ROTHAMSTED RESEARCH

Rothamsted - the Classical Experiments

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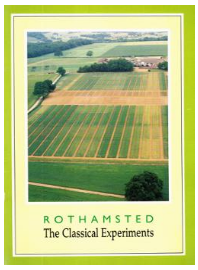

Park Grass

Rothamsted Research

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(2) From 1902 to 1939 no manures were applied and with few exceptions cereals were grown. Yields were recorded in some of the earlier years, residual effects of the previous treatments were very small in the absence of fresh nitrogen fertilizer.

(3) From 1940 to 1985 spring barley was grown and nitrogen fertilizer applied to all plots every year, initially at a single rate, from 1976 testing four rates. Nitrogen not only increased yields, which have been recorded since 1949, but also allowed the crop to take advantage of P and K residues remaining in the soil from the first period of the experiment. The effects of these were initially large but declined as amounts of phosphate in the soil declined (Table 6).

(4) Since 1986 spring barley has continued to be grown each year. Plots 2, 4, 6, 8 and 10 have continued unchanged from the third period and yields have continued to decline on these plots without fresh P or K (Table 6). Plots 1, 3, 5, 7 and 9 have all been given 144 kg N ha^{-1} and 83 kg K ha^{-1} annually and divided for an annual, cumulative test of 0 v 44 v 87 v 131 kg P ha^{-1}. Responses to fresh phosphate have been large (Table 7), even on plots with residues. Best yields now equal those from the earlier years despite including yields of the two exceptionally dry summers of 1989 and 1990.

TABLE 7

Exhaustion Land Spring Barley — Fresh P test

Mean yields of Triumph barley grain, t ha^{-1}, 1986-90

Annual P*kg ha^{-1} 1986-90	Plots 1, 5, no P, no K	Plot 7, residues of PK fertilizers 1856-1901	Plot 3, residues of FYM 1876-1901
0	2.0	3.4	3.7
44	4.0	4.4	4.6
87	4.4	4.7	4.8
131	4.4	4.4	4.5

*All plots received N at 144 kg and K at 83 kg ha^{-1} annually in this period

PARK GRASS

The Park Grass experiment, laid down in 1856, is the oldest on grassland in Great Britain. The field had been pasture for at least a century when the experiment began. It demonstrates in a unique way how continued manuring with different fertilizers affects both the botanical composition and the yield of a mixed population of grasses, clovers and other herbs. After more than 130 years, the boundaries of the plots are still clearly defined; the transition between adjacent treatments occupies 30 cm or less, showing that there is little sideways movement of nutrients in flat undisturbed soil.

The plots have been cut each year for hay, all at the same time, although no single date can be suitable for all plots. For a few years the aftermath was grazed by sheep, but from 1876 a second cut has been weighed and carted

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green. Since 1960 yields, corrected to dry matter, have been calculated from the weights of produce from sample strips cut with a forage harvester (two per plot). Yields of dry matter are now larger than previously because dry matter loss during haymaking in the field no longer occurs on the samples taken for yield. At the first cutting the produce of the remainder of each plot is made into hay; this allows the return of seeds to the soil as in the past. At the second cutting the whole produce is carted green. The position of the sample strips differs from year to year.

The soil of Park Grass, in contrast to that of the nearby arable fields, probably never received large dressings of calcium carbonate and the pH was probably about 5.7 when the experiment began. On plots treated with sulphate of ammonia increasing acidity caused a gradual change in the species composition, although not the yield, of the sward. Lawes made two tests of lime in 1883 and 1887, but these were without immediate effect. Regular liming was not begun until 1903. Then, and every fourth year until 1964, lime (originally burnt lime, more recently calcium carbonate) was applied to the southern halves of most of the plots (see plan). Except for plots 18, 19 and 20, a fixed amount was applied on each occasion. From 1965 each half-plot on plots 1 to 18 was further subdivided. (At this stage the old plots 5/1, 5/2 and part of 6, whose treatments had not been constant throughout were used for new experiments.) From 1965 only sub-plots 'd' remain unlimed; on some of these soil pH has changed little over many years, the values now range from 5.7 to 3.5 depending on treatment. Sub-plots 'c' (previously unlimed) now receive chalk calculated to give pH 5, sub plots 'b' to give pH 6 and (from 1976) sub-plots 'a' to give pH 7.

Since 1990 nitrogen fertilizer and lime have been withheld from half of all the sub-plots of plots 9 and 14 to study processes controlling soil acidification and heavy-metal mobilization and changes in botanical composition.

Park Grass (see plan on opposite page)

Treatments (every year except as indicated)

Nitrogen (applied in spring)

N1, N2, N3	sulphate of ammonia supplying 48, 96, 144 kg N ha^{-1}
N1*, N2*	nitrate of soda supplying 48, 96 kg N ha^{-1}
(N2), (N2*)	last applied 1989

Minerals (applied in winter)

P	35 kg P ha^{-1} as granular superphosphate (19% P_2O_5)
K	225 kg K ha^{-1} as sulphate of potash (50% K_2O)
Na	15 kg Na ha^{-1} as sulphate of soda (14% Na)
Mg	10 kg Mg ha^{-1} as sulphate of magnesia (10% Mg)
Si	Silicate of soda at 450 kg ha^{-1} of water soluble powder

Plot 20. Rates of manuring in years when FYM not applied:
30 kg N, 15 kg P, 45 kg K ha^{-1}

Organics (each applied every fourth year)

FYM 35 t ha^{-1} farmyard manure (bullocks) (1989, 1993)

Fish meal (about 6.5% N) to supply 63 kg N ha^{-1} (1991, 1995)

Lime

a, b, c	Lime applied as needed to maintain pH 7, 6 and 5 respectively
d	No lime applied (pH range 3.5 to 5.7, Plots 11/1 to 17 respectively)

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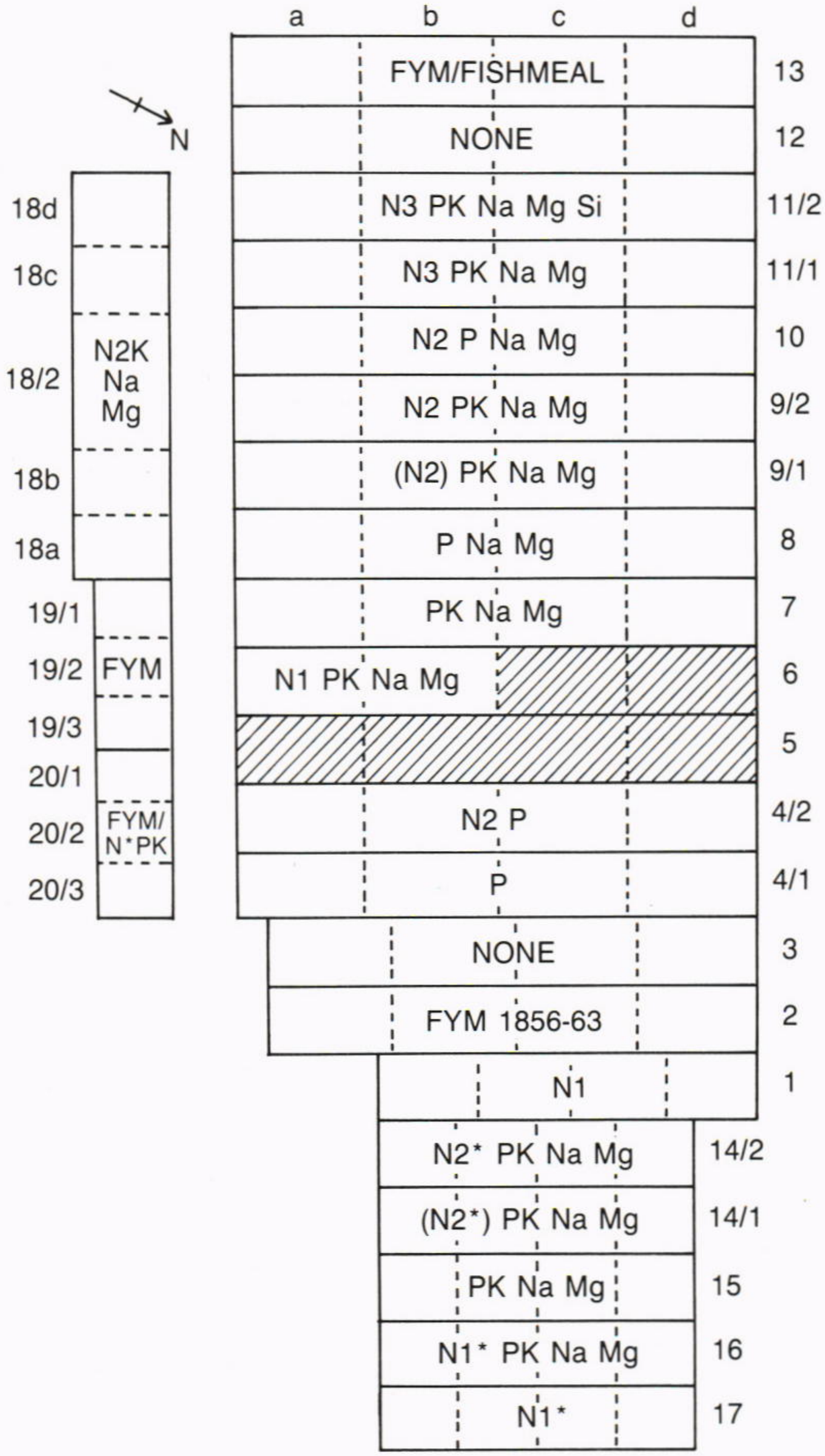
PARK GRASS
Hay since 1856



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(The botanical notes below have been supplied by Dr. E.D. Williams, formerly at Rothamsted, currently at the AFRC Institute of Grassland and Environmental Research, Aberystwyth).

The unmanured plots (2, 3 and 12), possibly with about 50-60 species, have the most diverse flora including many red clover (*Trifolium pratense*) plants and other broad-leaved species, but no species is dominant and yields are small. Although these swards are the nearest approximation to the state of the whole field in 1856, cumulative impoverishment of the soil soon caused decreases in rye-grass (*Lolium perenne*) and Yorkshire fog (*Holcus lanatus*) and later increases in common bent-grass (*Agrostis capillaris*), red fescue (*Festuca rubra*), rough hawkbit (*Leontodon hispidus*) and salad burnet (*Sanguisorba minor ssp minor*). Species characteristic of poor land e.g. quaking grass (*Briza media*) and cowslip (*Primula veris*) also occur on these plots. Lime alone does not greatly alter the character of the herbage but it decreases the contribution of bent and fescue and increases that of downy oat-grass (*Avenula pubescens*) and some broad-leaved species. P alone (Plot 4/1) has only minor effects; in particular, it slightly increases common sorrel (*Rumex acetosa*). Giving PK Na Mg (Plot 7) increases the amount of legume, especially meadow vetchling (*Lathyrus pratensis*) and red clover; on this plot lime greatly increases the vigour and yield of these two legumes and the contribution of false oat-grass (*Arrhenatherum elatius*), buttercups (*Ranunculus* spp), dandelion (*Taraxacum* spp) and hogweed (*Heracleum sphondylium*). Omitting K and giving P Na Mg (Plot 8) results in much less meadow vetchling but more ribwort plantain (*Plantago lanceolata*), and on this plot lime depresses yields.

With nitrogen, either as sulphate of ammonia or as nitrate of soda, yields (Table 8) are reasonable except on some of the unlimed sub-plots. Some of the most spectacular treatment effects and some of the largest changes with time have been caused by the acidifying effect of ammonium sulphate. On all the unlimed sub-plots of these plots earthworms are absent and the plots are dominated by acid-tolerant grasses and some have a peaty-layer of partly decomposed plant residues overlying the mineral soil. Applications of ammonium sulphate at 48 kg N ha^{-1} (Plot 1) or at 96 kg N ha^{-1} without P (Plot 18) have resulted in common bent becoming dominant, whereas sweet vernal-grass (*Anthoxanthum odoratum*) is dominant on plots 4/2, 9 and 10, receiving it at 96 kg N ha^{-1} plus P, and Yorkshire fog on plots 11/1 and 11/2 given it at 144 kg N ha^{-1} plus PKNa Mg. The long-limed halves of these plots have a wider range of grasses; the main species on plot 1 are downy oat and quaking grass, on plot 4/2 and 10, red fescue, and false oat and meadow foxtail (*Alopecurus pratensis*) on plots 9, 11/1 and 11/2 which yield as much as some sown grassland. Nitrate of soda (Plots 14, 16 and 17) supplies nitrogen without acidifying the soil; lime has a relatively small effect on these plots. Even without lime about 30 species of plants occur with the smallest amount of N alone (Plot 17). The dominant species on the other two plots (14 and 16) is false oat, together with meadow foxtail on the unlimed ends. The organic manures are applied on a four-year cycle of farmyard manure, none, fish meal, none to Plot 13 which has a well mixed herbage but yield is generally less than from the best fertilizer treatment.

The largest and most rapid recent changes in botanical composition have occurred as a result of applying lime for the first time to the previously unlimed

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TABLE 8

Park Grass

Mean annual yield of dry matter, t ha^{-1} (1986-90)

	Sub plots				
Plot	a	b	c	d	Mean
1	4.3	3.5	2.3	1.1	2.8
2	3.5	4.2	2.5	2.4	3.2
3	3.1	4.0	2.2	2.5	3.0
4/1	4.1	4.5	3.5	3.9	4.0
4/2	4.0	4.0	3.8	2.7	3.6
6	6.1	6.2	-	-	-
7	6.6	6.4	5.7	4.8	5.9
8	3.7	4.3	4.6	4.4	4.2
9	6.3	6.8	5.3	3.9	5.6
10	4.4	4.6	4.2	2.6	4.0
11/1	7.5	6.8	6.6	6.0	6.7
11/2	8.0	7.2	6.2	6.2	6.9
12	3.1	2.7	2.3	2.5	2.6
13	7.5	7.9	5.9	5.3	6.6
14	6.9	7.8	6.5	6.6	7.0
15	6.0	5.6	4.5	4.5	5.2
16	6.8	7.0	5.5	4.8	6.0
17	4.0	4.3	4.2	4.0	4.1
18/1	-	-	1.5	1.3	-
18/2	4.4	-	-	-	-
18/3	3.8	3.6	-	-	-
19/1	5.9	-	-	-	-
19/2	6.6	-	-	-	-
19/3	5.9	-	-	-	-
20/1	7.1	-	-	-	-
20/2	7.4	-	-	-	-
20/3	6.7	-	-	-	-

very acid sub-plots. Lime applied during 1965-68, in many instances only raised the pH of the surface litter, but it increased the mean number of species per sub-plot heading in early June from 4 in 1965 to 15 (range 11-21) in 1972. The number then remained fairly constant at about 12 during the rest of the 70s but only 9 were recorded in 1990. Visual surveys, and botanical analyses of hay samples during the mid 70s, indicated that the three acid-tolerant grasses were, to varying extents depending on treatment, replaced by red fescue, smooth-stalked and rough-stalked meadow grass (*Poa pratensis* and *Poa trivialis*), cocksfoot (*Dactylis glomerata*), false oat and meadow foxtail. The survey done in 1990, and for some plots those done in the late 70s, indicate reversion on most of these sub-plots to the botanical composition 3 to 5 years after the start of the new liming, possibly indicating the sensitivity of species balance to small changes in soil pH and resulting availability of other nutrients. Visual surveys have not detected large changes from increasing soil pH on previously-limed sub-plots a and b. Analyses of hay samples in 1974 however indicated that raising the pH on several of the b-sub plots of the acid plots favoured false oat at the expense of meadow foxtail.

The distributions in the soil of nodule bacteria (*Rhizobium spp.*) for clover, *Lathyrus* and *Lotus* correspond closely to the distributions of their hosts in the different plots; neither medicks nor their nodule bacteria occur. Acid sub-plots contain no nodule bacteria; increasing amounts of lime increases numbers. On limed sub-plots, N fertilizer has neither diminished the numbers nor altered the symbiotic effectiveness of the clover nodule bacteria.

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