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ROTHAMSTED  
RESEARCH

## Guide to the Experimental Plots - 1913

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### The Park - Grass Land Mown for Hay Every Year

#### Rothamsted Research

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THE PARK

THE PARK

GRASS LAND MOWN FOR HAY EVERY YEAR

The experiments upon grass at Rothamsted began in 1856, about 7 acres of the park close to the house being set aside for the purpose. The land has been in grass as long as any recorded history of it exists, for some centuries at least. It is not known that seed has ever been sown, and at the beginning of the experiments the herbage on all the plots was apparently uniform.

The plots, of which there are twenty in all, vary somewhat in size, which lies between one-half and one-eighth of an acre. Up to 1874 inclusive the grass was only cut once, the aftermath being fed off by sheep. Since that time there has been no grazing, and the plots are generally cut twice in the year. The grass is made into hay in the usual way, and the whole produce of each plot is then weighed.

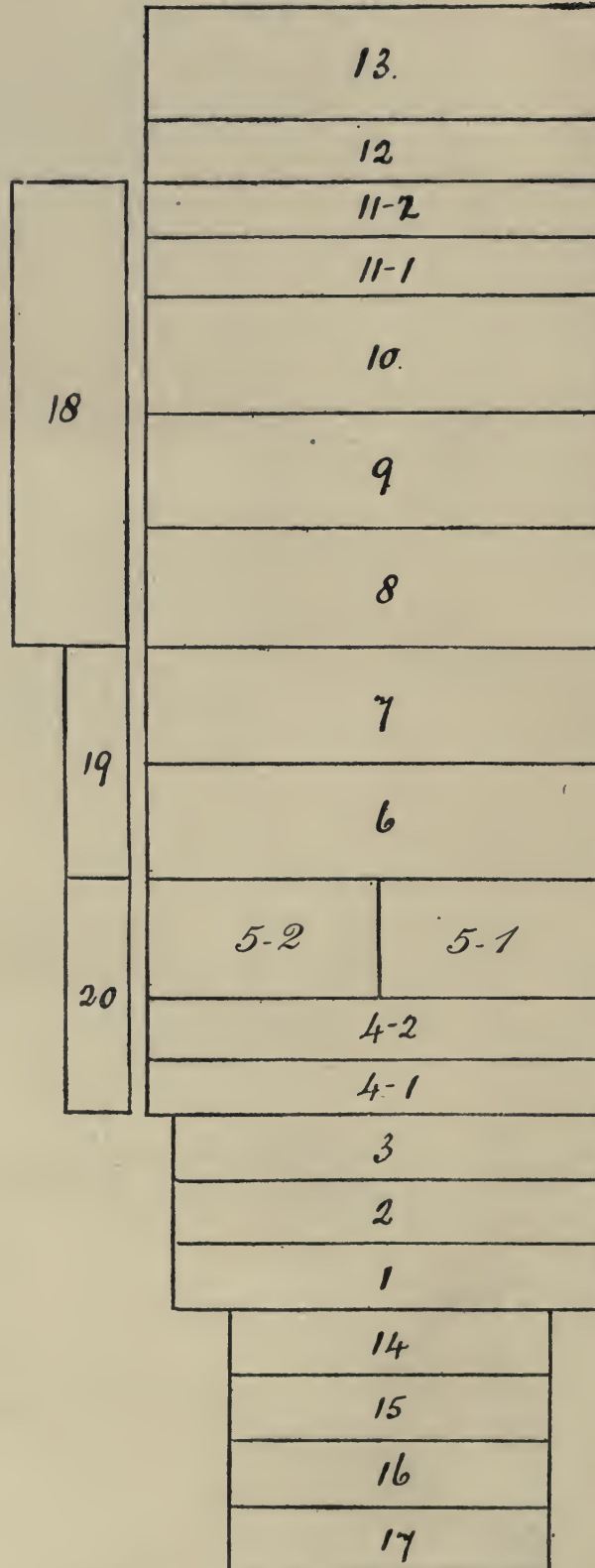
TABLE X.—*Manuring of the Permanent Grass Plots per acre per annum, 1856 and since.*

Plot.	Abbreviated Description of Manures.	Nitrogenous Manures.		Mineral Manures.				
		Ammonium-salts.	Nitrate of Soda.	Super-phosphate.	Sulphate of Potash.	Sulphate of Soda.	Sulphate of Magnesia.	Silicate of Soda.
		Lb.	Lb.	Cwt.	Lb.	Lb.	Lb.	Lb.
3 12	} Unmanured every year . . . . .	...	...	...	...	...	...	...
2		Unmanured; following Dung first 8 years .	...	...	...	...	...	...
5-1	(N. half) Unmanured; following Ammonium-salts alone for 42 years . . . . .	...	...	...	...	...	...	...
1	Ammonium-salts alone; with Dung also first 8 years . . . . .	200	...	...	...	...	...	...
5	Ammonium-salts alone (to 1897) . . . . .	400	...	...	...	...	...	...
17	Nitrate of Soda alone . . . . .	...	275	...	...	...	...	...
4-1	Superphosphate of Lime . . . . .	...	...	3.5	...	...	...	...
8	Mineral Manure without Potash . . . . .	...	...	3.5	...	*250	100	...
7	Complete Mineral Manure . . . . .	...	...	3.5	500	100	100	...
5-2	(S. half) Mineral Manure following Ammonium-salts alone for 42 years . . . . .	...	...	3.5	500	...	...	...
6	As Plot 7; Ammonium-salts alone first 13 years . . . . .	...	...	3.5	500	100	100	...
15	As Plot 7; Nitrate Soda alone first 18 years . . . . .	...	...	3.5	500	100	100	...
4-2	Superphosphate and Ammonium-salts . . . . .	400	...	3.5	...	...	...	...
10	Mineral Manure (without Potash) and Ammonium-salts . . . . .	400	...	3.5	...	*250	100	...
9	Complete Mineral Manure and Ammonium-salts . . . . .	400	...	3.5	500	100	100	...
11-1	Complete Mineral Manure and Ammonium-salts . . . . .	600	...	3.5	500	100	100	...
11-2	As Plot 11-1, and Silicate of Soda . . . . .	600	...	3.5	500	100	100	400
16	Complete Mineral Manure and Nitrate Soda . . . . .	...	275	3.5	500	100	100	...
14	Complete Mineral Manure and Nitrate Soda . . . . .	...	550	3.5	500	100	100	...

\* Reduced in 1905 to 100 lb.

C.—Plan of the Plots in the Park on which Experiments have been made on the Mixed Herbage of Permanent Grass Land.

1856 and onwards.



Total area under Experiment, about 7 acres.

Area of Plots { 1, 2, 3, 4-1, 4-2, 5-1, 5-2, 11-1, 11-2, and 12, each  $\frac{1}{4}$  acre.  
 6, 7, 8, 9, 10, 13, and 18, each  $\frac{1}{2}$  acre.  
 14, 15, 16, and 17, each  $\frac{1}{3}$  acre.  
 19 and 20, each  $\frac{1}{4}$  acre.

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## GRASS FOR HAY

TABLE XI.—*Produce of Hay per acre. Average over the period of 57 years (1856-1912), the 10 years (1903-1912), and the individual year 1912. Rothamsted. Total of first and second crops (if any).*

Plot.	Abbreviated Description of Manures.	Averages over		Season 1912.
		57 years (1856-1912).	10 years (1903-1912).	
3	Unmanured every year . . . . .	Cwt.	Cwt.	Cwt.
12		20·9	16·2	10·2
2	Unmanured; following Farmyard Dung for first 8 years	23·9	21·0	20·1
5-1	(N. half) Unmanured; following Ammonium-salts alone for 42 years . . . . .	28·6*	20·2	15·4
		14·4††	15·0	7·1
1	Ammonium-salts alone (= 43 lb. N.); with Farmyard Dung for first 8 years	35·9†	26·8	23·6
5	Ammonium-salts alone = 86 lb. Nitrogen (to 1897)	(26·1)**	...	...
17	Nitrate of Soda alone = 43 lb. Nitrogen . . . . .	33·7¶	33·2	31·2
4-1	Superphosphate of Lime . . . . .	21·6	21·0	17·2
8	Mineral Manure without Potash . . . . .	28·0	27·4	22·5
7	Complete Mineral Manure . . . . .	40·9	50·9	46·4
5-2	(S. half) Complete Mineral Manure; following Ammonium-salts alone for 42 years . . . . .	23·2††	21·9	15·8
6	Complete Mineral Manure as Plot 7; following Ammonium-salts alone first 13 years . . . . .	37·2‡	45·3	37·8
15	Complete Mineral Manure as Plot 7; following Nitrate of Soda alone first 18 years . . . . .	36·8§	45·8	37·0
4-2	Superphosphate and Ammonium-salts = 86 lb. N. . . . .	33·5	34·5	25·1
10	Mineral Manure (without Potash <sup>1</sup> ), and Ammonium-salts = 86 lb. N. . . . .	47·7	40·5	32·5
9	Complete Mineral Manure and Ammonium-salts = 86 lb. N. . . . .	54·3	54·7	36·0
11-1	Complete Mineral Manure and Ammonium-salts = 129 lb. N. . . . .	66·5	71·2	67·2
11·2	As Plot 11-1, and Silicate of Soda . . . . .	73·3	79·3	72·6
16	Complete Mineral Manure and Nitrate Soda = 43 lb. N. . . . .	46·3¶	48·1	40·7
14	Complete Mineral Manure and Nitrate Soda = 86 lb. N. . . . .	56·9¶	57·7	52·9

<sup>1</sup> Including Potash first 6 years.

* After the change.	Before the change, 42·9 cwt.	54 years only (1859-1912).
† " "	" 49·5 cwt.	¶ 55 years only (1858-1912).
‡ " "	" 30·6 cwt.	** 42 years (1856-1897).
§ " "	" 85·4 cwt.	†† 15 years (1898-1912).

### *The Unmanured Plots.*

Two of the plots have remained without manure during the whole of the experiment. They are situated near the extremities of the field, and show a slight but constant difference in crop. Taking the average of the whole period, these unmanured plots have produced rather more than a ton of hay per acre per annum. If we compare the successive ten-year returns, there is no sign of approaching exhaustion or great falling-off in crop from year to year. The impoverishment of these unmanured plots is more to be seen in the character of the herbage than in the gross weight of produce. Weeds of all descriptions occupy the land, and the relative proportion they bear to the grasses and clovers has increased from year to

year. A fair proportion of clovers, both red and white, is found on these plots, but the weeds, which amount to 28 per cent. taking the average

TABLE XII.—Percentages of Gramineous, Leguminous, and Miscellaneous Herbage. Average of determinations made at different times during 57 years (1856-1912, and 1902 separately). Rothamsted. First crops.

Plot.	Manures.	Averages of determinations over 57 years (1856-1912).			Season 1902.		
		Gram-ineae.	Legu-minosae.	Miscel-laneae.	Gram-ineae.	Legu-minosae.	Miscel-laneae.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
3	} Unmanured every year {	61.0	8.7	30.3	34.3	7.5	58.2
12		64.8	9.0	26.2	38.1	16.1	45.8
2	} Unmanured; following Farm- yard Dung for first 8 years .	75.5	4.3	20.2	24.4	5.7	69.9
5-1		(N. half) Unmanured follow- ing Ammonium-salts alone 42 years . . . . .	...	...	...	76.9	0.6
1	} Ammonium-salts alone (=43 lb N.); with Farmyard Dung for first 8 years . .	87.7	0.7	11.6	77.6	1.4	21.0
5		Ammonium-salts alone = 86 lb. N. (to 1897) . . . . .	(80.5)	(0.4)	(19.1)	...	...
17	} Nitrate of Soda alone = 43 lb. N. . . . .	68.8	1.5	29.7	43.8	3.4	52.9
4-1		Superphosphate of Lime . .	59.3	7.4	33.3	54.4	15.4
8	} Mineral Manure without Pot- ash . . . . .	61.0	9.2	29.8	28.8	22.1	49.1
7		Complete Mineral Manure . .	58.8	24.9	16.3	20.3	55.3
5-2	} (S. half) Complete Mineral Manure following Ammo- nium-salts alone for 42 years	...	...	...	68.7	0.8	30.5
6		Complete Mineral Manure as Plot 7; following Ammo- nium-salts alone first 13 yrs.	64.8	18.6	16.6	18.4	61.0
15	} Complete Mineral Manure as Plot 7; following Nitrate of Soda alone first 18 years . .	59.5	22.6	17.9	26.2	63.1	10.7
4-2		Superphosphate and Ammo- nium-salts = 86 lb. N. . . . .	89.1	0.1	10.8	91.5	(0.01)
10	} Mineral Manure (without Pot- ash *) and Ammonium-salts = 86 lb. N. . . . .	95.7	0.1	9.2	97.6	(0.01)	2.4
9		Complete Mineral Manure and Ammonium-salts = 86 lb. N. . .	89.9	0.3	9.8	91.2	1.3
11-1	} Complete Mineral Manure and Ammonium-salts = 129 lb. N.	96.5	0	3.5	99.2	0	0.8
11-2		As Plot 11-1, and Silicate of Soda . . . . .	97.4	0	2.6	99.5	0
16	} Complete Mineral Manure and Nitrate Soda = 43 lb. N.	82.9	5.4	11.7	61.7	12.8	25.5
14		Complete Mineral Manure and Nitrate Soda = 86 lb. N.	89.0	3.1	7.9	88.8	3.7

\* Including Potash first 6 years.

over the whole period, have of late years constituted nearly one-half of the herbage. The most prominent species among the grasses are the

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Quaking Grass, so generally taken as a sign of poor land, which constituted 20 per cent. of the whole herbage in 1903, and Sheep's Fescue; among leguminous plants the Bird's-foot Trefoil; and Burnet, Hawkbit, and Black Knapweed among the weeds.

### *Use of Nitrogenous Manures alone.*

Three of the plots—17, 5, and 1—show the effect of the long-continued use of nitrogenous without any mineral manures, Plot 5 for forty-two years received 86 lb. of nitrogen as ammonium-salts, Plot 17 half the quantity of nitrogen in the shape of nitrate of soda, and Plot 1 the same half quantity of nitrogen as ammonium-salts, though on this plot dung was applied in each of the first eight years of the experiment. The

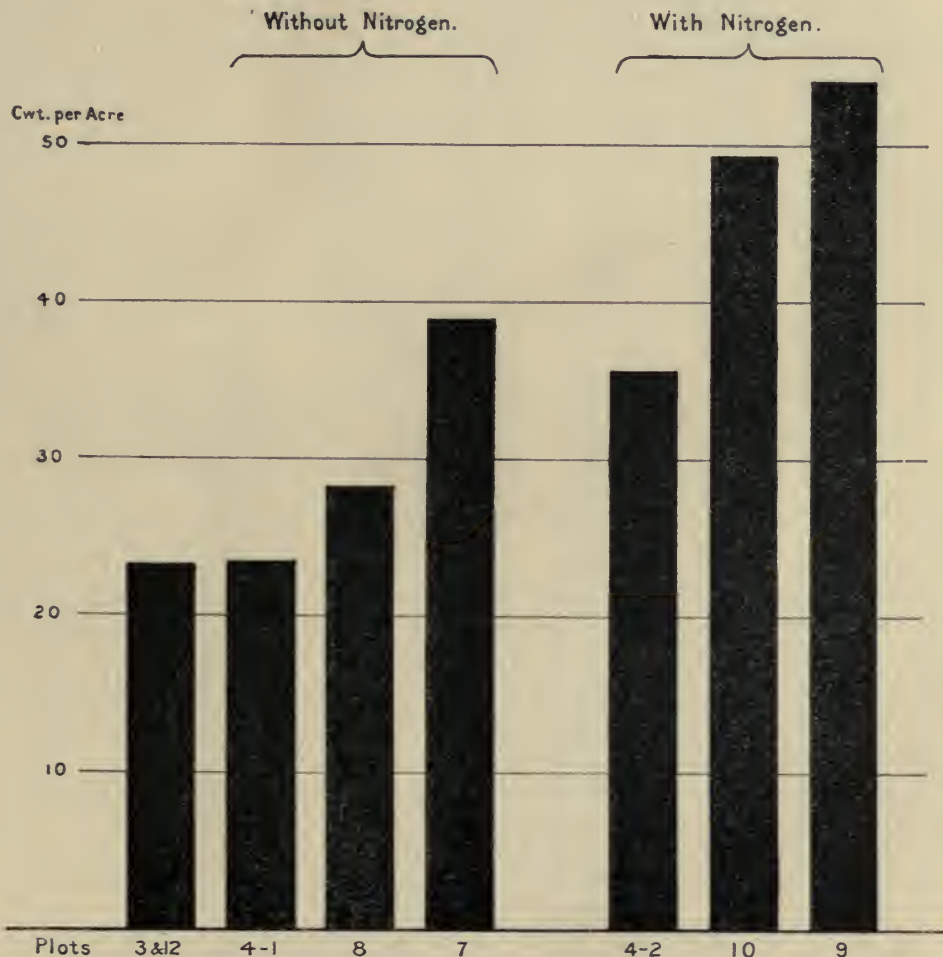


FIG. 6.—Effect of the various Ash constituents with and without Nitrogen on the produce of Hay per acre. Average over 47 years (1856-1902).

- |                                  |   |
|----------------------------------|---|
| Plots 3 and 12. Unmanured.       | Plot 4-2. Super. and Amm.-salts=86 lb. N.                   |
| Plot 4-1. Superphosphate.        | Plot 10. Minerals (without Potash) and Amm.-salts=86 lb. N. |
| Plot 8. Minerals with Potash.    | Plot 9. Complete Mineral Manure and Amm.-salts=86 lb. N.    |
| Plot 7. Complete Mineral Manure. |   |

treatment of Plot 5 is now altered, but during the years the ammonium-salts were applied the average yields per acre from these plots were:—

Plot 17, single nitrate (18 years, 1858-1875), 33·9 \* cwt.  
 „ 15, double „ (18 „ 1858-1875), 35·4 cwt.  
 Plot 1, single ammonia (34 years, 1864-1897), 37·7 † cwt.  
 „ 5, double „ (34 „ 1864-1897), 24·4 ‡ cwt.

It is very evident when a nitrogenous manure is used alone for grass, nitrate of soda is far more effective than the ammonium salts; *e.g.*, on Plot 17 it has given an average crop of 34 cwt. against 26 cwt. produced by double the quantity of nitrogen in ammonium-salts on Plot 5.

*Mineral Manures used alone.*

On three of the plots no nitrogenous manures have been applied since the beginning of the experiments. On Plot 7 a complete mineral manure, supplying phosphoric acid, potash, magnesia, and soda, is used; Plot 8 has received the same application, but without potash, since 1861, while Plot 4-1 receives superphosphate only. With the complete minerals a fair crop is grown, averaging over 1½ ton of hay for the first cut alone. The reason that the crop on this plot is maintained, although no nitrogen is supplied in the manure, lies in the free growth of leguminous plants. It will be seen that, taking the average over the whole period, the leguminous plants form 25 per cent. of the herbage, and the proportion has increased from year to year.

The omission of potash on Plot 8 has caused a very striking difference both in the crop and in the character of the herbage. The average crop has been about one-third less over the whole period, and shows a progressive decline in fertility, until at the present time it is little more than half that of Plot 7. The poor results on this plot, as compared with Plot 7, must be put down to its poverty in leguminous herbage, the development of which seems to depend on a free supply of potash. Of late years the proportion of leguminous plants on this plot has amounted to about one-half of that found on Plot 7, the grasses are also less, the difference being made up by an increased amount of weed.

Plot 4-1, which each year has received superphosphate only, now presents a very impoverished appearance, and is giving little more crop than the unmanured plots. Indeed, the aspect of this plot, where the most abundant grass is Quaking Grass, and where weeds, chiefly Hawkbit, Burnet, and Plantain, are unusually prominent, would seem to indicate that the land is more exhausted here than on the unmanured plot.

*Complete Manures—Nitrogen and Minerals.*

Among the plots which receive both nitrogenous and mineral manures, Plot 9, with a complete mineral manure and ammonium-salts should be compared with Plot 14, which is exactly similar except that the nitrogen is applied in the form of nitrate of soda, and again with Plot 16, where

\* Over the whole period of 55 yrs. (1858-1912) Plot 17 gave an average of 33·7 cwt. per acre.  
 † „ „ „ of 49 „ (1864-1912) „ 1 „ „ 33·6 „  
 ‡ „ „ „ of 42 „ (1856-1897) „ 5 „ „ 26·1 „

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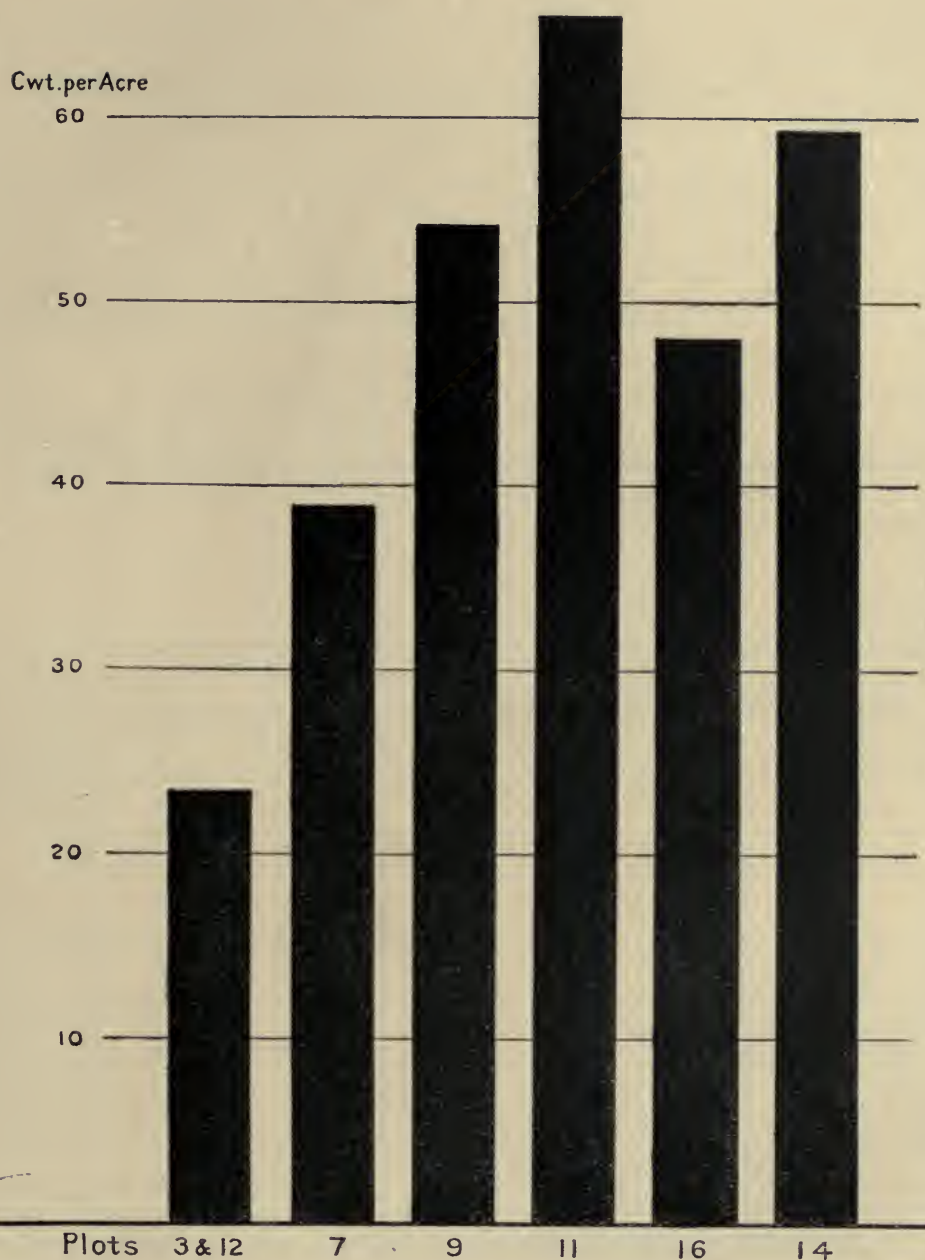


FIG. 7.—Effect of Nitrogenous Manures on the produce of Hay per acre. Average over 47 years (1856-1902).

Plot 3 and 12.	Unmanured.
Plot 7.	Complete Mineral Manure, no Nitrogen.
Plot 9.	Do. and Amm.-salts = 86 lb. N.
Plot 11.	Do. do. = 129 lb. N.
Plot 16.	Do. and Nitrate of Soda = 43 lb. N.
Plot 14.	Do. do. = 86 lb. N.

only half the amount of nitrogen is applied, but again as nitrate of soda. The nitrate of soda gives the heavier yield, the herbage is also more



diversified, and there is not the total absence of leguminous plants which marks the plots receiving ammonium-salts. Two characteristic plants, Soft Brome Grass and Beaked Parsley, are found only on the plots receiving nitrate of soda, the corresponding umbelliferous plant where ammonium-salts are used being the Earth Nut (*Conopodium*).

On Plot 11 the same mineral manures are applied with an extra amount of ammonium-salts, so that the nitrogenous manuring is excessive. As a result the vegetation consists entirely of tufts of three coarse grasses—Meadow Foxtail, Yorkshire Fog, and Tall Oat Grass. The soil has also become sour and unhealthy, with the result that the plant is dying in patches, except on the upper portion of the plot where lime has been applied, and on the half numbered 11-2 where the silicate of soda is used.

The effect of omitting potash from the complete manure is seen on Plot 10, and again on Plot 4-2, where superphosphate and ammonium-salts only are applied. It is noticeable that the grass on these plots is weak in the straw and liable to fungoid attacks.

*Effect of Lime.*

In November 1883 each plot was divided longitudinally, and upon the western half of each 2000 lb. per acre of fresh burnt lime (slacked) was applied, and in November 1887 the eastern half of most of the plots also received 2000 lb. per acre. Plot 5, however, received none, and the western portion of Plots 11-1 and 11-2, which had received the lime in 1883, in 1887 received 2000 lb. per acre more, while the eastern

ROTHAMSTED PARK HAY—FIRST CROP

TABLE XIII.—*Produce per acre on the unlimed and limed portions of the plots.*

Plot.	Unlimed.					Limed. (Lime applied January 1903.)				
	1903.	1904.	1905.	1906.	Average.	1903.	1904.	1905.	1906.	Average.
	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
2	13·35	26·91	20·21	15·43	18·98	20·28	37·12	22·89	15·94	24·06
3	10·61	22·46	15·79	12·18	15·26	16·34	30·20	18·78	11·88	19·30
4-2	35·29	43·19	24·72	23·41	31·65	43·77	47·84	33·08	27·62	38·08
7	49·46	61·87	44·34	34·38	47·51	51·91	61·83	47·15	41·40	50·57
8	23·17	39·59	25·08	21·12	27·24	21·63	35·45	25·71	19·74	25·63
9	50·07	63·69	36·87	39·01	47·41	60·49	69·76	52·18	49·95	58·10
10	37·55	44·02	30·04	28·92	35·13	45·00	48·86	38·40	32·52	41·20
11-1	70·20	85·42	24·71	42·89	55·81	80·84	88·40	50·97	51·62	67·96
11-2	79·46	87·90	50·16	61·68	69·80	77·87	81·64	56·30	65·46	70·32
13	56·46	64·67	22·38	17·69	40·30	60·43	70·60	25·76	17·18	43·49
16	48·68	53·34	46·19	39·25	46·87	45·68	52·12	41·97	38·47	44·56

half, which received none in 1883, then (1887) received 4000 lb. per acre. In December 1896, the eastern half of Plot 5 which had not previously received any lime, received 4000 lb. per acre of freshly burnt lime

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(slacked); and the western half, which had in 1883 received 2000 lb., received another 2000 lb. per acre.

In January 1903 the plots were divided transversely, and a dressing of 2000 lb. per acre of quicklime (ground) was applied to the south half of Plots 1 to 4-2, 7 to 11-2, 13 and 16, and this dressing was repeated in January 1907.

The results of the 1903 dressing are given in Tables XIII. and XIV., and show that distinct improvement is effected on the unmanured plot and those receiving sulphate of ammonia, viz., Plots 2, 3, 4-2, 9, 10, and 11-1. The effect of the liming had largely worn off in the fourth year after the application, excepting on Plots 9 and 11-1.

## ROTHAMSTED PARK HAY

TABLE XIV.—*Effects of Lime and the ordinary Manures. Mean of 3 years, 1904-6 (first crops). Produce and Botanical Composition of the Herbage.*

Plot.	Manures.	Produce, per acre.		Botanical Composition.					
				Gramineæ.		Leguminosæ.		Other Orders.	
		Unlimed.	Limed.	Unlimed.	Limed.	Unlimed.	Limed.	Unlimed.	Limed.
		Cwt.		Per cent.		Per cent.		Per cent.	
7	Complete Mineral Manure	46·9	50·1	53·3	42·0	20·8	34·4	25·9	23·6
8	Mineral Manure without Potash	28·6	27·0	39·9	45·8	11·7	18·6	48·4	35·6

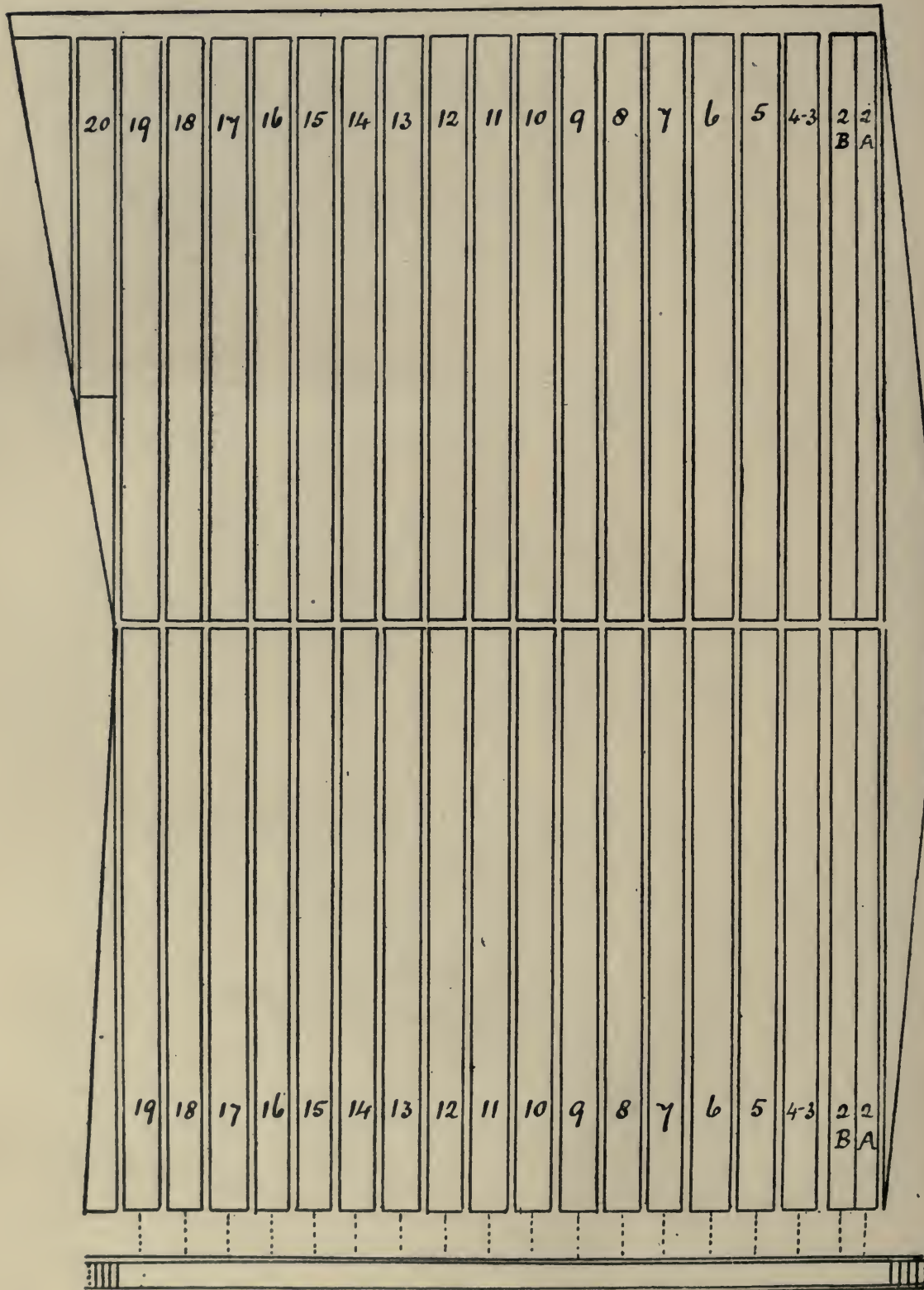
### *Changes in the Herbage following changes in Manuring.*

Plot 6 was up to 1868 manured with ammonium-salts alone, like the adjoining Plot 5; the ammonium-salts were then replaced by a complete mineral manure containing potash. The result is seen in the way leguminous plants have gradually invaded the plot until they now predominate, as they do on Plot 7, where mineral manures have been used throughout. The southern half of Plot 5 has also been manured with minerals instead of ammonium-salts since 1898, and the gradual invasion of leguminous plants may now be seen in progress. The northern half of Plot 5 has been unmanured since 1898, when the ammonium-salts were discontinued, and the invasion of the leguminosæ is much slower.

On Plot 15 nitrate of soda was applied up to 1875, when a change to a complete mineral manure was made, with the same result of the incoming of the leguminous plants.

Plot 18, which up to 1905 was in an impoverished condition, has since been receiving a complete manure except that phosphates are omitted.

D.—Plan of the Plots in Broadbalk Field on which Wheat has been grown since 1843-4.



Brick Trench for collecting the Pipe Drainage from each Plot.

Total area of ploughed land about 11 acres.

Area of Plots 3-4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, and 19, each  $\frac{1}{2}$  acre.

Area of Lands A and B of Plot 2, each  $\frac{1}{10}$  acre.

Area of Plot 20, about  $\frac{1}{2}$  acre.

The double lines indicate division paths between plot and plot; also a path across the centre of each plot.

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