leguminous plants seemed to be confined to fewer plots than formerly. Their limitation, or extension, according to manuring, is very striking; and it is to the degree and conditions of their distribution, that attention is now to be directed. The results relating to these points are given in the third Division of Table IX.

1.—*Lathyrus pratensis*—*Yellow or Meadow Vetchling.*

This plant is described to grow naturally on either moist or dry soils, but generally on such as are of good quality. Cattle generally eat it with avidity; and hence it is recommended to be grown on very dry soils. The creeping nature of its roots unfits it for growth in rotation, but not so much for permanent meadow. It flowers in July.

The Meadow Vetchling occurred in rather larger proportion than either of the other Leguminous plants on the unmanured land. It there amounted, however, to only 2 per cent. of the total produce. On the *mineral manured plot* its proportion was raised to 4½ per cent.; and on the plot with ammoniacal salts alone, there were about 2¼ per cent. In the produce by the mineral manure and ammoniacal salts together, none of this plant was observed. The produce by farm-yard manure gave about 2 per cent., and that by farm-yard manure and ammoniacal salts little more than 1 per cent. of the Meadow Vetchling.

2.—*Lotus corniculatus*—*Common Bird's-foot Trefoil.*

This plant is said to grow abundantly on dry elevated pastures, and heathy soils; and to be well deserving of cultivation on light, dry, elevated inferior soils, on which it will yield a greater bulk of herbage than any of the cultivated clovers. It is supposed to be highly nutritious, and is eaten with avidity by cattle. From the great depths to which its roots penetrate, it is not liable to be injured by drought, and is hence enabled to retain its verdure after the grasses and other plants are burnt up. It flowers from June to August.

The Bird's-foot Trefoil was found in the produce of only two of the experimental plots, namely, the *unmanured*, and the *mineral-manured* ones.

3.—*Trifolium pratense perenne*—*Perennial Red Clover.*

There are several varieties of this plant, of which the most important are the Native perennial Red Clover, and the Common

perennial Red Clover or Cow-grass. They are too well known to every farmer to require description here.

Perennial Red Clover amounted to little more than 1 per cent. of the total produce on the *unmanured* land, but to nearly 18 per cent. of that grown by *mineral manures alone.* Not any of it was found in the produce by either ammoniacal salts alone, or ammoniacal salts in conjunction with mineral manures. There was little more than 1½ per cent. of it in the produce by farm-yard manure alone, and less than ½ per cent. in that by farm-yard manure and ammoniacal salts.

The proportion of *total Leguminous Herbage* found in the produce of the *unmanured* plot, was about 5 per cent. This was made up of two parts Meadow Vetchling, rather less than two parts Bird's-foot Trefoil, and rather more than one part Perennial Red Clover. The produce by *mineral manures alone* was estimated to contain about 23 per cent. of Leguminous herbage, or about 4½ times as high a proportion as that grown without manure. These 23 parts comprised about 4½ parts Meadow Vetchling, about ½ a part of Bird's-foot Trefoil, and about 18 parts of Perennial Red Clover = 15 times as much as was found of it in the unmanured produce. The *ammoniacal salts alone, reduced* the proportion of total Leguminous plant to little more than 2 per cent. in the produce, and then it consisted entirely of Meadow Vetchling: the Bird's-foot Trefoil and the Perennial Red Clover being apparently extirpated. And, in the produce by *mineral manures and ammoniacal salts together, not any* Leguminous plant was to be found. The *farm-yard manure produce* contained less than 4 per cent. of Leguminous plant, which consisted of nearly equal parts Meadow Vetchling and Perennial Red Clover, to the exclusion of the Bird's-foot Trefoil. The *addition of ammoniacal salts* to farm-yard manure, *reduced* the proportion of Leguminous herbage to about one-half. There was still no Bird's-foot Trefoil; and the Perennial Red Clover, as before, gave way more than the Meadow Vetchling under the influence of the ammoniacal salts.

III. Miscellaneous Herbage, chiefly Weeds.

The fourth Division of the Table shows, that there were nine descriptions of these questionably useful, or even objectionable plants, detected in the samples from the experimental plots. Only seven of them were found together on the unmanured land, and a smaller number still on each of the manured plots. A few remarks will be made upon the characters, and conditions of occurrence, of these several plants, taking them in the order in which they occurred in the largest proportion on the unmanured land.

1.—*Plantago lanceolata—Rib-grass or Plantain.*

This plant is reputed to yield an herbage which, early in the season, is eaten by cattle, horses, and sheep; but which is disliked by them as the season advances. It is also objectionable on account of its spreading leaves, which tend to exclude other plants. It is natural to dry pastures. It flowers in June and July.

Nearly 16 per cent. of the produce *without manure* consisted of *Miscellaneous Weedy herbage*. This comprised seven descriptions of plant, yet nearly 11 out of the 16 parts consisted of the Rib-grass. None of it was found in the produce grown by mineral manures alone; scarcely any in that by ammoniacal salts alone; less still in that by the same amount of ammoniacal salts and the mineral manures; and none at all in that by the double amount of ammoniacal salts and the mineral manures. On the farm-yard manure plot less than 2 per cent. of the total produce, or only about one-sixth as much as on the unmanured land, consisted of the Rib-grass. The addition of ammoniacal salts to the farm-yard manure, however, greatly increased the proportion of Rib-grass in the produce—namely, to 8¼ per cent.

It appears, then, that the Rib-grass, which was so prominent an item on the unmanured land, was greatly reduced in its proportion by farm-yard manure and ammoniacal salts; still more by farm-yard manure alone; and nearly or entirely excluded by those artificial manures which increase the most the total produce of hay, and especially that of the Graminaceous herbage.

2.—*Carum carui—Common Caraway.*

This plant, though second in amount among the Miscellaneous Weedy herbage on the unmanured land, amounted there to less than 2 per cent. of the total produce, and to about the same proportion in the produce of the two farm-yard manure plots. It was much diminished in its proportion, or excluded altogether, by the purely-artificial manures, especially when ammoniacal salts were in relative excess.

3.—*Achillæa millefolium—Common Yarrow or Milfoil.*

The Milfoil is stated to be a grateful element in small admixture with other herbage for sheep; and it is recommended, therefore, to be sown with other seed for permanent sheep-pasture.

The Milfoil was found to the amount of somewhat more than 1 per cent. in the produce without manure. Its proportion was much diminished by farm-yard manure alone, mineral manure alone, and the mixtures of the mineral manure and ammoniacal salts. Where the larger amount of ammoniacal salts was used (with mineral manure) both the proportion and the actual

amount of this plant were considerably greater than where the smaller amount was employed with the mineral manures. Consistently with this effect of ammoniacal salts, the proportion of the Milfoil was very much increased by the addition of these salts to farm-yard manure; and it was the greatest—in fact, then nearly three times as great as without manure—where the ammoniacal salts were used alone.

If the characters of the Milfoil as sheep-food be such as above-described, it need not perhaps be much regretted that its growth seems to be favoured by nitrogenous manures.

4.—*Rumex acetosa—Sheep's-sorrel or Dock.*

This plant is undoubtedly objectionable. Unfortunately, however, it, as well as the Milfoil or Yarrow, was found in the produce of every plot; and, like the latter, it was increased in its growth by the use of ammoniacal salts. It was more or less increased by these salts in whatever combination they were employed. Farm-yard manure alone also notably increased the proportion of the Dock in the produce; but farm-yard manure and ammoniacal salts together increased it still more. With the latter combination the Dock amounted to more than 3 per cent. of the produce. As this obnoxious plant seems to be favoured in its growth by manuring, its expulsion must be attained by other means.

The remaining five plants that were detected in the samples are, without doubt, useless, if not obnoxious. They were each found, however, only on a few of the plots, and generally in but insignificant proportion.

5.—*Silene, or Catch-fly,*

was found in the unmanured produce only, and there to the extent of little more than ½ per cent.

6.—*Ranunculus—Crow-foot* (various species).

These plants were found in small quantity in the produce from the unmanured plot; in larger proportion in that grown by ammoniacal salts alone; and in larger proportion still on the two plots with farm-yard manure. Their growth was, however, very much discouraged by the most productive artificial manures.

7.—*Lazula Campestris—Field Wood-rush.*

This rush was found only in the sample from the unmanured land, and there in very insignificant amount.

8.—*Veronica chamædrys*—*Germander Speedwell*—

was found only in the produce by mineral manures alone, and by farm-yard manure alone; and in both cases in very small amount.

9.—*Galium verum*—*Common Yellow-flowered Bed-straw, or Cheese-rennet.*

This plant was only found in the sample grown by the mixed mineral manure in conjunction with the lesser quantity of ammoniacal salts.

It is possible that there were some other plants that either did not come within the reach of the scythe, or were otherwise excluded from our samples or determinations. Nor are the exact numerical proportions set down in the Table, to be considered, either within this or the other classes of plants, as anything more than approximations. Such, however, they undoubtedly are; and the facts brought out regarding the distribution, and development, of Miscellaneous Weedy herbage, according to manure, are very clear and striking.

From this examination the very satisfactory result appears, that by far the larger *number* of the obnoxious or comparatively-useless plants occurred in the produce of the *unmanured* land. Taken collectively, too, their *proportion* was there very much larger than under any of the other conditions, excepting the one where the farm-yard manure and ammoniacal salts were used together. It was chiefly the Rib-grass, and the Sheep's-sorrel or Dock, that were encouraged by this latter manuring. The *farm-yard manure alone* gave a larger proportion of Weedy herbage than any of the *artificial manures;* but not half as much as either the *unmanured* land, or that manured by *farm-yard manure and ammoniacal salts.* On all the artificially-manured plots the *number* of species found was reduced to about half that occurring on the unmanured land. In fact, those artificial manures which were the *most productive,* not only reduced the number of species of weeds considerably, but reduced the proportion of the total of such produce to about *one-tenth as much* as was developed *without manure.* It is certainly very satisfactory to find, that the most active artificial manures had the effect of very greatly *reducing* the proportion of the useless and obnoxious plants in the mixed herbage of the meadow. It is, on the other hand, somewhat discouraging to find, that the influence of *farm-yard manure,* which must be relied upon for the hay-crop to a certain extent, was not so favourable. It is to be hoped, that the facts which have been adduced regarding the conditions of development, and the amounts, of the Miscellaneous Weedy herbage on the meadow

land, may fix on the mind of the farmer, the clear idea which the discussion of actual figures conveys, of the real amount of objectionable produce which he may frequently grow, unless proper means of reduction or eradication be had recourse to.

Attention may now be turned from the detailed consideration of the circumstances of development of the *individual plants*, to a statement of the more general character of the herbage under the different manurial conditions. In the Summary Table X. (p. 48) are recorded the main facts necessary to such a review; and the most prominent results already noticed in their place in more detail, will supply the remainder.

1.—*Total Graminaceous Herbage.*

At the time of cutting, 76 per cent. of the produce without manure consisted of Graminaceous herbage. At the same period of time, the proportion of such herbage in the total produce was increased to about 87¾ parts by farm-yard manure alone, and to 79¾ parts by farm-yard manure together with ammoniacal salts. The produce by mineral manures alone contained scarcely 72 per cent. of Graminaceous herbage; 4 per cent. less, therefore, than the produce without manure. On the other hand, the produce by 400lbs. of ammoniacal salts per acre, contained 89 per cent.; that by the same amount of ammoniacal salts and mineral manures, 97⅓ per cent.; and that by the double amount of ammoniacal salts and the mineral manures, also, 97⅓ per cent. of Graminaceous herbage.

But the *Graminaceous produce itself* varied extremely in character according to the manure employed. At a given period of the season, the Graminaceous herbage grown without manure, consisted of 66 per cent. of flowering or seeding stem, and 34 per cent. of leaf and undeveloped stem. At the same period, the Graminaceous produce by farm-yard manure, comprised nearly 80, and that by farm-yard manure and ammoniacal salts, rather more than 80 per cent. of culm, in flower or seed. Against these amounts without manure, or by farm-yard manure, the Graminaceous produce grown by the artificial manures alone was composed as follows:—That by the mineral manures alone contained 59 per cent. of flowering and seeding stem; that by ammoniacal salts alone, only 40 per cent.; that by the same amount of ammoniacal salts and mineral manure, 75 per cent.; and that by the double amount of ammoniacal salts and mineral manure, 67 per cent., in flowering and seeding culm.

The general result is, *that those manures which much increased the produce of hay, at the same time very much increased*

its proportion of Graminaceous herbage. In fact, where the largest crops were obtained, namely, where the mixed mineral manure and ammoniacal salts were used together, the proportion of the whole produce that was Graminaceous, was more than 97 per cent., whilst that without manure was only 76 per cent. The characteristic effects of nitrogenous manures to increase the proportion of leaves and shoots, and of mineral manures to determine more to flowering and seeding, are also strikingly illustrated. It will be obvious, therefore, that not only must the character of the gross produce be very different according to the description of manure employed, but that the proper time of cutting must vary very considerably to secure the majority of the herbage at any given point of ripeness.

But it has been seen, that the Graminaceous herbage varied much in character according to the manure, not only in regard to its proportion in the total produce, and to the proportion of the whole that was leafy and stemmy respectively, but also in the description or species of plants developed.

Under the particular conditions of soil, season, original distribution of plants, and other circumstances of these experiments, common Rye-grass was the most predominant of the grasses in the unmanured produce. The inferior Woolly soft-grass occurred in nearly an equal quantity; and then succeeded in lesser quantities, in the order here given, the tall Oat-like grass, the Sweet-scented Vernal-grass, the Creeping-rooted Bent-grass, the common Quaking-grass, and the Crested Dog's-tail—the last in very small amount. Farm-yard manure, which increased the actual amount and proportion of total Graminaceous herbage, gave a considerably increased proportion of Rye-grass and of tall Oat-like grass; a somewhat diminished proportion of the Woolly soft-grass; scarcely any of the other grasses found on the unmanured plot; but a very large amount of the valuable Smooth-stalked Meadow-grass, which was not found at all in the produce without manure. The addition of ammoniacal salts to the farm-yard manure diminished the proportion of the more valuable Rye-grass, and Smooth-stalked Meadow-grass, but increased that of the tall Oat-like grass, and that of the inferior Woolly soft-grass.

Leaving out of consideration here, those artificial manures which did not much increase the total produce of hay, namely, the mixed mineral manure used alone, and the ammoniacal salts alone, the general result with the more active artificial combinations was as follows:—The mixed mineral manure with the more moderate amount of ammoniacal salts gave about 2½ times as much produce as the unmanured land, and the proportion of it that was Graminaceous was more than 97 per cent., instead of only 76 per cent. without manure. This enormously-increased Grami-

naceous produce contained twice as high a proportion of both the valuable Rye-grass, and the inferior Woolly soft-grass, as that without manure. The proportion of the Oat-like grass was, on the other hand, diminished; and, under the same conditions, all the other grasses were either very much reduced, or entirely excluded.

When the double and excessive amount of ammoniacal salts was employed (with the mineral manure), the produce was about $2\frac{3}{4}$ times as much as on the unmanured land, and the proportion of it that was Graminaceous was, as in the last case mentioned, more than 97 per cent. This greatly-increased Graminaceous produce, under the influence of an excess of ammoniacal salts, contained a smaller proportion of the common Rye-grass than the unmanured hay. On the other hand, the proportion of the inferior Woolly soft-grass was very much increased. There was, moreover, with this manure a very large proportion of Rough Cock's-foot—a grass which was found on very few of the other plots, and then in very small proportion. All the other grasses were either excluded, or much reduced in amount, under the influence of this excessive manuring.

2.—*Total Leguminous Herbage.*

The proportion of Leguminous herbage in the total produce without manure was about 5 per cent. Farm-yard manure reduced the proportion, but not the acreage amount, of such produce; and the combination of farm-yard manure and ammoniacal salts, very considerably reduced both the actual amount, and proportion, of this kind of herbage. In the produce by those artificial combinations (mineral manure and ammoniacal salts), which more than doubled or nearly trebled the amount of hay, and which increased the amount and proportion of the Graminaceous herbage so strikingly, not a trace of Leguminous herbage was found. Again, ammoniacal salts alone, which notably increased the Graminaceous herbage, almost excluded the Leguminous. In the produce with this manure, neither Bird's-foot Trefoil nor Perennial Red Clover was found; but the Meadow Vetchling occurred in about the same proportion as in the unmanured produce. On the other hand, mineral manures alone, which gave little or no increase of Graminaceous produce, increased very strikingly both the actual amount, and the proportion, of the Leguminous herbage. The proportion of total Leguminous herbage in the produce by mineral manures alone was 23 per cent., instead of only 5 per cent. in that without manure. The proportion of the Bird's-foot Trefoil was diminished by the mineral manures; that of the Meadow Vetchling was notably increased; and that of the Perennial Red Clover very considerably so.

The effect of *mineral* manures in developing a large proportion

of *Leguminous* herbage, and particularly of Clover, was therefore very striking. Artificial *nitrogenous* manures, on the other hand, seemed almost to extirpate such plants from the mixed herbage of the Meadow-land. These results are perfectly consistent with those observed in the manuring of Leguminous crops (beans, clover, &c.) when grown in *rotation*. Mineral manures have been found greatly to increase such crops, whenever a good plant could be once obtained and the season was not unfavourable. These crops, on the other hand—so highly nitrogenous both in their per-centage composition, and in their acreage yield—have not been found to be specially benefited by the direct use of ammoniacal salts; though nitrate of soda appears somewhat more favourable to their growth.

The general coincidence in the results obtained in regard to the action of characteristic descriptions of manure, on the agricultural plants included within each of these two great families (the Graminaceæ and the Leguminosæ), whether they be grown *separately and in alternation*, or *side by side in a mixed herbage*, is very striking. Such a coincidence, under such very varied conditions, must show, that the result is really due to the plants of the respective families requiring for their luxuriant growth a widely different relation of the mineral and nitrogenous supplies, respectively, *within the soil*. It cannot, under such circumstances, be attributed to mere local peculiarities, or to the mere accidental conditions of exhaustion induced by this or that agricultural practice. We have, then, in the facts observed in regard to the action of characteristic descriptions of manure in developing the different plants of which the *mixed herbage of a meadow* is made up, an unexpected, and very interesting confirmation, of those which have been established in regard to the development of the widely different plants which are grown *in rotation*. Such a coincidence must tend to inspire confidence in the conclusions arrived at in each of the widely different, and separately interesting, paths of inquiry.

3.—*Total Miscellaneous Herbage* (*chiefly Weeds*).

These plants were the most numerous in kind, and nearly in the greatest proportion, on the *unmanured* land. The produce without manure contained nearly 16, that grown by farm-yard manure and ammoniacal salts more than 16, and that by farm-yard manure alone 7 per cent., of Miscellaneous or Weedy herbage. In the produce without manure, about two-thirds of the amount of such herbage was Plantain or Rib-grass; and in that by the farm-yard manure and ammoniacal salts about the same proportion of the whole consisted of Rib-grass and Sheep's Sorrel or Dock together, the former in the larger, and the latter in the smaller quantity. On the other hand, the produce grown by

those artificial manures which gave the largest crops of hay, contained less than 2 per cent., and a very few species, of Miscellaneous Weedy herbage.

So much then for the results of this enquiry into the comparative development of the different plants of which the *complex herbage of a Meadow* is made up, according to the *manure* employed. The subject has been treated of with much more of system and detail than would otherwise have been necessary, inasmuch as, so far as we are aware, this is the first attempt that has been made, to trace the influence of special manures upon the individual plants of a complex herbage.

It must not be concluded, however, that the degree in which a particular description of manure develops any particular plant, when it is thus grown side by side with many others, is necessarily the same, either actually or relatively to those beside it, that it would be, were each plant grown separately, with such manure. The natural habit of a plant, its relative stage of progress at the different periods of the season, and its range of distribution both above and under ground accordingly, must indirectly affect the degree of luxuriance of the other plants associated with it. But, as it is in this *collective* way, that the various plants are grown in our permanent meadows, it is the action of different manures upon their development under these complex conditions, that is of the most interest to the farmer.

Again, the conditions of soil, situation, season, and of the original distribution and predominance of the respective plants, must, to a great extent, affect their relative development by different manures, when they are thus grown side by side. There is, moreover, evidence in the general observations made, or notes recorded, on the produce of the first two years in the experiments now in question, that there has been a *progression* from year to year, in the greater development of some plants, and in the reduction, or even exclusion, of others, the conditions of manuring remaining the same. It would appear, indeed, that great caution should be exercised in the application of artificial manures to *good feeding pastures*, lest the effect should be, to increase the growth of certain grasses of inferior quality, and to diminish or exclude those to which the high feeding value is attributable.

It is obviously very important, not only that the progressive action of the different manures should be carefully investigated for years to come, in the case of the experiments on the Rothamsted Meadow-land, but that experiments of a similar kind should be conducted by others, in different localities, and on different descriptions of soil. So far as our own part in the matter is concerned, we hope to follow up a subject which seems fraught with

so much interest both in a practical and scientific point of view. And we trust, that others will be found to lend their aid, in extending information in this important and hitherto untrodden field of inquiry.

From a review of the whole of the facts adduced in this Third Part of our Report, it would appear:—

1. That, however the produce of hay be considerably increased —whether by means of farm-yard manure alone, farm-yard manure and ammoniacal salts, or artificial mixtures of suitable mineral manure and ammoniacal salts—the proportion of the whole which will be *Graminaceous*, will be very much increased.

2. That the produce will be by far the *most Graminaceous* when the "*artificial mixtures*" are employed. In fact, when the increase of hay is obtained by artificial manures containing *both the necessary mineral constituents and ammoniacal salts*—and it is then greater than under any of the other conditions—both the *Leguminous* and the *Weedy* herbage are nearly excluded, and the produce is then, therefore, *almost wholly Graminaceous.*

3. That the *Graminaceous produce itself*, when grown by *farm-yard manure*, is less complex in character than that grown *without manure;* whilst that grown by the *most active artificial manures*, is *less complex still.*

4. That, up to an equal period of the season, the *Graminaceous* produce grown by the *active artificial manures*, will be in larger proportion in *flowering and seeding stem*, than that grown *without manure;* and that the produce grown by *farm-yard manure* will be in still larger proportion in that condition.

5. That the *description* of the produce grown by *farm-yard manure alone*, was upon the whole, superior to that grown *without manure.*

6. That when the crop was further increased, by the *addition of ammoniacal salts to the farm-yard manure*, the character of the produce was somewhat deteriorated, both in regard to the *description* of the *useful plants* grown, and on account of the large proportion of *Miscellaneous* or *Weedy herbage* then developed.

7. That, when in a *mixed mineral and ammoniacal manure* the ammoniacal salts were *not used in excessive amount*, the herbage, which was then almost exclusively *Graminaceous*, and comprised also but *very few species*, nevertheless, included a considerable proportion of grasses of recognised good quality. But, *when excessive amounts of ammoniacal salts were employed*, the character of the produce was deteriorated, both in regard to its *condition*, and to the *description of the grasses* that were developed.

Part IV.—Chemical Composition of the Hay.

Thus far it has been shown, that the produce of hay on permanent meadow land was more than doubled by means of manure alone. It has also been shown, that the description of the produce grown on the manured land was very different from that on the unmanured; and again, that it was widely different according to the kind of manure employed. The proportions respectively of the Graminaceous, the Leguminous, and the other herbage, varied very considerably; so also did the kind and amount of the several plants comprised within each of these main divisions; and so also did the proportions of leaf, stem, and seed, and the condition of maturity.

Now the Leguminous herbage generally contains about twice as high a percentage of nitrogen as the Graminaceous. It also varies in composition in other respects. Leaves, stems, and seeds, differ much in composition from one another. And again, the degree of maturity of vegetable produce very much affects its percentage amount of certain important constituents. It will be obvious, therefore, that the composition of the complex produce —*hay*, must vary very considerably when grown by different manures.

The object of this Fourth and last Part of our Paper is to show the variation according to season, and manuring, in the *composition* of the hay grown on the different experimental plots, the particulars of the manuring and produce of which have already been so fully considered in other points of view.

In each of the three seasons over which the experiments have extended, the percentage amounts of *total dry substance*, of *mineral matter*, and of *nitrogen*, have been determined in the produce from each of the separate plots. The *woody fibre* has been determined in the produce of each of the three years of those plots, which, in 1858, were selected for the botanical separations described in Part III. The *fatty matter* has been estimated in the produce of the same plots, but in that of the third season only (1858). Lastly, complete analyses of the *ashes* of the produce of five out of the seven plots selected for the botanical separations, and also of the mixed ash of the produce from all the plots, for each of the three years separately, have been made. The various analytical results will now be considered under separate heads.

1.—*Dry Matter.*

From each of the experimental plots, at the time the hay was carted, a sackful was taken, the samples being gathered from many parts of it. The whole of each of the specimens so taken

was then cut into chaff and well mixed. From the mixed sample in this condition two quantities of 25 ounces each were weighed, and in both of these the *dry matter* and the *mineral matter* were determined. Other samples were at the same time taken for the determinations of nitrogen, woody fibre, &c.

The *dry matter*, which alone is at present under consideration, was determined by submitting the duplicate 25-ounce samples, for a sufficient length of time, to a temperature of 212° F. in a large water-bath. The *means* only, of the two determinations in each case, are given in Table XI. These will be quite sufficient for the elucidation of the points to which the results are applicable. But the individual determinations are given for reference in Table I. in the Appendix.

In the lowest division of Table XI. are given the *mean* percentages of Dry matter of all the specimens for each of the three seasons. The average percentage for all the specimens of 1856 was 79·3; that for 1857 was 86·8; and that for 1858 was 84·1. The mean percentage over the three years together was 83·4. There was, therefore, a variation in the average proportion of Dry matter in the hay of more than 7 per cent., according to *season*. The produce of 1857 gave a very high, and that of 1856 a very low proportion, of Dry substance.

The season of 1856 was, in every respect, ill adapted for high and dry condition of the hay. Accordingly, analysis indicates a very low percentage of Dry matter in the produce of that season. The seasons of both 1857 and 1858 were very much better in this respect. Of the two, the produce of 1857 contained considerably the higher proportion of Dry matter. But a comparative examination of the climatic statistics of these two seasons leads to the conclusion, that the higher percentage of Dry matter in the produce of 1857 is not so much due to the conditions during the last two or three weeks before cutting, as to the influence of climatic circumstances somewhat earlier, which developed more the seeding tendency in 1857 than in 1858.

Among the percentages of Dry matter relating to the produce of the *individual* plots, there is not a single instance that does not show the same general relationship between the characters of the three seasons on this point, as is indicated by the *mean* results only of each season.

Nor was there much difference between the average proportion of Dry matter in the specimens of the produce of each season taken at the time of carting, and that found in the bulk of the hay from the same (and adjoining land) after it had been some time in the rick. As a check on this point, samples were cut from the top to the bottom of the ricks which contained the mixed produce, both experimental and otherwise, of the seasons of 1857 and 1858 respectively, and the Dry matter was determined in them.

TABLE XI.—PERCENTAGES of DRY SUBSTANCE in the HAY (Means of duplicate Determinations).

Plot, Nos.	MANURES. (Per Acre, per Annum.)	1856.	1857.	1858.	Average of 3 Years.
	SERIES 1.—Without Direct Mineral Manure.				
1	Unmanured	82·0	85·1	85.9	84·3
2	Unmanured (duplicate plot)	81 9	87·3	85·5	84·9
	Mean, or Standard Unmanured	81·9	86·2	85·7	84·6
3	2000 lbs. Sawdust	80·7	87·7	84·4	84·3
4	200 lbs. each, Sulphate and Muriate Ammonia	80·0	86·7	84·1	83·6
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	79·6	87·6	83·9	83·7
6	275 lbs. Nitrate of Soda	..	..	84·8	..
7	550 lbs. Nitrate of Soda	..	..	85·8	..
	Mean	80·5	87·0	84·8	84·0
	SERIES 2.—With Direct Mineral Manure.				
8	"Mixed Mineral Manure"*	80·2	86·7	85·6	84·2
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	80·5	86·8	84·1	83·8
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	79·0	87·0	82·1	82·7
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	77·3	87·2	83·8	82·8
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	79·2	86·8	82·4	82·8
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	78·1	85·9	80·7	81·6
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	..	..	86·4	..
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	..	..	85·2	..
	Mean	79·0	86·7	83·1	83·0
	SERIES 3.—With Farmyard Manure.				
16	14 Tons Farmyard Manure	76·1	87·3	84·6	82·6
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	79·6	86·2	82·7	82·8
	SUMMARY.				
	General Means for the Experimental Specimens	79·3	86·8	84·1	83·4
	Mixed Hay from the same Meadow; taken out of the rick December 1858	..	87·2	83·8	..

* For full description of the "Mixed Mineral Manure," see page 6.

The results are given at the foot of Table XI.; and the comparison afforded is as follows:—The average percentage of Dry matter in the experimental specimens of 1857 was 86·8; and that in the hay taken from the rick of that year (sampled Dec. 1858) was 87·2. Again, the average percentage of Dry matter in the experimental specimens of 1858 was 84·1; and that in the hay from the rick of that year (also sampled Dec. 1858) was 83·8. The general characteristics of the produce of the *different seasons*, in regard to its percentage of *Dry matter*, are, therefore, correctly represented in the results given in the Table in reference to the experimental specimens.

The differences in the percentages of Dry matter in the hay, due to different *manuring*, are by no means so great as those due to variation of season or climatic circumstance. Still the general tendency of the influence of characteristic descriptions of manure is clearly discernible. The indications of the coincident comparative conditions of the produce, according to the manure employed, are also consistent.

Up to the period at which the crops were cut, the use of *ammoniacal salts* had the almost invariable effect of giving a produce which contained a somewhat lower proportion of Dry matter, than that grown under otherwise exactly comparable conditions. Such is seen to be pretty uniformly the result, whether we compare the produce by ammoniacal salts alone with that without manure; that with ammoniacal salts and sawdust, with that with sawdust alone; that with ammoniacal salts and mineral manure, with that by mineral manure alone; that with ammoniacal salts sawdust and mineral manure, with that by sawdust and mineral manure alone; or that with the larger amount of ammoniacal salts and mineral manure, with that by the smaller amount of ammoniacal salts and the same mineral manure. A similar result is observed too, in two years out of the three, where ammoniacal salts were used in addition to farmyard manure. The results in the Table which appear to be exceptional to this generalisation in regard to the influence of ammoniacal manures upon the percentage of Dry matter of the hay taken at a given period of the season, occur in some of the cases with the artificial manures in 1857; and in 1856, in the case where the ammoniacal salts were used in addition to farmyard manure.

Ammoniacal salts which have thus been seen, other things being equal, to give a produce which contains a comparatively low percentage of Dry matter, gave, it should be remembered, also a much increased bulk and weight of hay over a given area; hence, even supposing that the description of the herbage, and the condition of maturity of the plants, were the same where the larger crops were grown with ammoniacal salts, and the smaller ones without them, we should still expect that the larger produce

would dry somewhat less, exposed to equal circumstances during the making. But the description of the herbage, and its degree of forwardness, have been seen to vary very much according to the manure employed. The produce grown by ammoniacal salts gave a much larger proportion of Graminaceous plants than that grown without them. The mere flowering and seeding stems of this Graminaceous herbage, would contain a higher percentage of Dry matter than the leaves and younger shoots. But besides the detached leafy matter, the larger culms grown by the ammoniacal salts, were themselves more luxuriant and succulent, and carried more green leaves and shoots than the smaller ones grown under otherwise comparable conditions, but without the ammoniacal salts.

It is obvious, then, that the percentage of the *Dry matter* in such complex and heterogeneous produce as *hay*, is dependent on too many coincident causes, to be of itself any unconditional indication of the character, or degree of maturity, of such produce.

The percentages of *mineral matter*, and of *nitrogen*, in the dry substance of the hay grown by the different manures, will be some further guide as to the comparative degrees of succulence, or maturity, of the produce developed under the different conditions.

2.—*Total Mineral Matter* (*Ash*).

The *mineral matter* was determined by burning to ash the portions of hay which had been dried at 212° F., and re-weighed for the determination of the dry matter. The burning was conducted on sheets of platinum placed in cast-iron muffles, heated by coke. Duplicate determinations were always made. The *mean* percentages only, of the two determinations, are given in Table XII.; and the *individual results* are recorded for reference in Tables II., III., and IV., in the Appendix.

In *ripened* produce, such as our crops of corn, the relations of the percentages of *mineral matter* in the dry substance in a series of comparable specimens, are pretty clear indications of the relative degrees of elaboration and ripeness of such produce. Other things being equal, the smaller the percentage of Mineral matter in the dry substance, the more highly elaborated, or the riper, is the specimen. The percentage of *nitrogen* in our ripened corn-crops is affected in a somewhat similar manner. Other things being equal, the lower the percentage of Nitrogen in the dry substance, the higher, taking the average of seasons, will be the condition of maturation of the produce.

The like generalisation appears to be more applicable to the composition of the complex and but partially ripened produce—*hay*, than would perhaps have been anticipated.

Experiments with Different Manures on Permanent Meadow Land.

Table XII.—Percentages of Mineral Matter (Ash) in the Hay (Means of Duplicate Determinations).

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Percentages in the Hay as taken from the Land.				Percentages in the Dry Substance of the Hay.			
		1856.	1857.	1858.	Average of 3 years.	1856.	1857.	1858.	Average of 3 years.
	Series 1.—Without Direct Mineral Manure.								
1	Unmanured	6·26	5·63	5·70	5·86	7·64	6·61	6·64	6·96
2	Unmanured (duplicate plot)	6·64	5·71	5·56	5·97	8·10	6·54	6·50	7·05
	Mean, or Standard Unmanured	6·45	5·67	5·63	5·91	7·87	6·57	6·57	7·00
3	2000 lbs. Sawdust	6·62	5·64	5·61	5·96	8·20	6·43	6·65	7·09
4	200 lbs. each, Sulphate and Muriate Ammonia	6·44	5·48	5·14	5·69	8·06	6·32	6·11	6·83
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	6·01	5·51	5·33	5·62	7·54	6·29	6·35	6·73
6	275 lbs. Nitrate of Soda	..	..	5·73	..	..	..	6·75	..
7	550 lbs. Nitrate of Soda	..	..	5·38	..	..	..	6·26	..
	Mean	6·38	5·59	5·67	5·79	7·92	6·40	6·45	6·91
	Series 2.—With Direct Mineral Manure.								
8	"Mixed Mineral Manure"*	6·92	6·16	6·48	6·52	8·63	7·10	7·57	7·77
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	7·31	6·60	6·47	6·79	9·08	7·60	7·70	8·13
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	6·77	6·28	6·53	6·53	8·58	7·21	7·95	7·91
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	7·03	6·42	6·80	6·75	9·09	7·36	8·11	8·19
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	6·72	6·72	6·68	6·71	8·49	8·49	8·11	8·36
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	6·57	6·42	6·35	6·45	8·41	7·47	7·87	7·92
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	..	..	6·40	..	..	..	7·40	..
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	..	..	6·52	..	..	..	7·65	..
	Mean	6·89	6·43	6·53	6·62	8·71	7·54	7·79	8·01
	Series 3.—With Farmyard Manure.								
16	14 tons Farmyard Manure	7·29	6·51	6·72	6·84	9·58	7·45	7·95	8·33
17	14 tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	7·52	6·45	6·74	6·90	9·45	7·48	8·14	8·36
	Summary.								
	General Means for the Experimental Specimens	6·80	6·15	6·16	6·37	8·58	7·15	7·73	7·82
	Mixed Hay from the same Meadow; taken out of the rick, December, 1858	..	5·58	5·73	..	..	6·40	6·84	..

* For full description of the "Mixed Mineral Manure," see page 6.

The hay-season of 1856 was wet and cold, and the produce it yielded contained a very low percentage of dry substance. The hay-seasons of 1857 and 1858 were, upon the whole, much drier and warmer, and, accordingly, the percentages of dry substance in their produce were much higher. Coincidently with the much lower percentage of dry matter in the produce of 1856, there was a considerably higher percentage of Mineral matter in the dry substance of that produce than in that of either 1857, or 1858. Again, the average percentage of dry substance in the hay was lower in the produce of 1858 than in that of 1857; and in accordance with this, the average percentage of Mineral matter in the dry substance of the produce of 1858, was higher than in that of 1857. It appears then, that, *comparing season with season*, the general result on this point in regard to hay, is in conformity with that generally observed in the case of more equably ripened produce. That is to say, the lower the condition of elaboration of the constituents of the produce, the lower is the percentage of the Dry substance, and the higher the percentage of the Mineral matter in that dry substance.

So much for the results in regard to the percentage of *Mineral matter* in the hay, as affected by *season*. We turn now, to the influence of *manuring* on the composition of the hay in regard to Mineral matter.

When it is borne in mind—that the proportion of the produce which will consist of Graminaceous, Leguminous, or other herbage, —that the proportion of the respective plants comprised within each of these main classes—that the proportion of each that will be in leaf and culm respectively—and that the condition of maturity at any given time—will vary very considerably according to the manure employed, it will be obvious that the variations in the percentages of Mineral matter, due to *manuring*, will be the resultants of many coincidently operating causes. On these points it may be observed—that the dry substance of Leguminous herbage contains on the average about 1⅓rd time as high a percentage of Mineral matter as that of Graminaceous herbage; that the dry substance of the leafy portion of the produce contains a higher percentage than that of the stemmy portion; and lastly, that the riper the produce the lower will be the percentage of Mineral matter in the dry substance. But again, in our green and unripened produce more especially, the *percentage* of Mineral constituents, as well as the actual amounts assimilated over a given area of land, are very much affected by the deficiency or liberality of their supply, in available form, within the range of collection of the growing crop.

The Table (XII.) shows that where no mineral manure was employed—and especially where nitrogenous manures were used alone, and the production thus pushed to the extreme limit of

the available supplies of the mineral constituents of the soil itself—the percentage of Mineral matter, in the dry substance of the hay, was comparatively low. A somewhat similar result has been observed in the case of corn-crops grown under similar circumstances. In illustration of the point in regard to the hay, it is seen that, whilst the average percentage of Mineral matter in the dry substance of the specimens grown without mineral manure was 6·91, that taking the average of the cases where artificial mineral manure was employed, was 8·01. It is true that, in those cases where mineral manure was employed with ammoniacal salts, the *stemmy* produce was somewhat less ripe, and hence, so far, the percentage of Mineral matter in the dry substance would be expected to be comparatively high. On the other hand, the produce in these cases was almost entirely Graminaceous, and the Graminaceous produce itself contained a large proportion of stem to leaf, and both of these circumstances would, other things being equal, tend to a low percentage of Mineral matter in the dry substance. In fact, upon the whole, the evidence is pretty clear, that the lower percentage of Mineral matter in the dry substance of the produce grown without mineral manure, was due to a relalative deficiency of available mineral constituents in the soil. The direct influence of the supply of mineral constituents by manure, upon the assimilation of them by this voracious crop, will be further illustrated presently, when speaking of the *composition of the ash* of the produce grown by the different manures.

Where the mineral manures were used alone, more than one-fifth of the produce consisted of Leguminous herbage. Hence, it might be supposed, that the percentage of Mineral matter in the gross produce, or hay, would be higher than where nitrogenous manures were also employed, and the produce was almost entirely Graminaceous. Again, where the mineral was used without the nitrogenous manure, the proportion of the Graminaceous produce that was leafy was much greater than where nitrogenous manures were also used. This circumstance, again, would tend to a high percentage of Mineral matter in the produce grown by the mineral manures alone. But the fact was, that the percentage of Mineral matter in that produce was comparatively low. The result was, doubtless, due to the fact, that a large proportion of this produce by mineral manure alone, was much riper than that grown by the mineral and nitrogenous manures combined.

It appears then, that in the case of the complex and unripened produce—*hay*, the description of the herbage, the character of development, the stage of progress at which the plants are cut, and the supplies within the reach of the growing crop, all have a marked influence upon the percentage of *Mineral matter* in the produce. The effects of different manure, in one and the same

season, upon this percentage are, therefore, at least complicated, if not indirect. Nor do the relative percentages among a series of specimens so clearly indicate the comparative conditions of elaboration and maturation merely, as they generally do in the case of professedly ripened produce.

3.—*Constituents of the Ash.*

The influence of the artificial supply of mineral constituents upon the total amount of them assimilated by the crop over a given area of land, has been illustrated in Part II. of our Report. The influence of such supply upon their percentage in the dry substance of the produce has now been shown. By the aid of complete analyses of the *ashes* of the produce of some of the experimental plots, further light will be thrown on the effects of a liberal provision of mineral constituents in the soil on the mineral composition of the crop.

In the first Division of Table XIII. is given the *percentage composition* of the ashes from the produce of five of the experimental plots; in the second Division of the Table the amounts of each of the several mineral constituents in the average annual *total produce* per acre on each of the plots; and in the third Division the *increase* in the amounts of the several mineral constituents obtained, per acre, in the crop, under the influence of the different manures.

The plots selected were—the unmanured; the one with ammoniacal salts alone; the one with mixed mineral manure alone; that with the mixed mineral manure and the smaller amount of ammoniacal salts; and that with the mixed mineral manure and the larger, or double amount of ammoniacal salts. In the case of each of the 5 plots, an equal mixture of the ash of its produce in each of the three years was operated upon. In this way the average effect of each condition of manuring upon the mineral composition of the crop is taken over a three-years' continuance of that condition.

The ash-analyses were made in the Rothamsted laboratory, by Mr. Robert Warington, jun.; and we are glad to take this opportunity of expressing our full confidence in the accuracy of his results.

The facts which the figures in the Table disclose are very interesting. But our comments on them must be very brief, and be confined to their practical bearings.

It has been shown in Parts I. and III. of our Paper, that ammoniacal salts alone gave an almost entirely Graminaceous produce, but that that produce was stunted, very dark green, leafy, and, comparatively, not much more in weight per acre than that without manure. Mineral manures alone, on the other hand, increased the weight of produce somewhat more than the ammoniacal salts alone; but the increase in this case was chiefly Leguminous herbage—the Graminaceous herbage benefiting but little by this

Effects of Different Manures on the Mixed Herbage of Grass-Land.

Table XIII.—Percentage Composition of the Ash; and Quantities of the several Mineral Constituents in the Total Produce, and in the Increase by Manure, per Acre.

	Percentage Composition of the Ash.					Mineral Constituents in Total Produce (lbs.).					Mineral Constituents in Increase (lbs.).			
	No Manure.	Ammonia Salts. (82 lbs. N.)	Mineral Manure.	Mineral Manure and Ammonia Salts. (82 lbs. N.)	Mineral Manure and Ammonia Salts. (164lbs.N.)	No Manure.	Ammonia Salts. (82 lbs. N.)	Mineral Manure.	Mineral Manure and Ammonia Salts. (82 lbs. N.)	Mineral Manure and Ammonia Salts. (164 lbs.N.)	Ammonia Salts. (82 lbs. N.)	Mineral Manure.	Mineral Manure and Ammonia Salts. (82 lbs. N.)	Mineral Manure and Ammonia Salts. (164lbs.N.)
Peroxide of Iron	0·13	0·12	0·31	0·45	0·52	0·2	0·3	0·7	1·9	2·4	0·1	0·5	1·7	2·2
Lime	14·98	13·85	13·38	9·60	8·65	23·7	31·0	32·4	41·7	39·8	7·3	8·7	18·0	16·1
Magnesia	4·14	4·70	3·70	3·41	3·98	6·6	10·5	9·0	14·8	18·3	3·9	2·4	8·2	11·7
Potash	20·40	17·09	29·77	28·08	28·89	32·3	38·2	72·2	121·9	132·9	5·9	39·9	89·6	100·6
Soda	8·43	10·31	4·58	7·05	8·49	13·3	23·0	11·1	30·6	39·0	9·7	−2·2	17·3	25·7
Phosphoric Acid	4·86	4·64	6·67	6·30	5·97	7·7	10·4	16·2	27·4	27·5	2·7	8·5	19·7	19·8
Sulphuric Acid	6·09	7·56	7·78	6·27	5·71	9·6	16·9	18·9	27·2	26·3	7·3	9·3	17·6	16·7
Chlorine	6·22	14·66	6·52	16·49	19·93	9·8	32·8	15·8	71·6	91·7	23·0	6·0	61·8	81·9
Carbonic Acid ..	5·62	3·21	6·63	1·87	1·73	8·9	7·2	16·1	8·1	7·9	−1·7	7·2	−0·8	−1·0
Silica	25·91	21·17	18·82	18·57	15·89	41·0	47·3	45·6	80·6	73·1	6·3	4·6	39·6	32·1
Sand	1·41	1·95	0·82	2·84	2·98									
Charcoal	3·19	4·08	2·54	3·04	2·13									
	101·38	103·34	101·52	103·97	104·87									
Deduct O = Cl. *	1·40	3·31	1·47	3·72	4·50									
Totals	99·98	100·03	100·05	100·25	100·37	153·1	217·6	238·0	425·8	458·9	64·5	84·9	272·7	305·8

* In the absence of knowledge which chemistry does not supply, as to the state of combination, either in the plant itself, or in the ash, of the several constituents determined in a plant-ash, it is considered far better to make no assumptions on the point. It is, moreover, far more convenient, both for the comparison of the composition of one ash with that of another, and for the purposes of any calculations with a practical view, to represent the whole of the sodium and potassium as soda and potash; instead of part as such, and part as chlorides, as is frequently done when chlorine is present. This method, of course, requires the deduction from the sum of the constituents, of an amount of oxygen equivalent (chemically) to the total chlorine.

manure, excepting in forwardness and seeding tendency. But the mixture of the two manures—ammoniacal and mineral—gave an enormous increase of crop, and the amount of mineral constituents taken off an acre of land, under the influence of the combination, was nearly twice as great as that in the crop by either of the manures used separately. It was quite obvious, that where the *ammoniacal salts* were used *alone*, the available supply of some of the necessary *mineral* constituents fell short of the amount required for a more abundant crop. It was equally clear, that where the *mineral manures* were used *alone*, there was a deficiency of *nitrogen* available for the increased growth of the Graminaceous herbage. The results in the Table show that it was chiefly for its supply of *potash*, and next for that of *phosphoric acid*, that the mixed mineral manure was so efficacious in increasing the growth of the *grasses*, when there was a sufficiency of available *nitrogen* within the soil. They also point to a probable deficiency of soluble *silica* in the case of the heavier crops.

To turn to the figures in the Table: the most striking point of contrast afforded by the view of the results of the five analyses given side by side, is the very great increase in the percentage of *potash*, wherever the mineral manure containing it was employed. There is, at the same time, always a diminution in the *soda*, either in its actual percentage, or in its proportion to that of the potash, or in both these points of view. This was the case, notwithstanding that soda as well as potash was liberally supplied in the mineral manure. The preference of the growing plants for potash rather than soda is sufficiently manifest. And judging from the analogy of other crops it may almost certainly be concluded that, if all the plants of the hay had been allowed to fully ripen, the ash would then have contained but very little soda, if any at all. The increase in the percentage of *potash* in the ash, where it was supplied in manure, is at the expense of the lime and magnesia, though these constituents were also supplied in the mixed mineral manure. In fact, the ash both of the produce without manure, and of that by ammoniacal salts alone, gave a somewhat higher percentage of both lime and magnesia than even where the mineral manures alone were used, and the produce contained so much Leguminous herbage, the ash of which is richer in lime and magnesia than is that of the Grasses proper. The percentage of lime more particularly, was still further reduced, when the ammoniacal salts were mixed with the mineral manure, by which the growth of the Grasses, demanding so much potash, was so much increased.*

* It is seen that wherever the ammoniacal salts were employed, which consisted of a mixture of the sulphate and hydrochlorate, the amount of *chlorine* in the ash is very much increased. This constituent, like soda, is found only seldom,

The percentage of *phosphoric acid*, as well as that of potash, was increased notably, though not in so great a degree, where the mineral manure containing it was used.

The percentage of *sulphuric acid* in the ash is pretty uniform throughout, though it was supplied largely both in the ammoniacal salts and in the mixed mineral manure. Whether or not, the whole of the sulphuric acid found, existed *as such* in the plant, in combination with bases, or whether, on the other hand, there has been any loss of it, or of sulphur in some form, during the incineration, may be a question. It is, at any rate, worthy of remark how very much larger is the proportion of *chlorine* found in the ash of this succulent produce wherever it was used in manure, notwithstanding that this substance (chlorine) may be supposed to be in a far less degree than sulphur or sulphuric acid, if at all, essential to the elaboration of the final products of the plants.*

Carbonic acid is seen to be in the largest proportion in the produce grown without manure, and in that by mineral manures alone. The Carbonic acid is the product of the incineration of some other organic acid. Its comparatively large amount in the ash of the produce of the two plots mentioned is due to the Leguminous and other non-Graminaceous herbage, occurring in large proportion on those plots. The ash of such herbage (the non-Graminaceous) contains, indeed, little or no silica, and frequently a great deal of Carbonic acid due to salts of organic acids.

The percentage of *silica* is, nevertheless, much higher in the ash of the produce grown without manure than in that grown by any of the artificial manures now in question. The percentage of *silica* in the ash is the less where the proportion of the Graminaceous herbage—which so peculiarly requires it—is the greater. And where the total Graminaceous herbage was thus the greater, it was also in the larger proportion in flowering and seeding stem; and as the stem increases, so, when not in defect, does the proportion of *silica*. It is true that where the Graminaceous produce was so large, and the proportion of it that was in flowering and seeding stem was also large, those stems were not so

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or in small quantity, in the ash of perfectly-ripened vegetable produce. It probably serves more as a vehicle of bases, than as an essential constituent of any of the final products of the organism.

* The fact, that in such highly siliceous ashes the amounts of chlorine should not only in some cases be very large, but that the variations in amount should have such very obvious connection with the manurial conditions supplied, is quite in accordance with the experiments of Mr. Way, showing that a loss of chlorine need seldom be feared when the process of incineration is carefully conducted. It is true, that the percentage of chlorine is the lowest where that of the silica is the highest, and that of the chlorine is the highest where that of the silica is the lowest; but the differences in the proportions of the respective constituents have, at the same time, as has been said, a very obvious connection with the known conditions of their supply or deficiency.

ripe as were those of the smaller Graminaceous crops; and it is as the Graminaceous plants progress to ripeness, that their ashes increase so much in percentage of *silica*. It would appear from these considerations, that there was a deficient supply of *available silica* for the greatly-increased growth. But a better view of the probable mineral requirements, or deficiencies, of the crop, will be gained by attention to the actual or increased amounts of the several constituents in the *acreage produce* under the different manuring conditions, as shown in the second and third Divisions of the Table (XIII.).

By the use of *ammoniacal salts alone*, the amount of total mineral constituents taken off in the crop is about 1½ time as much as without any manure at all. From the obvious limit that there was to the Graminaceous increase by ammoniacal salts alone, it is assumed that, in the case of some of the mineral constituents of the soil, its supplies were drained to the utmost that the range of distribution of the underground feeders of the plant would permit. Supposing this to be the case, it is seen that the gain in both *potash* and *silica* was proportionally less than that of any other important constituent. But, as soon as potash is added in manure, even though without ammoniacal salts, the acreage amount of it in the crop is increased in larger proportion than that of any other important mineral constituent, except phosphoric acid. The *silica*, which was not supplied in the manure, was comparatively but little increased in the produce. When the ammoniacal salts as well as mineral manure were employed, the amount of *potash* in the acreage produce was nearly twice as much as when the mineral manures were used alone; and it was from 3 to 4 times as much as when no manure at all, or ammoniacal salts alone, were employed. Under the same circumstances, the acreage amount of *phosphoric acid* increased in almost an equal degree. So also did that of the *sulphuric acid*. The *silica* even, was about doubled; though there was no supply of it in manure. And, lastly, the *magnesia*, but especially the *lime* (though both were supplied in the manure) increased very much less in acreage amount than the potash.

From the whole it appears, that the much less acreage produce of hay, when the ammoniacal salts were used alone, than when they were used in conjunction with the mixed mineral manure, was due to a deficiency of available *potash* and *phosphoric acid* within the range of the roots of the crop. It also appears probable, that there was a relative deficiency of available *silica*, notwithstanding that the range of collection of the roots of the crop would be considerably increased where the ammoniacal salts and the non-siliceous mineral constituents were employed. It is true that the *acreage* yield of Silica was considerably increased where the

larger crops were grown; though it was so not at all commensurately with either the potash or the phosphoric acid. How far the increased amount of Silica, such as it was, was due to its being liberated in available form by the chemical action of the constituents of the manures employed, or how far only to the increased distribution and range of collection of the roots of the more actively growing crop, we do not decide.

To call to mind even more clearly than by the above statements how great is the drain upon the soil, more particularly of potash, phosphoric acid, and of silica, by a heavy hay-crop, it will be useful to quote here a few figures from the Table.

Whilst the unmanured produce contained only 32⅓ lbs., and that by ammoniacal salts alone only 38¼ lbs. of *potash*, that grown by the mineral manure alone (supplying potash) contained 72¼ lbs., that by the mineral manure and smaller amount of ammoniacal salts nearly 122 lbs., and that by the mineral manure and the larger amount of ammoniacal salts nearly 133 lbs. of potash, per acre, annually.

The *phosphoric acid* was increased from about 7¾ lbs. per acre per annum without manure, to scarcely 10½ lbs. with ammoniacal salts alone, to 16¼ lbs. with mineral manure alone, and to about 27½ lbs. by the mineral manure and ammoniacal salts together.

The *silica* amounted to 41 lbs. per acre per annum in the produce without manure, to 47⅛ lbs. in that by ammoniacal salts alone, to nearly 45⅝ lbs. in that by mineral manure alone, to 80⅝ lbs. in that by the mineral manure and the smaller amount of ammoniacal salts, and to a little more than 73 lbs. in that by the mineral manure and the larger amount of ammoniacal salts.

We have already prominently called attention to the fact that the hay-crop, both from the large amount of mineral constituents it generally carries from the land, and from the generally more inadequate return of them by the home or other manures, is liable to be much more exhausting to the soil than the rotation crops of a farm. It has been stated, too, that *potash* was perhaps the constituent most likely first to show a deficiency. These ash-analyses, and the discussion to which they have led, cannot fail to impress upon the mind of the farmer still more forcibly the necessity of a due return to the land, at least of *potash* and *phosphoric acid*, if not even of available *silica* (which would be accomplished by farmyard-manure), if he would hope to obtain anything like maximum crops of hay, year by year, by the aid of artificial nitrogenous manures.

It has just been seen how very variable is the composition of the *ash* of the mixed herbage of meadow-land according to the *manure* employed. It has before been shown that the composi-

tion of the total mixed produce, or *hay*, varied very much according to *season*—both in regard to the percentage of Dry substance, and to that of the Mineral matter in that Dry substance. It will also presently be seen that the percentages of total Nitrogenous compounds likewise varied very much according to *season*. The *composition of the ash* does not, however, appear to be so much affected by variation in *season* as from the influence of the latter on the composition of the hay in other points of view might have been anticipated.

The much less effect of variation in *season*, than in *manuring*, on the *composition of the ash* of the experimentally-grown hay, is illustrated by the results given in Table XIV., which now follows:—

TABLE XIV.—Showing the COMPOSITION of the ASHES of MEADOW-HAY grown Experimentally in different Seasons.

	Mixed Ashes of the Produce by 16 different Manures in each Year.			
	1856.	1857.	1858.	Calculated Mean (1856-7-8).
Peroxide of Iron	0·14	0·33	0·25	0·24
Lime	13·02	12·13	11·92	12·36
Magnesia	3·59	3·93	3·97	3·83
Potash	26·83	26·43	25·26	26·17
Soda	6·40	7·45	9·58	7·81
Phosphoric Acid	5·59	5·68	5·52	5·60
Sulphuric Acid	6·02	7·14	7·18	6·78
Chlorine	11·37	12·15	12·25	11·92
Carbonic Acid	3·37	2·74	2·73	2·95
Silica	22·28	19·93	20·23	20·81
Sand	2·15	2·89	2·29	2·44
Charcoal	2·22	2·22	2·17	2·20
	102·98	103·02	103·35	103·11
Deduct O = Cl *	2·56	2·74	2·76	2·69
Totals	100·42	100·28	100·59	100·42

* See note at foot of Table XIII.

In the first column of the Table is given the composition of an equal mixture of the ashes of the produce from all the experimental plots in 1856; in the second column, the composition of a similarly mixed ash from the produce of all the plots in 1857; and in the third column, the composition of the mixed ash from all the plots in 1858. The fourth column gives the calculated mean of the three analyses.

The uniformity in the composition of the three mixed ashes,

representing as they do the percentage mineral composition of the produce of three very different seasons—the characters of which differed so widely in several other respects—is somewhat remarkable. The differences are indeed too slight to justify the deduction from them of any very defined conclusions. Still, it may be observed, that the tendency of the variations is to show a scarcely maintained, and in some cases an even diminished proportion, of those constituents which may be considered the most characteristic of the hay crop, when it is supplied liberally with all the necessary mineral constituents. Thus, the proportion of phosphoric acid is about equal in the three seasons, whilst that of the lime, the potash, and the silica, show a tendency to decrease from year to year. The carbonic acid too, which is characteristic of the ash of the non-Graminaceous part of the herbage, also diminishes somewhat from the first to the third year. On the other hand, the soda and the chlorine—constituents the most of all characteristic of crude and succulent growth—increase very obviously in their proportion in the ash from year to year.

Upon the whole then, these results, comparatively slight as the differences are, still indicate, as did those which have gone before, that there was a probable relative deficiency of *lime*, *potash*, and *silica*;—especially of the latter two.

With regard to the results given in the fourth column attention may be called to the fact, that the figures represent the mean composition of the ash of specimens of hay grown under sixteen different manuring conditions, in each of the three widely differing seasons. The results may therefore be taken as showing the average mineral composition of the mixed herbage grown under a great variety of circumstances.

4.—*Nitrogen.*

For the information of the chemical reader it may be mentioned, that the *nitrogen* in the hay, as given in the Table, was determined by burning with soda-lime, and estimating by the volumetric method. Duplicate determinations were always made. The individual results are given for reference in Tables V., VI., and VII., in the Appendix. The *mean* results only, are given in Table XV. on the next page; and these will be in sufficient detail for the purpose of our illustrations. The *nitrogen* was thus determined, in the hay from every one of the experimental plots, in each of the three years of the experiments. The figures in the first set of four columns (Table XV.) represent the percentages of Nitrogen in the *fresh hay*—that is, in the condition in which it was carted from the land. The figures in the second Division represent the percentages in the *Dry substance* of the hay.

Table XV.—Percentages of Nitrogen in the Hay (Means of Duplicate Determinations).

Plot, Nos.	MANURES (Per Acre, per Annum).	Percentages in the Hay as taken from the Land.				Percentages in the Dry Substance of the Hay.			
		1856.	1857.	1858.	Average of 3 years.	1856.	1857.	1858.	Average of 3 years.
	Series 1.—Without Direct Mineral Manure.								
1	Unmanured	1·68	1·29	1·40	1·46	2·05	1·52	1·63	1·73
2	Unmanured (duplicate plot)	1·79	1·43	1·34	1·52	2·18	1·64	1·57	1·80
	Mean, or Standard Unmanured	1·73	1·36	1·37	1·49	2·11	1·58	1·60	1·76
3	2000 lbs. Sawdust	1·67	1·38	1·41	1·49	2·07	1·57	1·67	1·77
4	200 lbs. each, Sulphate and Muriate Ammonia	1·57	1·55	1·65	1·59	1·96	1·78	1·96	1·90
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	1·59	1·49	1·56	1·55	1·99	1·71	1·86	1·85
6	275 lbs. Nitrate of Soda	..	..	1·68	..	..	..	1·98	..
7	550 lbs. Nitrate of Soda	..	..	1·71	..	..	..	1·99	..
	Mean	1·64	1·44	1·56	1·55	2·03	1·66	1·84	1·84
	Series 2.—With Direct Mineral Manure.								
8	"Mixed Mineral Manure"*	1·67	1·51	1·40	1·53	2·09	1·74	1·64	1·82
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	1·77	1·48	1·39	1·55	2·21	1·71	1·65	1·86
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	1·23	1·18	1·25	1·22	1·55	1·36	1·52	1·48
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	1·26	1·11	1·17	1·18	1·64	1·27	1·40	1·44
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	1·47	1·33	1·35	1·38	1·85	1·55	1·64	1·68
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	1·49	1·62	1·71	1·61	1·88	1·88	2·12	1·96
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	..	..	1·52	..	..	..	1·76	..
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	..	..	1·32	..	..	..	1·55	..
	Mean	1·48	1·37	1·39	1·41	1·86	1·58	1·66	1·70
	Series 3.—With Farmyard Manure.								
16	14 Tons Farmyard Manure	1·35	1·31	1·18	1·28	1·77	1·50	1·40	1·58
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	1·62	1·08	1·27	1·32	2·04	1·26	1·53	1·61
	Summary.								
	General Means for the Experimental Specimens	1·53	1·37	1·43	1·44	1·93	1·58	1·70	1·74
	Mixed Hay from the same Meadow, taken out of the rick December, 1858	..	1·33	1·16	..	..	1·53	1·38	..

* For full description of the "Mixed Mineral Manure," see page 6.

It will be found, that the percentage of *nitrogen* in the Dry substance of such heterogeneous and irregularly ripened produce as hay, is, like that of the mineral matter, contingent upon many coincident circumstances. Still, the results will show, as already alluded to, that, other things being equal, the lower the condition of maturation of the produce, the higher will be the percentage of Nitrogen, and *vice versâ*.

In accordance with this general observation, the Table shows that the season which gave the produce yielding the lowest average percentage of Dry substance, and the highest average percentage of Mineral matter in that dry substance (1856), gave also a produce containing a higher percentage of *nitrogen* in its dry substance than that of either of the years of higher condition of the hay. Conversely, the second season (1857), the produce of which showed the highest average percentage of dry matter, and the lowest average percentage of mineral matter in that dry substance, gave, at the time of cutting, a hay which contained the lowest average percentage of Nitrogen in that dry substance. As between the produce of one season with that of another, then, the general result was, that the more matured the condition of the hay, the lower was the percentage of Nitrogen in its dry substance. This is in general accordance with what we have elsewhere shown to obtain in the case of ripened crops—wheat and barley. It is true, that in the case of the hay-crop, the object is not a fully ripened produce. There is, therefore, of course, a limit below which a depreciation in the percentage of Nitrogen, the result of over-ripening, will be a disadvantage. At the same time, we believe that, comparing the produce of hay of one season with that of another, each cut at its proper stage of progress, that which has the lower percentage of Nitrogen in its dry substance will, taking the average of seasons, have its constituents in the better condition of elaboration, and be, therefore, a better food for animals.

The variations in the percentage of Nitrogen in the hay within one and the same season, according to the *manuring*, are very marked and interesting.

Taking the average result of the three seasons, the produce grown on the plot manured with ammoniacal salts alone, contained a much higher percentage of Nitrogen in its dry substance than did that grown without manure. Again, the produce grown by ammoniacal salts and sawdust gave a higher percentage of Nitrogen than that grown by sawdust alone. When the ammoniacal salts were thus supplemented to the unmanured, or to the merely sawdusted conditions, the supply of Nitrogen was in considerable relative excess; as was shown by the greatly increased produce when the mixed mineral manure was superadded.

Under these circumstances, the percentage of the deficiently-provided Mineral constituents was comparatively low, whilst that of the relatively excessively supplied Nitrogen was considerably increased. The percentage of Nitrogen was thus increased, notwithstanding that the produce was almost entirely Graminaceous where the ammoniacal salts were used; whilst, where they were not employed, it contained a notable proportion of Leguminous herbage, the percentage of Nitrogen in which is generally about twice as high as in purely Graminaceous produce. The high percentage of Nitrogen in the produce grown by ammoniacal salts without mineral manure was, therefore, due to an increased percentage of it in the Graminaceous herbage. This highly nitrogenised Graminaceous produce consisted, it will be remembered, in very large proportion of *leaf;* it was stunted in growth; and was of a very dark green colour compared with the produce where there were larger crops.

The mixed mineral manure used alone, or in conjunction only with sawdust, gave a produce which contained a higher percentage of Nitrogen than either that grown without manure or with sawdust alone. The percentage of Nitrogen under these conditions was nearly as high as where the ammoniacal salts, or the ammoniacal salts and sawdust (without mineral manure), were used, which gave the stunted, dark green produce, above referred to. But the high percentage of Nitrogen in the produce now under consideration, namely, that grown by mineral without nitrogenous manure, was not due to a high percentage in the Graminaceous part of it. It was due to the fact, that the produce grown under these conditions contained a large proportion of Leguminous herbage, the percentage of Nitrogen in which is, as above stated, generally about twice as high as that in purely Graminaceous hay.

It has been seen, then, that the mineral manure alone gave a produce containing a high percentage of Nitrogen by increasing the proportion in it of the highly nitrogenous Leguminous herbage. It has also been seen, that the use of ammoniacal salts alone, mineral constituents being in defect, gave a stunted Graminaceous produce, also with a considerably increased percentage of Nitrogen. The addition of ammoniacal salts, when there was at the same time a liberal provision of mineral constituents, gave a very different result, both as to the character and amount of the crop, and as to the percentage of its Nitrogen.

If we compare the composition of the produce manured with both ammoniacal salts and the mineral manure, with that grown by the mineral manure alone, or again, if we compare the produce by ammoniacal salts, sawdust, and mineral manure, with that by the sawdust and mineral manure without the ammoniacal

salts, the Table shows that, in both cases, the percentage of Nitrogen in the produce was considerably lower where the ammoniacal salts were employed than in the comparable instances without them. This lower percentage of Nitrogen in the hay, by the addition of ammoniacal salts to mineral manure, was partly due to the fact, that the produce grown by the mineral manure without the ammoniacal salts, contained so large an amount of the highly Nitrogenous Leguminous herbage, whilst that grown with ammoniacal salts in addition, was almost entirely Graminaceous. But the percentage of Nitrogen in this Graminaceous produce grown by ammoniacal salts together with a liberal supply of mineral constituents, was also very much lower than that in the equally Graminaceous produce where the nitrogenous supply was in excess; that is to say, where the ammoniacal salts were used without the mineral manure. Thus, taking the average of the three years, the percentage of Nitrogen in the dry substance of the hay grown by ammoniacal salts alone, was 1·9; whilst that in the dry substance of the produce grown by the same amount of ammoniacal salts, but in conjunction with the mineral manure, was only 1·48. This produce grown by the nitrogenous and mineral manure combined, was about $1\frac{2}{3}$ time as great as that grown by the use of ammoniacal salts alone; it was of a far lighter, and more lively green colour whilst growing; it was far more luxuriant; and it gave a much larger proportion of flowering and seeding stem. Such were the comparative characters of the produce, which contained much the lower percentage of Nitrogen. The higher percentage of Nitrogen in the produce grown by the ammoniacal salts without the mineral manure was, therefore, coincident with a much smaller yield of hay, with a much less luxuriance of growth, and with a much larger proportion of leafy produce. In fact, in the case of hay, as in that of the ripened cereal grains, a relatively low percentage of Nitrogen (within certain limits) is, in cases comparable on the point, more likely to be associated with a relatively high, than with a relatively low condition, and degree of elaboration, of the constituents; and it is also more likely to be the result of moderately luxuriant, than of either stunted, or over-luxuriant growth.

The points last referred to, are aptly illustrated by a comparison of the characters, and nitrogenous percentage, of the hay grown by the double amount of ammoniacal salts with the mineral manure, with those of the produce grown by the smaller amount of ammoniacal salts and the same mineral manure. The average percentage of Nitrogen in the dry substance of the scarcely too heavy or luxuriant produce grown by the mineral manure and the smaller amount of ammoniacal salts, was only 1·48; whilst, that in the dry substance of the over-luxuriant, unevenly-ripened

and laid and damaged produce, grown by the same mineral manure and the double or excessive amount of ammoniacal salts, was 1·96. It will not be doubted, that the higher percentage of Nitrogen was, under these circumstances, coincident with a more crude and less favourable condition of the constituents of the hay. It has been shown experimentally by Professor Voelcker, that succulent plants may contain a part of their nitrogen in the condition of ammoniacal salts; and Professor Sullivan has more recently called attention to the apparently frequent occurrence of both ammonia and nitric acid in the sap of plants. We had too, ourselves, long since pointed out, that turnips in which the percentage of Nitrogen was raised beyond a comparatively low amount by means of highly nitrogenous manures, were, weight for weight, of less feeding value than those having a far lower percentage of Nitrogen, but which were in a less crude and succulent, and a more highly elaborated condition. Indeed such highly nitrogenous turnips were even purgative and injurious.*

Attention should be called to the fact, that the produce grown by *nitrate of soda* alone, like that grown by ammoniacal salts alone, contained a much higher percentage of Nitrogen, than that grown without manure.† Again, the addition of mineral manure to the nitrate of soda, by which the crop was considerably increased, gave a produce containing a lower percentage of Nitrogen than that grown by nitrate of soda alone.

Before leaving the results of Table XV., it may be observed that, *taking the average of the three seasons*, the addition of ammoniacal salts to *farmyard manure*, gave a produce containing a slightly higher percentage of Nitrogen. In the second season, however, which was the one of the highest dryness and maturation of the hay, at the time of cutting, a contrary result was obtained.

From the whole of the results in regard to *nitrogen*, it would appear, that a *high percentage* is by no means a safe indication of relatively high feeding quality. In fact, in succulent and unripened produce more particularly, it is an uncertain indication even of high amount of elaborated nitrogenous vegetable compounds.

5.—*Cellular Matter, or Woody Fibre.*

The constituent of vegetable food-stuffs, to which the term "*woody fibre*" is frequently given, is that portion which remains undissolved after the application of such solvents as are supposed to remove all the other vegetable compounds—namely, the nitro-

* 'Jour. Roy. Agr. Soc. Eng.,' vol. x. (1849), pp. 306–315 inclusive.

† As the amount of nitrogen in the hay grown by the *nitrate of soda*, was determined by combustion with soda lime, and estimation as ammonia by the volumetric method, the high amount recorded in the Table could not be due to undecomposed nitric acid or nitrate.

genous substance, the fatty matter, the starch, the sugar, the gum, the extractive matters, &c. The substance so remaining generally retains, however, a certain amount of mineral matter, the quantity of which is determined by the incineration of the fibre. The attainment of certain results in regard to the amount of this so-called "woody-fibre" is, however, in practice, not a very easy matter. It is seldom that two experimenters have adopted the same methods for its quantitative estimation. And, although it is comparatively easy to determine whether or not the product of the process still retains some of the other matters enumerated above, it is by no means so easy to settle whether or not any portion of the substance which it is intended to include under the term Woody-fibre, has itself been rendered soluble and removed. For the results we have to lay before the reader under this head, as well as for those relating to the Fatty matter, to which we shall refer further on, we are indebted to M. Thomas Segelcke, of Copenhagen, who kindly undertook this part of the investigation whilst staying in the Rothamsted laboratory.

It would be out of place to go elaborately into the question of method here; and it is the less necessary as M. Segelcke has given a separate paper on the subject elsewhere.* It may be mentioned, however, that he in vain tried to get results which corresponded with one another when using the different methods that have been recommended. In fact, constancy of result seemed to be only attainable, when solvents of a constant strength were employed, for a fixed period of time, and at a given temperature. The necessity for observing fixed time and temperature, has been insisted upon by M. Millon; and the strength of solvents which M. Segelcke adopted in the analysis of the hays, as giving pretty uniform results, was very much the same as recommended by M. Peligot.

The method by which the results given in the Table were obtained, was briefly as follows. About 10 grammes of the finely ground hay were first fully dried at a temperature of 212° F. The substance was next digested for three-quarters of an hour at a temperature, as nearly as it could be maintained, of 180° F., in 150 septems† of sulphuric acid, composed of one part, by volume, oil of vitriol, and two parts, by volume, water.‡

* "On the Current Methods for estimating the Cellular matter, or 'Woody-fibre,' in Vegetable Food-stuffs;" see "Report of The British Association for the Advancement of Science, for 1859." Aberdeen Meeting; Section B.

† A septem measure is that of $\frac{1}{1000}$th of a pound avoirdupois, or 7 grains, of water.

‡ The above is the strength of acid recommended by M. Peligot. In subsequent investigation M. Segelcke has found, that results of which the duplicates were much more closely agreeing, and which still ranged very close to those recorded in the Table and obtained by the method described in the text, could be insured by using a weaker acid, but at a higher temperature. So far as his experiments have yet proceeded, the strength of acid which he has found to be the

After this digestion, the whole was diluted with hot water, filtered, and the insoluble matter well washed with hot water. At this stage the product retained several per cent. of nitrogenous substance, and a considerable amount of other matters which were dissolved in the next step of the process. The substance was removed from the filter, and then boiled for half an hour with 600 septems of very dilute caustic soda. The whole was again thrown on a filter and well washed with hot water. A drop of sulphuric acid was, however, added to the wash-water after the main portion of the washings had passed off; and the washing was continued until the water no longer came through acid. The matter was then washed from the filter, dried, and weighed as *woody fibre*. After this treatment, the product still retained 0·1 per cent., or less, of its weight of nitrogenous substance, and some mineral matter; both of which were determined and deducted by calculation.

The individual determinations of this Woody-fibre are given for reference in Table VIII. in the Appendix; and an examination of them will show within what limits the duplicate or triplicate results agree with one another. It is believed that the figures are probably very trustworthy as a comparative series, comparing specimen with specimen as to the respective amounts of Woody-fibre of a given degree of insolubility or induration; but they are pretty certainly too low considered as including the whole of the *cellulose*. At least M. Segelcke found that even Swedish filtering paper was somewhat reduced in amount by the second part of the process, namely, the treatment with the alkali after the acid, though it was not so by the digestion with either the acid or the alkali only. On the other hand, with any less treatment with the alkali, not only higher results, but inconstant duplicates or triplicates, were obtained; and the product at the same time retained a considerably higher amount of nitrogenous substance.

As already intimated, the *woody fibre* was only determined in the hay of certain plots, namely, those selected for the botanical separations referred to in Part III. It was, however, determined in the produce of those plots, in each of the three years of the experiments. We are enabled, therefore, to trace the effects of both *season* and *manuring* on the percentage of the more insoluble *woody fibre*—so far as it can be indicated by

best is, 1 volume of oil of vitriol to 16 volumes of water; the temperature that of the boiling point; and the time of action a quarter of an hour. A great practical advantage of substituting the use of a stronger acid, and a temperature below the boiling point, by a weaker acid and the boiling point, is the ease by which constancy in the latter temperature can be secured. Indeed, the discrepancies, such as they are, between the duplicate and triplicate determinations recorded in the Appendix, Table VIII., M. Segelcke attributes mainly to the accidental fluctuations in practice, somewhat above or below his then adopted temperature of 180° F.

the results of the method above described. The *means* only, of the two or more determinations made on each specimen, are given in Table XVI. which now follows; and it is these to which we shall confine attention.

The professed object of determining the amount of *woody-fibre* in our food-stuffs, is to acquire some means of judging of their amount of probably indigestible and effete material. Now, it is sufficiently apparent from the researches of many able investigators, among whom we may mention Mulder, Harting, Boussingault, Millon, Peligot, Mitcherlich, Chevreul, Fremy, Cramer, and Payen, that the substance to which is given the somewhat generic term *woody-fibre*, comprises many modifications, which vary from each other, in physical characters, and in behaviour to solvents, according to age, and other circumstances of their deposition, and to the character and amount of the incrusting matters, and of the injected or foreign matters with which they are associated. In fact, some of the modifications which yield most easily to certain chemical solvents, seem to be separated by almost imperceptible lines of demarcation, from the admittedly more digestible starchy bodies. The two series of bodies appear, indeed, to be mutually transformable, not only in the laboratory of vegetable existence, but more or less in that of the chemist also.

How then, are we by the chemical analysis of a food, to determine exactly at what point of aggregation, induration, or protection by foreign substances, its Cellular or Woody matter is to be accounted as indigestible, innutritious, and effete? So long as the Cellular substance is in such a condition as to be easily acted upon by chemical solvents, or to be transformable within the plant, we may perhaps venture to assume, that it would not be wholly refractory to the digestive agencies of animals. If, therefore, it be admitted, that the amounts of matter recorded as *woody fibre* in our Table, do not include the more delicate and changeable Cellulose of the vegetable substance examined, they may, nevertheless, on that account, the more nearly represent the proportions of the respective hays, that will be necessarily indigestible and effete. In fact, although we do not at all claim that the results do indicate the *total cellulose* of the specimens examined, we still believe, that, so far as present experience goes, results so obtained are the best means at command for the purpose of comparing the specimens one with another, in regard to the relative proportion in each of the more refractory Cellular matter. And, so far as the substance which resists the action of solvents employed in the degree above described, may be found to be really indigestible and effete, a large relative proportion would, in this point of view, be objectionable. At the same time, it must be

Table XVI.—Percentages of Woody Fibre in the Hay (Means of Duplicate Determinations).

Plot, Nos.	MANURES. (Per Acre, per Annum.)	1856.	1857.	1858.	Average of 3 Years.
	Percentages in the Hay as taken from the Land.				
1	Unmanured	24·5	22·9	22·9	23·4
4	200 lbs. each, Sulphate and Muriate Ammonia	24·8	23·1	22·9	23·6
8	"Mixed Mineral Manure" *	24·0	23·0	25·0	24·0
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	25·5	25·3	24·1	25·0
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	25·6	24·2	23·6	24·5
16	14 tons Farm-yard Manure	23·7	25·8	24·5	24·7
17	14 tons Farm-yard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	23·6	25·0	24·3	24·3
	Means	24·5	24·2	23·9	24·2
	Percentages in the Dry Substance of the Hay.				
1	Unmanured	29·9	26·9	26·6	27·8
4	200 lbs. each, Sulphate and Muriate Ammonia	31·0	26·6	27·2	28·3
8	"Mixed Mineral Manure"	30·0	26·5	29·2	28·6
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	32·3	29·0	29·4	30·2
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	32·8	28·2	29·3	30·1
16	14 tons Farm-yard Manure	31·2	29·6	29·0	29·9
17	14 tons Farm-yard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	29·7	29·0	29·4	29·4
	Means	31·0	28·0	28·7	29·2

* For full description of the "Mixed Mineral Manure," see page 6.

borne in mind, that a certain proportion of this otherwise useless and effete matter, is absolutely essential to give bulk, and to aid the digestion of the other constituents of the food, especially of our ruminant animals.

With these brief observations on the character, and the relationships, of the substance the amounts of which, in the respective hays, are recorded in the Table, attention may now be directed to the results there given.

In the upper portion of Table XVI., the percentages of *woody-fibre*, or more properly of comparatively indurated Cellular matter, in the *fresh hay* are given; and in the lower Division, the percentages in the *Dry substance* of the hay. The latter indicate the most clearly the differences in the composition of the vegetable substance of the hay. Comparing the produce of one season with that of another, the percentage of this comparatively insoluble Woody-fibre is, on the average, considerably the highest in that of the wet, cold, and ungenial season 1856, and the lowest in that of 1857. It will be remembered that the produce of 1856, which shows the largest proportion of comparatively refractory Woody matter in its Dry substance, gave a very low percentage of Dry substance; but high percentages of both Mineral matter, and Nitrogen (in a questionable degree of elaboration), in that Dry substance. And, conversely, the produce of 1857, which now gives the lowest proportion of such Woody fibre in its Dry substance, gave the highest proportion of Dry substance, and the lowest proportion of Mineral matter, and of Nitrogen, in that Dry substance.

It might perhaps not have been anticipated, that the season which gave the most crude, succulent, and ill-conditioned produce, would at the same time give a vegetable substance containing a high proportion of comparatively indurated Cellular or Woody matter. In all cases, the specimens were so far dried soon after they were collected, as to leave in them only about 5 per cent., or less, of moisture; and in this condition they were ground and preserved. And, as the Woody-fibre determinations have only recently been made, the produce of 1856 has had some considerable time for change, were it liable to it. Under the circumstances of the preparation and preservation of the specimens, however, it would be difficult to conceive of any changes that would raise the percentage of indurated Cellular matter in the remaining substance, to the extent indicated in the Table above that in the produce of the other years. Against the probability of such change, may be noted the fact, that the produce of 1857, which had been preserved for nearly 2 years when examined, gave a *lower* percentage of this Woody-fibre in its Dry substance, than that of 1858 which, of course, had not been preserved so long. On the

other hand, neither do any of our records as to the character of the produce in the several years, or as to the characters of the seasons themselves, lead to the belief that the produce of 1856 was either in such large proportion *stemmy*, or so *forward*, at the time of cutting, as that of the other seasons. Should then, future researches confirm the indications of these results, we should have to adopt the important conclusion, that a crude and succulent produce—a large proportion of whose more soluble constituents exists in a low condition of elaboration—may at the same time have a large proportion of its more fixed constituents in the condition of comparatively indurated and innutritious Cellular matter. Or, may it be, that, when there is a low condition of elaboration of some of the more soluble constituents, so large a proportion of these undergo change, as to leave the more fixed Woody matter in larger proportion in the remaining total dry substance?

When the observed variations in the character of the produce are borne in mind, the effects of *manures* upon the relative percentages of the more fixed Woody-fibre in its Dry substance, are more clearly in accordance with what would be expected than are those of *season*. Taking the average result of the 3 years, the Dry substance of the *unmanured* produce, contained a comparatively low percentage of such Woody-fibre. This produce contained a large proportion of non-Graminaceous herbage; a fair proportion was stemmy, but it was backward; and with these characters there is a low percentage of Woody-fibre in the Dry substance. The Dry substance of the produce by *ammoniacal salts alone*, whose Graminaceous stems were comparatively ripe, but which contained a very large proportion of leaf, contained at the same time a comparatively small proportion of the "woody fibre." The produce by *Mineral manures alone*, consisted of a good deal of non-Graminaceous herbage, and the Graminaceous herbage comprised a considerable proportion of leaf, though its stems were comparatively ripe. With these characters, the percentage of the "woody-fibre" in the Dry substance was comparatively low. Where the *mixed mineral manure and ammoniacal salts were used together*, the produce was, comparatively, somewhat unripe; but it was almost entirely Graminaceous, and in very large proportion stemmy, and coincidently there is a comparatively large proportion of the "woody fibre" in the Dry substance. The produce by *farm-yard manure* was in a still larger proportion stemmy; but it contained also a considerable proportion of non-Graminaceous herbage. The result was, that its Dry substance contained a comparatively high percentage of the "woody-fibre," but not quite so high as that where the mineral manure and ammoniacal salts were used, and the produce was more exclusively Graminaceous.

Adopting the experimental indications which have been recorded, as the most trustworthy which in the existing condition of our knowledge on the points in question could be supplied, the result upon the whole would appear to be, that, on the one hand, a generally low condition of elaboration of succulent produce may still be associated with a high proportion of comparatively indurated, and therefore probably innutritious Cellular matter, in its dry substance. On the other hand, comparing the produce by different *manures*, in one and the same season, the more Graminaceous, the more stemmy, and the riper, the higher will be the proportion of the comparatively indurated Woody or Cellular matter.

6.—*Fatty Matter.*

In the analysis of animal and vegetable food-stuffs, it is usual to estimate as "*Fatty Matter*," that portion which is dissolved out from the dried substance by means of Ether. In the case of animal substances, or of ripened vegetable ones, such as grain, the substance so determined does generally represent a fatty matter of high respiratory and fat-forming capacity. Not so, however, in the case of crude, unripened, vegetable produce. In fact, in such produce, the so-called *fatty matter*, separated merely by extraction with ether, is largely contaminated with waxy and green colouring matter, a considerable proportion of which passes from the animal in its solid excrements. A relatively large proportion of such impure fatty substance can hardly be regarded, therefore, as an advantage. Still, it is useful to ascertain the amount of such matter, if it be only that, by a careful consideration of the conditions of growth, and other admitted qualities of the hay yielding the larger or the smaller proportions of it, we may be the better able to form a valid decision, whether or not the substance in question is likely really to indicate the high condition of elaboration of the constituents, which a large proportion of *pure fatty matter* might be supposed to do. A further reason for determining the amount of this substance, notwithstanding that we consider it of such doubtful value, is the fact, that this mode of analysis has been adopted with apparent confidence by most of our predecessors; whilst an accurate separation of the several bodies which compose this Ether-extract, would have increased the labour of analysis beyond that which it was practicable to devote to it. Nor, is the quantity of this impure Fatty matter in hay so large, as to render the differences in its amount of much importance in any other point of view, than as indicating the general character and condition of the produce.

The method adopted by M. Segelcke, in his determinations

of the *crude fatty matter*, was to pass ether through a dried and weighed portion of the finely ground hay, until it came through colourless. For this purpose, he devised an apparatus, by means of which the ether was continuously distilled from the extract, and repassed through the substance. At the end of the first treatment in this way, that is, when the ether passed through colourless, the substance was re-dried in the water bath, and then submitted to a second extraction in the ether-apparatus. The ether was finally distilled from the total ether-extract; and the remaining *green fatty matter* was dried in a water bath, until it no longer lost weight.

From what has already been said of the character of the "Fatty matter," the quantity of which in the respective hays, was determined by the methods just described, it would be useless to go into much detail as to the amounts found in the different specimens. It is the less desirable, too, to do so, as the circumstances and extent of its occurrence will be sufficiently brought to light, in taking the summary view of the composition of the different hays, with which we now propose to conclude our Report. The individual determinations of the Fatty matter will be found in Table IX. in the Appendix; and the mean percentages of it are embodied with those of the other constituents in Table XVII., to which attention is next, and lastly, to be directed.

7.—*Summary of the Composition of the Hay.*

In Table XVII. is given a summary view of the collective composition of the specimens of hay grown in the Third Season (1858), on those plots the produce of which was selected for the botanical separations. In the upper Division of the Table, the percentages of the several constituents *in the fresh hay as carted from the land*, are given. In the middle Division, the percentages in the *Dry substance* of the hay are given. And in the lowest Division, is a summary statement of the general description of the herbage on the respective plots. The means are thus afforded, of considering the chemical composition of the respective hays, in connection with the other known characters of the herbage. The constituents given are—

1st. Nitrogenous substance.
2nd. Fatty matter.
3rd. Woody-fibre.
4th. Other non-nitrogenous vegetable compounds.
5th. Mineral matter.
6th. Total Dry substance.
7th. Water.

A few brief remarks should first be made, as to the character of the several substances represented in the above enumeration.

Nitrogenous substance.—The most practicable and usual mode of getting at an approximate estimate of the total amount of Nitrogenous compounds, in vegetable or animal food-stuffs, is to determine the amount of *nitrogen*, and calculate from it the amount of Nitrogenous substances, on the assumption that they consist of the so-called *proteine compounds.* Adopting this assumption, the amount of Nitrogen has only to be multiplied by 6·3, to give, very nearly, the amount of Nitrogenous proximates that it would represent. This is the method which, from convenience, we have adopted. From what has been said under the head of Nitrogen, however, it will be obvious, that this mode of estimation affords, more particularly in the case of succulent and unripened produce, at best but an uncertain indication of the amount of elaborated and nutritive Nitrogenous compound. The so-calculated Nitrogenous substance may, in fact, not only include a quantity of matter in a low condition of elaboration, but even ammoniacal salts. It will be understood, therefore, with what degree of reservation the recorded amounts of "*nitrogenous substance*" must be taken, as indicating the probable amounts of nutritive proteine compounds.

Fatty matter.—The substance given under the head of Fatty matter, includes, as has been already explained, a quantity of waxy and green colouring matter, and must not be taken, therefore, as representing pure Fatty matter of high respiratory and fat-forming capacity.

Woody-fibre.—It will be borne in mind, that the substance recorded as Woody-fibre, is not supposed to include the whole of the Cellular matter in its various modifications; but only that amount of it which seems to possess a certain fixed degree of persistence, on the application of such solvents as are required to remove the other compounds. It is possible, however, that at any rate the easily changeable, and easily dissolved portions of the Cellular substance, may be amenable to the digestive organs of animals.

Other non-nitrogenous matters.—The substances put down as *other non-nitrogenous matters*, are all those which remain after deducting the "Nitrogenous substance," the "Fatty matter," and the "Woody-fibre," as above defined, and also the "Mineral matter." They comprise probably starch, dextrine, gum, sugar, and certain extractive matters. They will also include so much of the more easily changeable Cellular substance, as may have been dissolved by the re-agents required to remove all the other matters, in the process adopted for separating and estimating that portion which is recorded as "Woody-fibre." The characters, and

TABLE XVII.—COLLECTIVE VIEW of the COMPOSITION, and DESCRIPTION, of the MIXED HERBAGE.

CONSTITUENTS.	HAY FROM SELECTED EXPERIMENTAL PLOTS.								Mixed Hay from same Meadow; cut out of rick December, 1858.
		Artificial Manures.				Farmyard Manure.		Mean.	
	Unmanured. (Plot 1.)	Ammoniacal Salts, alone. (Plot 4.)	"Mixed Mineral Manure." (Plot 8.)	"Mixed Mineral Manure" and Ammoniacal Salts. (Plot 10.)	"Mixed Mineral Manure" and double quantity Ammoniacal Salts. (Plot 13.)	Alone. (Plot 16.)	With Ammoniacal Salts. (Plot 17.)		
1.—Composition per Cent. in the Fresh Hay.									
Nitrogenous Substance (N. × 6·3, reckoning 15·875 N. in Nit. Sub.)	8·82	10·39	8·82	7·87	10·77	7·43	8·00	8·87	..
Fatty Matter (Ether Extract)	2·87	3·00	2·55	1·99	2·36	2·48	2·80	2·58	..
Woody Fibre	22·88	22·87	24·97	24·11	23·64	24·51	24·31	23·90	..
Other non-Nitrogenous Vegetable Compounds (Starch, Sugar, Gum, &c.)	45·63	42·70	42·78	41·60	37·58	43·46	40·85	42·08	..
Mineral Matter (Ash)	5·70	5·14	6·48	6·53	6·35	6·72	6·74	6·24	5·73
Total Dry Substance	85·90	84·10	85·60	82·10	80·70	84·60	82·70	83·67	83·80
Water	14·10	15·90	14·40	17·90	19·30	15·40	17·30	16·33	..
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	..
2.—Composition per Cent. in the Dry Substance of the Hay.									
Nitrogenous Substance (N. × 6·3, reckoning 15·875 N. in Nit. Sub.)	10·27	12·35	10·33	9·58	13·36	8·82	9·64	10·62	..
Fatty Matter (Ether Extract)	3·34	3·57	2·98	2·42	2·93	2·93	3·39	3·08	..
Woody Fibre	26·63	27·20	29·17	29·37	29·30	28·97	29·40	28·58	..
Other non-Nitrogenous Vegetable Compounds (Starch, Sugar, Gum, &c.)	53·12	50·77	49·95	50·68	46·54	51·33	49·43	50·27	..
Mineral Matter (Ash)	6·64	6·11	7·57	7·95	7·87	7·95	8·14	7·45	6·84
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	..
3.—Summary Statement of the Description of the Herbage.									
Graminaceous Stems bearing Flower or Seed	50·25	35·91	42·18	72·66	65·08	69·76	64·62	57·21	..
Graminaceous Leafy Produce	25·85	53·20	29·64	24·72	32·27	17·91	15·05	28·38	..
Leguminous Herbage	5·12	2·20	22·89	..	..	3·70	1·78	5·10	..
Miscellaneous Herbage (chiefly weeds)	15·73	6·14	1·71	1·85	1·67	7·05	16·43	7·23	..
Shedded Seeds, and Indeterminate Vegetable Matter	3·05	2·55	3·58	0·77	0·98	1·58	2·12	2·08	..
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	..

the feeding capacity, of the substances grouped together under this head of *other non-nitrogenous matters*, will probably depend much upon the *condition* of the hay. The worse the condition of the hay, the greater probably will be the proportion of them, which will consist of the ill-defined "extractive matters."

Mineral matter.—The so-designated Mineral matter, is that which remains as *ash*, on the incineration of the hay. It is needless to say that Mineral constituents are essential in the food of animals. In most vegetable foods, however, they generally exist in a larger proportion to the other constituents than they are probably required; and hence their large amount in any food is no criterion of high feeding value. On the contrary, as, in comparable cases, a high percentage of Mineral matter is generally coincident with a low degree of elaboration of the collateral vegetable substances, the smaller percentage among a series of specimens of produce of like description, will most probably be associated with a higher relative feeding capacity.

The proportions of these several constituents, in the hay grown by the different manures, may now be briefly noticed.

The *unmanured* hay contained a notable proportion of Leguminous, and other non-Graminaceous herbage; and the Grasses themselves were stunted. Under these circumstances, the Dry substance of the hay contained a medium percentage of the calculated Nitrogenous compounds, and comparatively a very small proportion of the estimated Woody-fibre. Comparing the produce of one manuring condition with that of another, in one and the same season, a low percentage of indurated Woody-fibre indicates greenness and immaturity. Coincidently with this, the unmanured hay shows a relatively high amount of the impure Fatty matter.

The produce grown by *ammoniacal salts alone*, contained a very high percentage of Nitrogenous compounds, or at least of Nitrogen in some form. This was due, it will be remembered, not to a large amount of Leguminous herbage, but to the condition of the almost exclusively Graminaceous hay, which was stunted, dark green, leafy, and backward. The Dry substance of the hay having these characters, at the same time contained only a small proportion of the comparatively stable Cellular or Woody matter; but it had the highest amount of any in the series of the green impure Fatty matter. The fact, that the highest percentage of this merely ether-extracted substance, was found in this stunted, dark-green, leafy, and backward produce, may perhaps be taken as some indication, that a relatively high amount of Fatty matter as so determined, in succulent produce, does not really represent a high amount of *pure fat* of the high feeding capacity which that substance is assumed to possess.

The produce by *mineral manure alone*, which contained the highest proportion of any, of Leguminous herbage, nevertheless

contained but a moderate percentage of Nitrogenous compounds. This arose from the fact, that the *grasses*, which still constituted by far the largest proportion of the produce, though meagre and stunted in growth, were still comparatively forward. With these characters, the percentage of the so-called Woody-fibre is comparatively high, and that of the impure Fatty matter is comparatively low.

The produce of the plot manured with the *mineral manure and the smaller amount of ammoniacal salts* was bulky, almost wholly Graminaceous, and very stemmy. Consistently, the dry substance of this hay contained a low proportion of Nitrogenous compounds, the lowest amount of any in the series of the green Fatty matter, and a high percentage of the more fixed Cellular substance.

The *mineral manure* together with the *double and excessive amount of ammoniacal salts*, gave an over-luxuriant, succulent, and unevenly ripened, but stemmy and almost exclusively Graminaceous produce. To the former characters may be attributed a very high percentage of the calculated Nitrogenous compounds; and to the latter a somewhat low percentage of the impure Fatty matter, and a high one of the Woody-fibre. The percentage of the green Fatty matter is, however, as would be expected, higher than in the produce grown by the mineral manure and the smaller amount of ammoniacal salts. The remainder, designated as "other non-nitrogenous matters," is less in this over-luxuriant produce than in any of the other cases.

The produce by *farm-yard manure alone*, comprised a moderate proportion of Leguminous and other non-Graminaceous herbage; but, on the other hand, its Graminaceous herbage was in very large proportion in the condition of flowering and seeding stem. Consequently, the Dry substance of the hay contained a low percentage of the Nitrogenous compounds, a low percentage of the impure Fatty matter, and a high percentage of the Woody-fibre.

The hay grown by *farm-yard manure and ammoniacal salts together*, comprised a larger proportion of non-Graminaceous herbage, than that grown by farm-yard manure alone; but, the Graminaceous herbage itself was in as great a proportion stemmy. The result was a hay containing in its dry substance, a considerably higher proportion both of the calculated Nitrogenous compounds and of the impure Fatty matter, and at the same time a high percentage of the Woody-fibre.

The general result, comparing the produce by the different manures in one and the same season, seems to be, that the more the produce is Graminaceous, the more it goes to flower and seed, and the more it is ripened, the higher will be the percentage of *dry substance* in the hay. Under the same circumstances, the higher will be the percentage of the *comparatively indurated*, and therefore *probably effete*, Cellular matter or "*Woody-fibre*;" and the

lower will be that of the *calculated nitrogenous compounds*, of the *impure green fatty matter*, and of the *mineral matter* in the Dry substance. On the other hand, a large proportion of the non-Graminaceous herbage, over-luxuriance, succulence, a large proportion of leaf, and unripeness, are likely to be associated with a small proportion of the *more refractory or effete, Cellular or Woody-matter*, but with a large one of *nitrogenous substance in a questionable degree of elaboration*, a large one of *impure fatty matter* of doubtful nutritive capacity, and a large one of the *mineral matter* also, in the Dry substance of the hay.

This subject obviously throws open a wide field for future investigation. And, if we consider, not only the very complex character, in so many points of view, of the substance included under the term—*hay*, but also the inadequacy of the data, although so copious, which we have collected and recorded in the course of our long Paper, it will be at once apparent, that it would be inconsistent with a proper spirit of inquiry, to attempt to do more than draw attention to the prominent indications, and leading directions, of the experimental evidence that has been adduced. There will, nevertheless, be much really gained, if a clear idea be conveyed of the multiplicity of circumstances, upon which must depend the proportion, and relative feeding value, of the various chemical compounds of which the complex produce is made up. It will, then, be understood—and it is very important that it should be—that even supposing there were no question as to the proper relationship to one another, of the different elaborated compounds in our stock-foods, it would still be impracticable to get a true and unconditional estimate of comparative feeding value of *crude vegetable substances*, by the simple determination of the percentage amount of one or two important constituents, as is frequently assumed to be sufficient for that purpose. The next step in advance in these inquiries can only be attained, when our knowledge of the proximate compounds, of lower or of higher condition of elaboration, into which the ultimate constituents of our food-stuffs are grouped, has been much extended, and when the digestibility, and applicability to the purposes of the system, of these various proximate compounds, have been experimentally determined.

[For the general conclusions in regard to the other separate Sections of the subject into which our Report has been divided, see concluding portions of Parts I., II., and III., at pages 22-4, 41-2, and 67-8, respectively.]

APPENDIX.

APPENDIX.—TABLE I.—Duplicate Determinations of DRY MATTER (at 212° F.) in the HAY of the Seasons 1856, 1857, and 1858.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Season 1856. Experiment 1.	Season 1856. Experiment 2.	Season 1857. Experiment 1.	Season 1857. Experiment 2.	Season 1858. Experiment 1.	Season 1858. Experiment 2.
	SERIES 1.—Without Direct Mineral Manure.						
1	Unmanured	82·1	81·8	85·0	85·3	86·0	85·9
2	Unmanured (duplicate plot)	81·6	82·2	87·3	87·3	85·8	85·1
	Calculated Means of Unmanured	81·8	82·0	86·1	86·3	85·9	85·5
3	2000 lbs. Sawdust	80·6	80·8	87·9	87·5	84·2	84·6
4	200 lbs. each, Sulphate and Muriate Ammonia	79·0	81·0	87·2	86·1	84·0	84·2
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	79·8	79·5	87·7	87·6	84·0	83·8
6	275 lbs. Nitrate of Soda	..	..	..	..	84·6	85·0
7	550 lbs. Nitrate of Soda	..	..	..	..	85·7	86·0
	SERIES 2.—With Direct Mineral Manure.						
8	"Mixed Mineral Manure"*	80·5	80·0	86·8	86·7	85·6	85·6
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	80·6	80·4	86·8	86·8	84·0	84·2
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	78·9	79·0	87·1	87·0	82·0	82·2
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	77·8	76·8	87·6	86·8	83·9	83·8
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	79·4	79·0	86·5	87·1	82·4	82·4
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	77·8	78·4	86·1	85·8	80·2	81·1
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	..	..	..	..	86·1	86·7
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	..	..	..	..	85·4	85·0
	SERIES 3.—With Farmyard Manure.						
16	14 Tons Farmyard Manure	76·0	76·2	87·4	87·3	85·0	84·2
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	79·5	79·6	86·4	86·1	82·4	83·0

* For full description of the "Mixed Mineral Manure," see page 6.

EXPERIMENTS with DIFFERENT MANURES on PERMANENT MEADOW LAND.

APPENDIX.—TABLE II.—Duplicate Determinations of MINERAL MATTER (Ash), in the Hay of the Season 8561.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Percentages in the Hay as taken from the Land.		Percentages in the Dry Substance of the Hay.	
		Experiment 1.	Experiment 2.	Experiment 1.	Experiment 2.
	SERIES 1.—Without Direct Mineral Manure.				
1	Unmanured	6·25	6·27	7·61	7·66
2	Unmanured (duplicate plot)	6·60	6·68	8·09	8·12
	Calculated Means of Unmanured	6·42	6·48	7·85	7·89
3	2000 lbs. Sawdust	6·60	6·64	8·19	8·21
4	200 lbs. each, Sulphate and Muriate Ammonia	6·75	6·13	8·55	7·56
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	5·95	6·06	7·47	7·62
	SERIES 2.—With Direct Mineral Manure.				
8	"Mixed Mineral Manure"*	6·94	6·91	8·62	8·64
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	7·39	7·23	9·18	8·99
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	6·64	6·91	8·42	8·74
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	7·23	6·83	9·29	8·90
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	6·78	6·67	8·54	8·44
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	6·74	6·40	8·66	8·16
	SERIES 3.—With Farmyard Manure.				
16	14 Tons Farmyard Manure	7·30	7·29	9·59	9·56
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	8·66†	6·38†	10·88†	8·01†

* For full description of the "Mixed Mineral Manure," see page 6.

† There is obviously some error in these determinations; whether due to the accidental mixture with one another of a portion of the duplicate quantities, or to adventitious matter in the case of the higher number, is doubtful. It will be easily understood, that in such complex and uneven produce as hay, the determinations of both Dry matter, and Mineral matter, will be more liable to uncertainty than in that of corn, and other comparatively uniform produce.

APPENDIX.—Table III.—Duplicate Determinations of Mineral Matter (Ash), in the Hay of the Season 1857.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Percentages in the Hay as taken from the Land.		Percentages in the Dry Substance of the Hay.	
		Experiment 1.	Experiment 2.	Experiment 1.	Experiment 2.
	Series 1.—Without Direct Mineral Manure.				
1	Unmanured	5·58	5·68	6·56	6·66
2	Unmanured (duplicate plot)	5·71	5·71	6·54	6·54
	Calculated Means of Unmanured	5·65	5·69	6·55	6·60
3	2000 lbs. Sawdust	5·60	5·68	6·37	6·49
4	200 lbs. each, Sulphate and Muriate Ammonia	5·52	5·44	6·33	6·31
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	5·55	5·47	6·33	6·25
	Series 2.—With Direct Mineral Manure.				
8	"Mixed Mineral Manure"*	6·00	6·32	6·91	7·29
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	6·83	6·36	7·87	7·33
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	6·32	6·24	7·26	7·17
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	6·43	6·40	7·34	7·37
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	6·78	6·67	8·54	8·44
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	6·49	6·35	7·53	7·40
	Series 3.—With Farmyard Manure.				
16	14 Tons Farmyard Manure	6·46	6·56	7·39	7·52
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	6·48	6·42	7·50	7·46

* For full description of the "Mixed Mineral Manure," see page 6.

Experiments with Different Manures on Permanent Meadow Land.

APPENDIX.—Table IV.—Duplicate Determinations of Mineral Matter (Ash), in the Hay of the Season 1858.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Percentages in the Hay as taken from the Land.		Percentages in the Dry Substance of the Hay.	
		Experiment 1.	Experiment 2.	Experiment 1.	Experiment 2.
	Series 1.—Without Direct Mineral Manure.				
1	Unmanured	5·73	5·68	6·66	6·61
2	Unmanured (duplicate plot)	5·56	5·56	6·48	6·53
	Calculated Means of Unmanured	5·64	5·62	6·57	6·57
3	2000 lbs. Sawdust	5·60	5·62	6·65	6·64
4	200 lbs. each, Sulphate and Muriate Ammonia	5·39	4·88	6·42	5·80
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	5·34	5·32	6·36	6·34
6	275 lbs. Nitrate of Soda	5·80	5·66	6·85	6·66
7	550 lbs. Nitrate of Soda	5·37	5·39	6·26	6·27
	Series 2.—With Direct Mineral Manure.				
8	"Mixed Mineral Manure"*	6·48	6·48	7·57	7·57
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	6·48	6·46	7·71	7·68
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	6·53	6·54	7·96	7·95
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	6·96	6·64	8·30	7·92
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	6·69	6·67	8·12	8·10
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	6·32	6·38	7·88	7·86
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	6·37	6·43	7·39	7·42
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	6·38	6·66	7·47	7·83
	Series 3.—With Farmyard Manure.				
16	14 Tons Farmyard Manure	6·73	6·71	7·92	7·97
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	6·72	6·75	8·15	8·13

* For full description of the "Mixed Mineral Manure," see page 6.

APPENDIX.—Table V.—Duplicate Determinations of Nitrogen, in the Hay of the Season 1856.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Percentages in the Hay as taken from the Land.		Percentages in the Dry Substance of the Hay.	
		Experiment 1.	Experiment 2.	Experiment 1.	Experiment 2.
	Series 1.—Without Direct Mineral Manure.				
1	Unmanured	1·70	1·66	2·07	2·03
2	Unmanured (duplicate plot)	1·79	1·79	2·19	2·18
	Calculated Means of Unmanured	1·74	1·72	2·13	2·10
3	2000 lbs. Sawdust	1·69	1·66	2·09	2·06
4	200 lbs. each, Sulphate and Muriate Ammonia	1·57	1·57	1·96	1·96
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	1·56	1·62	1·96	2·03
	Series 2.—With Direct Mineral Manure.				
8	"Mixed Mineral Manure" *	1·67	1·68	2·08	2·10
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	1·80	1·75	2·24	2·18
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	1·22	1·24	1·54	1·57
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	1·28	1·25	1·66	1·62
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	1·48	1·46	1·86	1·85
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	1·49	1·49	1·88	1·88
	Series 3.—With Farmyard Manure.				
16	14 Tons Farmyard Manure	1·35	1·35	1·77	1·78
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	1·65	1·60	2·07	2·01

* For full description of the "Mixed Mineral Manure," see page 6.

Experiments with Different Manures on Permanent Meadow Land.

APPENDIX.—Table VI.—Duplicate Determinations of Nitrogen, in the Hay of the Season 1857.

Plot, Nos.	MANURES, (Per Acre, per Annum.)	Percentages in the Hay as taken from the Land.		Percentages in the Dry Substance of the Hay.	
		Experiment 1.	Experiment 2.	Experiment 1.	Experiment 2.
	Series 1.—Without Direct Mineral Manure.				
1	Unmanured	1·29	1·29	1·52	1·52
2	Unmanured (duplicate plot)	1·42	1·45	1·63	1·66
	Calculated Means of Unmanured	1·35	1·37	1·57	1·59
3	2000 lbs. Sawdust	1·38	1·38	1·57	1·57
4	200 lbs. each, Sulphate and Muriate Ammonia	1·59	1·51	1·83	1·74
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	1·54	1·45	1·76	1·66
	Series 2.—With Direct Mineral Manure.				
8	"Mixed Mineral Manure"*	1·51	1·51	1·74	1·74
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	1·49	1·48	1·72	1·71
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	1·19	1·18	1·37	1·36
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	1·12	1·10	1·29	1·26
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	1·38	1·29	1·60	1·51
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	1·62	1·62	1·89	1·88
	Series 3.—With Farmyard Manure.				
16	14 Tons Farmyard Manure	1·29	1·33	1·48	1·52
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	1·07	1·10	1·24	1·28

* For full description of the "Mixed Mineral Manure," see page 6.

APPENDIX.—TABLE VII.—Duplicate Determinations of NITROGEN, in the Hay of the Season 1858.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Percentages in the Hay as taken from the Land.		Percentages in the Dry Substance of the Hay.	
		Experiment 1.	Experiment 2.	Experiment 1.	Experiment 2.
	SERIES 1.—Without Direct Mineral Manure.				
1	Unmanured	1·39	1·42	1·62	1·65
2	Unmanured (duplicate plot)	1·35	1·34	1·58	1·57
	Calculated Means of Unmanured	1·37	1·38	1·60	1·61
3	2000 lbs. Sawdust	1·41	1·42	1·67	1·68
4	200 lbs. each, Sulphate and Muriate Ammonia	1·69	1·61	2·01	1·92
5	200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	1·56	1·56	1·86	1·86
6	275 lbs. Nitrate of Soda	1·67	1·69	1·97	1·99
7	550 lbs. Nitrate of Soda	1·71	1·71	1·99	1·99
	SERIES 2.—With Direct Mineral Manure.				
8	"Mixed Mineral Manure" *	1·39	1·42	1·63	1·66
9	"Mixed Mineral Manure," and 2000 lbs. Sawdust	1·39	1·39	1·65	1·65
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	1·25	1·26	1·52	1·53
11	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Sawdust	1·18	1·17	1·41	1·40
12	"Mixed Mineral Manure," 200 lbs. each, Sulphate and Muriate Ammonia, and 2000 lbs. Cut Wheat-Straw	1·34	1·36	1·63	1·65
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	1·70	1·72	2·11	2·13
14	"Mixed Mineral Manure," and 275 lbs. Nitrate of Soda	1·52	1·52	1·76	1·76
15	"Mixed Mineral Manure," and 550 lbs. Nitrate of Soda	1·31	1·34	1·54	1·57
	SERIES 3.—With Farmyard Manure.				
16	14 Tons Farmyard Manure	1·18	1·18	1·40	1·40
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	1·29	1·25	1·56	1·51

* For full description of the "Mixed Mineral Manure," see page 6.

Experiments with Different Manures on Permanent Meadow Land.

APPENDIX.—Table VIII.—Individual Determinations of Woody Fibre, in the Hay from Selected Plots; Seasons 1856, 1857, and 1858.

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Percentages in the Hay as taken from the Land.			Percentages in the Dry Substance of the Hay.		
		Experiment 1.	Experiment 2.	Experiment 3.	Experiment 1.	Experiment 2.	Experiment 3.
	Season 1856.						
1	Unmanured	24·76	24·27	..	30·2	29·6	..
4	200 lbs. each, Sulphate and Muriate Ammonia	24·96	24·72	..	31·2	30·9	..
8	"Mixed Mineral Manure"*	23·98	24·14	..	29·9	30·1	..
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	25·52	25·52	..	32·3	32·3	..
13	"Mixed Mineral Manure," and 400 lbs. each Sulphate and Muriate Ammonia	25·85	25·38	..	33·1	32·5	..
16	14 Tons Farmyard Manure	24·12	23·44	..	31·7	30·8	..
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	23·56	23·72	..	29·6	29·8	..
	Season 1857.						
1	Unmanured	23·32	23·15	22·11	27·4	27·2	26·1
4	200 lbs. each, Sulphate and Muriate Ammonia	22·89	23·41	22·89	26·4	27·0	26·4
8	"Mixed Mineral Manure"	23·06	23·06	22·89	26·6	26·6	26·4
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	25·40	24·97	25·40	29·2	28·7	29·2
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	24·14	24·57	23·79	28·1	28·6	27·7
16	14 Tons Farmyard Manure	26·19	26·19	25·14	30·0	30·0	28·8
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	24·57	24·91	25·43	28·5	28·9	29·5
	Season 1858.						
1	Unmanured	22·68	22·68	23·28	26·4	26·4	27·1
4	200 lbs. each, Sulphate and Muriate Ammonia	22·54	22·96	23·13	26·8	27·3	27·5
8	"Mixed Mineral Manure"	25·08	24·65	25·17	29·3	28·8	29·4
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	24·05	24·55	23·73	29·3	29·9	28·9
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	23·24	23·32	24·37	28·8	28·9	30·2
16	14 Tons Farmyard Manure	24·19	24·11	25·21	28·6	28·5	29·8
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	24·15	24·15	24·64	29·2	29·2	29·8

* For full description of the "Mixed Mineral Manure," see page 6.

APPENDIX.—Table IX.—Duplicate Determinations of Fatty Matter (by Ether), in the Hay from Selected Plots (Season 1858).

Plot, Nos.	MANURES. (Per Acre, per Annum.)	Experiment 1.	Experiment 2.	Mean.
	Percentages in the Hay as taken from the Land.			
1	Unmanured	2·87	2·86	2·86
4	200 lbs. each, Sulphate and Muriate Ammonia	3·04	2·96	3·00
8	"Mixed Mineral Manure" *	2·58	2·52	2·55
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	2·04	1·93	1·99
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	2·43	2·29	2·36
16	14 Tons Farmyard Manure	2·49	2·46	2·47
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	2·81	2·79	2·80
	Percentages in the Dry Substance of the Hay.			
1	Unmanured	3·34	3·33	3·34
4	200 lbs. each, Sulphate and Muriate Ammonia	3·61	3·52	3·57
8	"Mixed Mineral Manure"	3·01	2·94	2·98
10	"Mixed Mineral Manure," and 200 lbs. each, Sulphate and Muriate Ammonia	2·49	2·35	2·42
13	"Mixed Mineral Manure," and 400 lbs. each, Sulphate and Muriate Ammonia	3·01	2·84	2·93
16	14 Tons Farmyard Manure	2·94	2·91	2·93
17	14 Tons Farmyard Manure, and 100 lbs. each, Sulphate and Muriate Ammonia	3·40	3·38	3·39

* For full description of the "Mixed Mineral Manure," see page 6.