ROTHAMSTED RESEARCH

Yields of the Field Experiments 1898

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Permanent Grass Land; the Park

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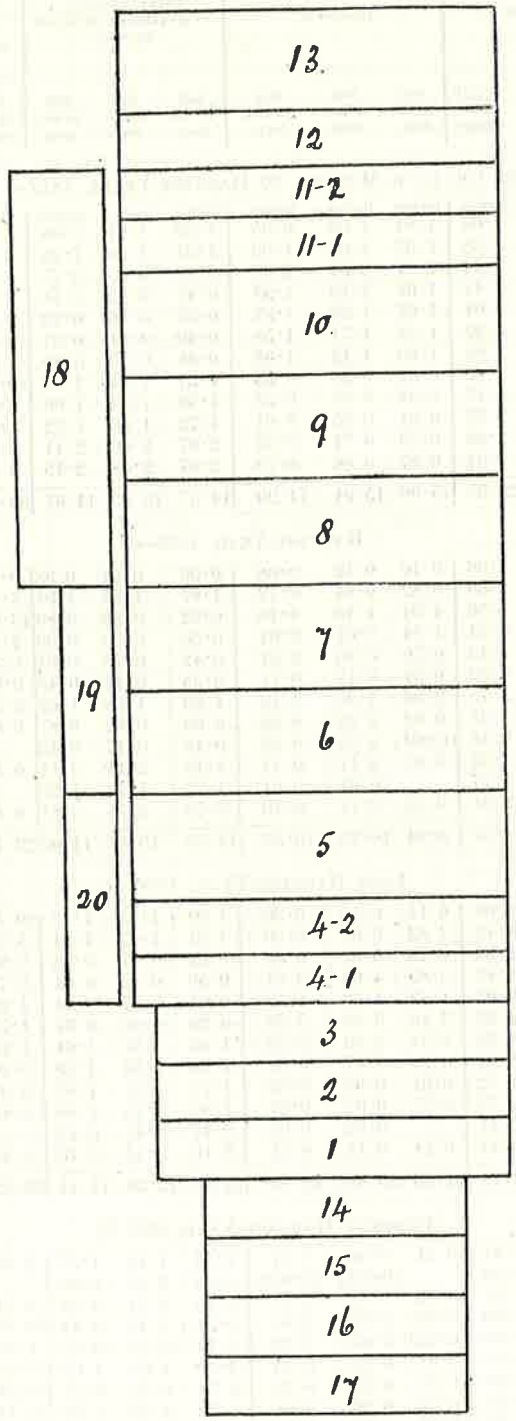
PLAN OF THE PLOTS IN THE PARK, ON WHICH EXPERIMENTS HAVE BEEN MADE, ON THE MIXED HERBAGE OF PERMANENT GRASS LAND.

43 years, 1856–1898 inclusive.

[For a brief summary of results and conclusions, see opposite page.]



Total area under Experiment about 7 acres.

Area of Plots.
- 1, 2, 3, 4–1, 4–2, 11–1, 11–2, and 12, each ¼ acre.
- 5, 6, 7, 8, 9, 10, 13, and 18, each ½ acre.
- 14, 15, 16, and 17, each ⅛ acre.
- 19 and 20, each ⅛ acre.

[For details of the manuring and produce, see pp. 22 and 23.]

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Results of Experiments made in THE PARK,
On the Mixed Herbage of Permanent Grass-land.

These experiments were commenced in 1856, so that 1898 is the 43rd year of their continuance.

In the experiments with individual crops grown separately, on arable land, it was found, that those of the same natural Order—Wheat, Barley, and Oats, for example—had certain characters and manurial requirements in common; that those of the Leguminous Order had widely different characters and requirements; whilst crops of other Orders, such as Root-crops, Potatoes, &c., exhibited characteristics differing from the Gramineous, and more from the Leguminous crops. Compared with the conditions of growth of such individual crops grown separately, those of the *Mixed Herbage of Grass-land* are extremely complicated. It comprises, besides numerous Gramineous and Leguminous species, representatives of many other Natural Orders; and of some of great prominence and importance as regards their prevalence and distribution in vegetation generally. If, under the influence of characteristically different manures, there are notable differences in the degree of luxuriance, and in the character of development of closely allied plants when each is grown separately, and much greater differences between plants of different Orders when so separately grown it is only what might be expected, that there should be very remarkable variations of result when different manures are applied to an already established Mixed Herbage of perhaps some 50 species growing together, representing perhaps nearly 20 Natural Orders.

Accordingly, even in the early years of the experiments, it was observed that those manures which were the most effective with Wheat, Barley, or Oats—that is with Gramineous species grown separately—were also the most effective in bringing forward the *grasses proper*, in the Mixed Herbage. Again, those manures which were the most beneficial to beans or clover, the most developed the Leguminous species in the Mixed Herbage, and *vice versâ*. There was also great variation in the predominance of individual species among both the grasses, and the representatives of other Orders. And again, there was very great difference in the tendency to produce merely increased leafy vegetation on the one hand, or to develop stem and seed formation on the other, according to the manure employed. Thus, the final product—the *hay*—was one thing when grown under certain manurial conditions, and quite another when grown under others. For example, the unmanured produce on the average included nearly 50 species—about 17 grasses, 4 leguminous plants, and 27 or more of other Orders; whilst the hay contained from 65 to 70 per cent. of gramineous produce, about 7½ of leguminous herbage, and 20 to 25 per cent. of herbage of other Orders. Compared with this, the produce by farmyard manure contained fewer species, a higher proportion by weight of gramineous, and lower of both leguminous and miscellaneous herbage. Or, to take an extreme case, an excessive application of both mineral and nitrogenous manures for many years in succession, has reduced the number of species traceable, to only about 15, whilst gramineous herbage has contributed from 95 to 98 per cent., or even more of the total hay, leguminous herbage has been excluded, and miscellaneous herbage nearly so. It may be said that any manure that increases the luxuriance of some individual plants, more or less reduces the number of species, and of course alters the proportion of the different species in the final product—the hay; whilst there will, according to the conditions, be different proportions of leaf and stem, and different tendencies to maturation. It is obviously, therefore, very difficult to summarise in a few sentences the results of experiments with 20 different conditions of manuring, carried on over a period of more than 40 years.

It may be said, that the effect of purely nitrogenous manures, such as nitrate of soda, and more still, ammonium-salts, is to reduce the total number of species, characteristically to increase the growth of gramineous species, almost to exclude leguminous herbage, and to reduce the number and proportion of miscellaneous species, but to increase the luxuriance of a few of those that remain. Purely mineral manures, supplying abundance of potash and phosphoric acid, in a less degree reduce the total number of species, do not increase the luxuriance, though they favour the stemminess and maturation of the grasses, but reduce the percentage by weight of such herbage in the hay. Such manures, however, greatly increase the luxuriance, and proportion by weight in the hay, of leguminous species; whilst they reduce, both the number of species, and proportion by weight in the hay, of the miscellaneous herbage.

It is thus obvious that the weights of hay per acre yielded under the varying conditions of manuring, do not represent the comparative value of the produce grown under the different conditions. For example, there has been an average of only about 1 ton per acre of first-crop hay without manure, the produce being, however, the most complex of all. With purely mineral manures, containing potash, the average annual yield of first-crop hay has been rather more than 1½ ton; with fewer species, but containing a considerable proportion of leguminous herbage; in fact, the hay grown by such manures, is of better quality than that produced by any other of the manures in the series. With an excess of mineral and nitrogenous manures together, the average yield per acre has been nearly 3 tons of first-crop hay; but the produce has contained no leguminous, and very little miscellaneous herbage, and from 95 to 98 per cent. of gramineous herbage, perhaps 90 per cent., consisting of only 4 to 6 of the most freely growing and coarser species, which have been characterised by great stemminess. Further, it may be stated, that the one ton of the very complex unmanured hay would contain about 7½ lb. of phosphoric acid, about 25 lb. of potash, and about 30 lb. of nitrogen; that the 1½ ton of hay grown by the purely mineral manures, with its ripened grasses, and large proportion of leguminous herbage, would contain about 18 lb. phosphoric acid, 75 lb. of potash, and 50 lb. of nitrogen; whilst the 3 tons of almost exclusively gramineous, and very stemmy hay, grown by excessive amounts of mineral and nitrogenous manures together, would remove about 30 lb. of phosphoric acid, about 145 lb. of potash, and about 108 lb. of nitrogen.

Between the extremes above indicated, the 20 plots afford examples of very great variety, not only in quantity of produce, but also in quality, depending on both the botanical and chemical composition, and on the character of development of the plants. The experiments were not arranged to provide exact examples for practice, but to ascertain the characteristic effects of different manurial agents on the quantity and quality of the Mixed Herbage, and thus to afford data for application in actual practice. The general result has been to show, that if artificial manures are largely or mainly relied upon, certain descriptions of herbage will be unduly forced at the expense of others, and also that the character of development of the plants will be materially affected. In order to maintain a due admixture of herbage on grass-land mown for hay, farmyard or stable dung should be liberally applied; and it is also conducive to the same end to consume the second crop on the land, with cake or corn. The more a good condition of the herbage is induced and maintained by such means, the more safely may some increased luxuriance, and so increased produce, be obtained, by the judicious use of artificial manures. Provided dung be liberally used it will not as a rule be necessary to apply potash artificially; but phosphates may advantageously be used as basic slag, and nitrogenous manure in the form of nitrate of soda, which, however, should seldom be used at the rate of more than 1 cwt., or at most 1½ cwt. per acre.

For details of the manuring and produce of the different plots, see pages 22–23.

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The Land has probably been laid down with Grass for some centuries. No fresh seed has been artificially sown within the last 50 years certainly; nor is there record of any having been sown since the Grass was first laid down. The experiments commenced in 1856, at which time the character of the herbage appeared fairly uniform over all the plots. The present season, 1898, is therefore the 43rd year of the experiments. Excepting as explained in the Table, and in the foot-notes, the same description of Manure has been applied year after year to the same plot.

During the first 19 years of the experiments, 1856-1874, the first crop only, each year, was mown, made into hay, removed from the land, and weighed. As a rule, the second crops were fed-off by sheep having no other food, the object being not to disturb the condition of the manuring. A given number was allotted to each plot, according to the amount of produce, penned upon a portion of it, and the area extended, day by day, until the whole was eaten down. Frequently, however, the animals suffered considerably; and in 1866, 1870, 1873, and 1874, the second crops (and third, if any) were cut, and spread on the respective plots. In the twentieth season, 1875, the second crops being unusually heavy, and the weather favourable, they were, for the first time, cut, weighed as hay, and removed. In 1876 they were cut and spread on the plots. In 1877 and 1878 the second crops were made into hay, weighed, and removed. In 1879, 1882, 1891, 1892, 1894, 1896 and 1897, the second crops were cut, sampled, carted, and weighed, green; the dry matter in the weighed samples was determined, and the produce reckoned into hay by adding one-fourth to the calculated dry matter per acre. In 1880, 1881, 1883, 1886, 1888, 1889, 1890, 1893, and 1895, the second crops were again made into hay, weighed and removed; and it is intended in future to adopt this plan whenever the weather will permit. In 1884, 1885, and 1887, owing to the dryness of the seasons after cutting the first crops, there was but little growth; the second crops were therefore again cut, but spread on the respective plots. Owing to the change in the treatment of the crops, the average produce per annum is given, separately, for the first 20 years, 1856-1875, first crops only; and for the succeeding 20 years, 1876-1895, first and second crops (13). On January 7, 1881, coarsely broken chalk, in the

(Area under experiment,

1 acre	= (about)	0·404	Hectare	or 1·585	Prussian Morgen.
1 lb. (pound avoir.)	= (about)	0·453	Kilogramme	or 0·907	Zollverein Pfund.
1 cwt. (hundredweight)	= (about)	50·8	Kilogrammes	or 1·016	Centner.
1 ton	= (about)	1015·6	Kilogrammes	or 20·32	Centner.
1 lb. per acre	= (about)	1·12	Kilogramme per Hectare	or 0·572	Zollv. Pfd. per Pr. Morgen.
1 cwt. per acre	= (about)	125·6	Kilogrammes per Hectare	or 0·641	Centner per Pr. Morgen.
1 ton per acre	= (about)	2512	Kilogrammes per Hectare	or 12·82	Centner per Pr. Morgen.

PLOTS.	Manures, per acre, per Annum. [In 1897, and since, 400 lbs. Basic Slag used throughout instead of Superphos.]
1	1856-63, 8 years, 14 tons Farmyard Manure, and 200 lbs. Ammonium-salts (1); average produce 49½ cwts. 1864 and since, 200 lbs. Ammonium-salts alone; average produce (12 years, 1864-75) 38⅜ cwts.
2	1856-63, 8 years, 14 tons Farmyard Manure; average produce 42⅞ cwts. 1864 and since, unmanured; average produce (12 years, 1864-75) 32⅞ cwts.
3	Unmanured, continuously
4 {1	3½ cwts. Superphosphate of Lime (2)
4 {2	3½ cwts. Superphosphate of Lime, and 400 lbs. Ammonium-salts
5	400 lbs. Amm.-salts, 42 yrs., 1856-97; 1898, half Unmanured, half 400 lb. Basic Slag, and 500 lb. Sulph. Pot.
(3) 6	1856-68, 13 years, 400 lbs. Ammonium-salts; average produce 30½ cwts. 1869-78, 300 lbs., 1879 and since 500 lbs., Sulph. Potash, 100 lbs. Sulph. Soda, 100 lbs. Sulph. Magnesia, 3½ cwts. Superphosphate; average produce (7 yrs., 1869-75) 31¼ cwts.
7	1856-78, 300 lbs., 1879 and since 500 lbs., Sulphate Potash, 100 lbs. (4) Sulphate Soda, 100 lbs. Sulphate Magnesia, and 3½ cwts. Superphosphate
(3) 8	1856-61, 6 years, 300 lbs. Sulph. Potash, 200 lbs. Sulph. Soda, 100 lbs. Sulph. Magnesia, and 3½ cwts. Superphosphate; average produce 36 cwts. 1862 and since, 250 lbs. (5) Sulphate Soda, 100 lbs. Sulphate Magnesia, and 3½ cwts. Superphosphate; average produce (14 years, 1862-75) 27½ cwts.
9	1856-78, 300 lbs., 1879 and since 500 lbs., Sulph. Potash, 100 lbs. (4) Sulph. Soda, 100 lbs. Sulph. Magnesia, 3½ cwts. Superphosphate, and 400 lbs. Ammonium-salts
(3) 10	1856-61, 6 yrs. 300 lbs. Sulph. Potash, 200 lbs. Sulph. Soda, 100 lbs. Sulph. Magnesia, 3½ cwts. Superphosphate, 400 lbs. Ammonium-salts; average produce 55½ cwts. 1862 and since, 250 lbs. (5) Sulph. Soda, 100 lbs. Sulph. Magnesia, 3½ cwts. Superphosphate, 400 lbs. Ammonium-salts; average produce (14 yrs., 1862-75) 42¼ cwts.
11 {1	1856-78, 300 lbs., 1879 and since 500 lbs., Sulph. Potash, 100 lbs. (4) Sulph. Soda, 100 lbs. Sulph. Magnesia, 3½ cwts. Superphosphate, 600 lbs. (6) Ammonium-salts
11 {2	1856-78, 300 lbs., 1879 and since 500 lbs., Sulph. Potash, 100 lbs. (4) Sulph. Soda, 100 lbs. Sulph. Magnesia, 3½ cwts. Superphosphate, 600 lbs. (6) Ammonium-salts, and 400 lbs. Silicate Soda (7)
12	Unmanured continuously
13	1856-78, 300 lbs., 1879 and since 500 lbs., Sulph. Potash, 100 lbs. (4) Sulph. Soda, 100 lbs. Sulph. Magnesia, 3½ cwts. Superphosphate, 400 lbs. Ammonium-salts, 2000 lbs. Cut Wheat-straw
14	550 lbs. Nitrate Soda (8), 1858-78, 300 lbs., 1879 and since 500 lbs., Sulph. Potash, 100 lbs. (4) Sulph. Soda, 100 lbs. Sulph. Magnesia, and 3½ cwts. Superphosphate
15	1858-75, 18 years, 550 lbs. Nitrate Soda 1876-78, 300 lbs., 1879 and since 500 lbs., Sulphate Potash, 100 lbs. Sulphate Soda, 100 lbs. Sulphate Magnesia, and 3½ cwts. Superphosphate
16	275 lbs. Nitrate of Soda, 500 lbs. (300 lbs., 1858-78), Sulph. Potash, 100 lbs. (200 lbs., 1856-63) Sulph. Soda, 100 lbs. Sulph. Magnesia, and 3½ cwts. Superphosphate
17	275 lbs. Nitrate of Soda
18	Mixture supplying the quantity of Potash, Soda, Lime, Magnesia, Phosphoric acid, Silica, and Nitrogen, contained in 1 ton of Hay (commencing 1865)
19	275 lbs. Nitrate of Soda, 290 lbs. Sulphate of Potash, and 3½ cwts. Superphosphate (commencing 1872)
20	327 lbs. Nitrate of Potash, and 3½ cwts. Superphosphate (commencing 1872)

(1) "Ammonium-salts"—in all cases equal parts Sulphate and Muriate of Ammonia of Commerce.

(2) "Superphosphate of Lime," 1856 to 1888 inclusive, made from 200 lbs. Bone-ash, 150 lbs. Sulphuric Acid, Sp. gr. 1·7 (and water); 1889, and since, made from high percentage mineral phosphates, and containing 37 per cent., or more, of soluble phosphate.

(3) Plots 6, 8, and 10, had, besides the Manures specified, 2000 lbs. Sawdust per acre per annum for the first seven years, 1856-1862, but without effect. (4) 200 lbs., 1856-63 inclusive. (5) 500 lbs. in 1862 and 1863.

(6) 800 lbs. 1856-'58; 400 lbs. 1859-'61; 800 lbs. 1862-'81; 600 lbs. 1882 and since.

(7) The application of Silicates did not commence until 1862; 9 years (1862-1870), 200 lbs. Silicate Lime, and 200 lbs. Silicate Soda; 1871, and since, 400 lbs. Silicate Soda. (8) 550 lbs. Nitrate of Soda is reckoned to contain the same amount of Nitrogen as 400 lbs. of "Ammonium-salts."

(9) The Manures specified were first applied in 1859 (previously, 1856-7 and 8, Sawdust only).

PERMANENT GRASS LAND.

condition of moisture in which it was brought from the pit, was applied at the rate of 2000 lbs. per acre, for a length of 49 links down each of the Plots 1 to 13 inclusive; and on February 26, partially dried and finely ground and sifted chalk, was applied to the same portion of the same plots, at the rate of 1000 lbs. per acre. In November 1883, each plot (1 to 20 inclusive) was divided, and upon one-half of each 2000 lbs. per acre of fresh burnt lime (slacked), was applied, in addition to the ordinary manures as stated in the Table; and in November 1887, the other half of most of the plots also received 2000 lbs. per acre; the exceptions being, that Plot 5 did not receive any in 1887, and that the portions of Plots 11–1 and 11–2, which had received the Lime in 1883, in 1887 received 2000 lbs. per acre more, and the other half which did not receive any in 1883, then (1887) received 4000 lbs. per acre. Lastly, in December 1896, the half of Plot 5, which had not previously received any lime, received 4000 lbs. per acre of freshly burnt lime (slacked); and the other half, which had formerly received 2000 lbs., now received another 2000 lbs. per acre, making in all 4000 lbs., the same as on the other half.

It was not until some years after the application of chalk, early in 1881, to small portions of some of the plots as above referred to, that the effects were sufficiently marked to render it desirable to cut and weigh the produce separately; and it was not until 1884 that it was so treated. The produce of the whole of these chalked portions was, however, excluded from the reckoning of the average produce of the plots, as given in this annual report, in the case of all the first crops of 1881, 1882, 1883, and 1886 to 1897 inclusive. It was also excluded in 1884 and 1885, in the case of the plots where the produce was separately weighed (Plots 6, 7, and 8, 1884, and 3, 6, 7, 8, and 11–1, in 1885), but included in the other cases in those two years. Again, in the case of the second crops, it was only in those of 1881 (a few of those of 1882), 1886, 1891, 1892, 1894 and 1896 (excepting Plots 6, 7, and 8), and 1897, that the produce of the chalked portions was included. In the case of the remaining or main portion of the plots, to one-half of which a dressing of slacked lime was applied in November 1883, and to the other half in November 1887, there has, on some plots, been marked effect, but it is the average produce of the two portions that has each year been given, as the produce of the plots. Below is given, besides the usual averages, the produce for both 1896 and 1897.

For Plan of the Plots, and brief summary of results and conclusions, see pp. 20–21.

about 7 acres.)

Plots.	Produce per Acre, Weighed as Hay.												Plots.
	Average per Annum, 20 Years, 1856–75. (First Crops only.)			Average per Annum, 20 Years, 1876–95. (First and Second Crops.)			Forty-first Season, 1896.			Forty-second Season, 1897.			
	10 Years, 1856–65.	10 Years, 1866–75.	20 Years, 1856–75.	First Crops(12).	Second Crops(14).	Total.	First Crop.	Second Crop(15).	Total	First Crop.	Second Crop(15).	Total.	
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	
1	48 3/8	37 3/4	43	26 7/8	11 5/8	38 1/2	16 1/4	3 1/4	19 1/2	25 3/4	(16)	25 3/4	1
2	41 5/8	32	36 7/8	20 5/8	9	29 7/8	11 3/8	0 7/8	12 1/4	18 1/8	(16)	18 1/8	2
3	22 1/2	20	21 1/4	17 1/8	8 3/4	25 7/8	10 1/4	1	11 1/4	15 1/2	(16)	15 1/2	3
4 (1)	23 1/4	21 1/4	22 1/4 (9)	17 3/4	8 7/8	26 3/8	9 3/4	1	10 3/4	19	(16)	19	1
4 (2)	33 7/8	30 1/2	32 1/4 (9)	29 3/4	10 7/8	40 5/8	10 5/8	2	12 5/8	28 3/4	(16)	28 3/4	2 } 4
5	30 1/2	22	26 1/4	17 1/4	10	27 1/4	2	0 3/8	2 3/8	20 5/8	(16)	20 5/8	5
6	31 3/8	30 1/4	30 3/4	28 5/8	12 3/8	41	16 1/8	4 1/8	20 1/4	32 1/8	1 1/2	33 5/8	6
7	33 7/8	36 3/4	35 1/4	29 3/4	14 1/2	44 1/4	15 1/2	4 3/8	19 7/8	31 7/8	1 1/4	33 1/8	7
8	33 5/8	26 1/4	30 1/8	19 1/8	9 5/8	28 3/4	12	1 5/8	13 5/8	21 1/8	0 5/8	21 3/4	8
9	53 5/8	48 1/2	51	44 7/8	15 7/8	60 3/4	20 1/4	8	28 1/4	51 1/8	1 7/8	53	9
10	52 3/4	39 5/8	46 1/8	37 1/8	15 5/8	52 3/4	17 1/8	6 1/4	23 3/8	44 1/2	0 7/8	45 3/8	10
11 (1)	61 3/4	53 5/8	57 5/8	48	26 5/8	74 5/8	32 7/8	10 1/8	43	58 7/8	2	60 7/8	1 } 11
11 (2)	63 1/4	61 3/4	62 1/2	57 7/8	25 1/4	83 1/8	44 3/8	12 5/8	57	60 1/2	2 5/8	63 1/8	2 }
12	25	22 7/8	24	17 5/8	10 3/4	28 3/8	11 1/4	1 1/8	12 3/8	18 1/4	(16)	18 1/4	12
13	55 1/4	59 5/8	57 1/2	49 1/2	20 3/8	69 7/8	18 1/2	8 1/2	27	51 3/4	1 7/8	53 5/8	13
14	53 1/8	60 1/2	57 (10)	49 5/8	13 7/8	63 1/2	39 1/2	6 1/2	46	42 5/8	0 7/8	43 1/2	14
15	36 1/8	35	35 3/8 (10)	26 5/8	10 3/8	37	23 1/4	3 1/2	26 3/4	34 7/8	(16)	34 7/8	15
16	45 1/4	47 5/8	46 1/8 (10)	39 1/2	12 3/4	52 1/4	27 3/4	3 1/2	31 1/4	41	(16)	41	16
17	34 1/4	33 1/2	33 7/8 (10)	28 1/2	10 3/4	39 1/4	21 3/4	3	24 3/4	31 1/4	(16)	31 1/4	17
18	21	33 1/4	32 1/8 (11)	29 3/4	13 1/8	42 7/8	17 3/8	4 1/2	21 7/8	30	1 3/8	31 3/8	18
19	..	..	38 3/4 (12)	37	12 1/8	49 1/8	30	5 1/8	35 1/8	38 3/8	0 3/4	38 5/8	19
20	..	..	36 1/2 (12)	39	11 5/8	50 5/8	38	5 7/8	43 7/8	45 1/4	0 3/8	45 5/8	20

(10) Averages of 8 years, 10 years, and 18 years, as these experiments did not commence until 1858.
(11) Averages of (1 year), 10 years, and 11 years, as the experiment only commenced in 1865. (12) Averages of 4 years only, 1872–75.
(13) In 1888 and 1890, the first crops being got up in bad condition, the weights of hay per acre were corrected by adding one-fifth to the determined dry substance. This corresponds to an uniform amount of 16⅔ per cent. of moisture in the first crops of hay.
(14) As in 1876 the second crops were not removed, those of 1875, which were, are brought in instead; and as also in 1884, in 1885, and in 1887, the second crops were not removed, the aggregate second crops of the 17 years (1875, 1877–83, 1886, and 1888–95) are divided by 20 estimating the average amount of produce of second crops removed per annum over the 20 years. See also Note (15).
(15) In 1897, as in '79, '82, '88, '90, '91, '92, '94, and '96, the second crops being got up in bad condition, the produce of hay per acre was corrected by adding one-fourth to the determined amount of dry substance. This corresponds to an uniform amount of 20 per cent. of moisture in the second crops of hay. (16) On these plots the crop was too small to weigh or remove.

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