

**THE PARK GRASS EXPERIMENT**  
**on the effect of fertilisers**  
**and liming on the botanical**  
**composition of permanent grassland,**  
**and on the yield of hay**

by

**JOAN M. THURSTON, G. V. DYKE**  
**and E. D. WILLIAMS**

With Appendix  
by  
R. W. Snaydon

**Rothamsted Experimental Station**  
1976

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#### INTRODUCTION

This experiment was started in 1856 by Sir John Lawes, the founder of Rothamsted, on a field near Rothamsted Manor which had already been under grass for hundreds of years. The experiment still continues, and although it began as an agricultural investigation, its results are as interesting to ecologists, crop physiologists and chemists as they are to farmers - a fact already evident by 1880 (Lawes and Gilbert, 1880). Some treatments were changed and a few plots were added in the early years of the experiment in the light of experience gained (Lawes Agricultural Trust, 1970) but 15 plots retain their original treatments. Two plots whose treatments were changed in the early years, were dropped from the main experiment in 1965 and are now used for small-plot tests of treatments, rates and combinations not represented on the large plots (Plan 1, Plots 5 and 6). The vegetation on plot-sections still receiving their original treatments alters very little between successive years while showing some steady drifts, but on those receiving the new liming rates it is now changing. The plant communities differ greatly according to treatment, and as the soil type, aspect, weather and management are the same for all plots, these differences can result only from applying fertilisers and lime.

#### METHODS

The 8-acre (3.24 ha) field is level. The soil is silt loam overlying stiff yellow-red clay upon chalk. Drainage is good and agricultural drains are unnecessary. The mixed vegetation of Gramineae, Leguminosae and other families appeared fairly

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uniform over the whole area at the start and consisted entirely of indigenous species and strains of plants.

SLIDE 1

The plan of the experiment since 1965 is shown on page 12. The plots differ in shape and are from 0.2-0.05 hectares. Mean yields of hay from the first cut in tonnes dry matter per hectare are marked in bold figures on half-plots. Approximate pH values are shown by small italic numbers. Plots 1-13 are the oldest. Plots 14-17 were added to compare the effect of nitrogen as sodium nitrate with ammonium sulphate used on the older plots, and plots 18-20 compare unlimed and two different liming-rates for three treatments not represented in plots 1-17. The shape of the field and the presence of trees determined the lay-out of the experiment.

There are two completely unmanured plots at opposite ends of the experiment (plots 3 and 12) but other treatments are neither replicated nor randomised. The grass is cut in June every year and made into hay on the plot on which it grew. At first the plots were grazed by sheep after the hay was carted, but since 1873 a second cut has been taken in autumn, recently by forage-harvester, and the field is never grazed now. The forage-harvester is also used at the first cutting, to cut narrow sample strips from which the yield of each plot is estimated, sub-samples being taken for the determination of the percentage of dry matter.

Liming of half-plots began in 1903 because acidity had developed on plots receiving ammonium sulphate, but no major changes were made between 1903 and 1964. The liming scheme was revised in 1965, and five of the most acid plots are now divided into four sub-sections, one unlimed and three with different amounts of lime, aimed at producing four pH values for

each fertiliser treatment. Some others have light liming on half of the old unlimed end.

Fertiliser treatments applied annually to the same plots are in three main groups: (1) No Nitrogen, (2) Nitrogen as ammonium sulphate, (3) Nitrogen as sodium nitrate. Within these groups there are plots without other applied nutrients and plots with various combinations of phosphorus (given as superphosphate), potassium, sodium and magnesium sulphates. Three plots receive farmyard manure (dung) every fourth year; of these one receives sodium nitrate, phosphorus and potassium in each of the other three years and another receives fish meal once in four years alternating with dung. These applications of partly-rotted dung made with straw litter in cattle-yards and spread as evenly as possible are not the same as dung left by grazing animals. The dung plots of Park Grass also do not receive the trampling and fresh urine of grazing animals.

The herbage on the plots began to differ in botanical composition in the second year of treatment. Differences increased with time but eventually the plant communities stabilised and altered very little between 1919 (Brenchley, 1924) and 1948 (Brenchley, revised Warington, 1969). By 1903, the soil on plots receiving ammonium sulphate was very acid so half of each plot was limed then and every following 4th year. After 120 years the boundaries between contrasting plant communities on adjacent plots are straight and distinct, confirming that treatments have been applied accurately and that neither soil nor fertilisers have moved between plots.

Yields are recorded annually and published in the 'Yields of the Field Experiments'. These are now given as dry matter but

SLIDE 2

in the past they were presented as yields of hay. Samples are dried and stored so that chemical analyses can be made if required on bulked samples of the produce of several seasons. Visual botanical surveys are made twice yearly before cutting. Botanical analyses of hay sampled (Lawes, Gilbert and Masters, 1882; Brenchley, 1924; Brenchley, revised Warrington, 1969) and chemical analyses of produce and soil (Lawes and Gilbert, 1900; Warren and Johnston, 1964) have been made at intervals and soil pH has also been studied.

RESULTS

Only selected results and main conclusions can be given here. Botanical and chemical details and yields are published in the references cited.

The effect of chemical treatments on floristic composition and yield

SLIDES 4 and 7 The unmanured plots are the nearest approximation to the original vegetation. They have about 60 species of higher plants (Brenchley and Warrington, 1969). Every plant found on the other plots also occurs on the unmanured ones and some grow only on the unmanured. Fertilisers and liming encourage some species and discourage others, but do not cause invasion by species not previously present. Gaps in the sward occur only on very acid plots after severe winters. There is no dominant species on the unmanured plots. Gramineae, Leguminosae and other families are all present, including some plants characteristic of poor land e.g. Briza media (quaking grass), Primula veris (cowslip). The vegetation is short and hay yield

3

10 and 12

28

7 and 29

is small. Some plants rare in the locality occur here e.g. Dactylorhiza fuchsii (common spotted orchid) Listera ovata (twayblade) and the small fern Ophioglossum vulgatum (adder's tongue). Dactylorhiza was recorded for the first time in 1963 and flowered again in 1964 and 1965. It does not occur elsewhere on Rothamsted farm and may have been there from the beginning, possibly not flowering.

SLIDES 31, 32, 34

The addition of phosphorus, potassium, sodium and magnesium but no nitrogen encourages most Leguminosae, (especially Lathyrus pratensis meadow vetchling, Trifolium pratense red clover and, to a lesser extent, T. repens white clover) but not Lotus corniculatus birdsfoot trefoil; the vegetation is still short and contains many species. The yield is double that of a limed but unmanured plot, and liming increases it further.

26 and 27

Annual applications of ammonium sulphate without other fertilisers or lime eliminate all the Leguminosae and all except the most acid-tolerant grasses and weeds. The vegetation is chiefly Agrostis tenuis (common bent grass) with some Anthoxanthum odoratum (sweet vernal), Festuca rubra (red fescue) and occasional plants of Rumex acetosa (sorrel) and Potentilla reptans (creeping cinquefoil). The very acid plots develop a layer of peat above the soil. The grasses tend to root in this and are then easily killed by frost or drought, especially where vigorous harrowing has pulled the peat away from the underlying soil. The mean yield is less than half that of an unmanured, unlimed plot.

20 and 21

11 and 13

12

16

The addition of phosphorus as well as ammonium sulphate, but without lime, produces a sward dominated by Anthoxanthum

18

SLIDES

odoratum but with some Agrostis tenuis and less R. acetosa.

- 5, 10, 12 Where potassium is given in addition to phosphorus, sodium and magnesium, plus the highest rate of ammonium sulphate, but where acidity is not corrected by liming, Holcus lanatus (Yorkshire fog) is dominant, with a mat of undecayed vegetation below it. The shorter grasses have disappeared. After a severe winter, the Holcus dies in patches, but when a mild winter is followed by a moist spring, the soil is completely covered and no other species is present. A few plants of Chamaenerion angustifolium (rosebay willow-herb) may invade the bare patches, but do not persist, being discouraged by cutting and ousted by Holcus regenerated from seed. Liming prevents excessive mat formation and encourages formerly agriculturally useful grasses, especially Alopecurus pratensis (meadow foxtail) but recently Arrhenatherum elatius (false oat grass) has exceeded them in abundance. Some less desirable species e.g. Taraxacum officinale (dandelion) are also encouraged but Leguminosae cannot survive under the dense cover of tall grasses. This plot and its neighbour with sodium silicate in addition, yield the most in the experiment. Even in the absence of potash, liming improves the sward.
- 6 and 8
- 15 and 17

- 9 and 20 Where nitrogen is applied as sodium nitrate, lime is unnecessary. With complete fertilisers including sodium nitrate, Alopecurus pratensis and Dactylis glomerata (cocksfoot) flourish and Arrhenatherum elatius is also abundant. The hay crop is heavier than on the limed half of a plot receiving complete fertilisers, including the same amount of nitrogen as ammonium sulphate, and there is no peat layer.

The first effect of lime added in 1965 to previously very

acid quarter plots was seen in the spring immediately after application, when the dead vegetation rotted more quickly on the newly-limed areas. Liming also delayed the flowering of Holcus right from the start and the effect has persisted. A few seedlings of Taraxacum officinale and Trifolium pratense were seen on plots 11<sup>1</sup>c and 11<sup>2</sup>c in 1966; during the next two years both species became well established on most of the recently-limed previously acid sub-plots. During 1967 Festuca rubra increased greatly on many c sub-plots and it is now abundant on 1c, 4<sup>2</sup>c and 10c, which lack potassium. Since 1967 many other grasses appeared and have become plentiful on 11<sup>1</sup>c and 11<sup>2</sup>c; Arrhenatherum elatius, Poa pratensis, Poa trivialis, Alopecurus and Dactylis are now abundant on these sub-plots and the % contribution of Holcus has declined from around 97% to 33%. However, on plots 9c and 10c recent lime has increased % Holcus, in 1973 from 13 to 44% and 0.1 to 21% respectively. The contribution of Anthoxanthum on 4<sup>2</sup>c, 9c and 10c has on average decreased from 72 to 8%. Poa pratensis is now common on 4<sup>2</sup>c, 9c and 10c. On 1c and 18c lime has decreased the % contribution of Agrostis from 80% to 20% and 50% respectively but affected it little on the other sub-plots.

There has also been a general introduction of many dicotyledonous plants. Legumes, mainly Trifolium pratense and Lathyrus pratensis, are now common on 9c and to a lesser extent on 1c. Although Anthriscus sylvestris (9c and 11<sup>2</sup>c), Cerastium holosteoides (1c and 18c), Conopodium majus (1c and 18c), Heracleum sphondylium (9c), Plantago lanceolata (1c) and Rumex acetosa (1c, 18c) are conspicuous in summer they do not, with the exception of 1c, contribute greatly to the dry matter.

SLIDES

These 'other species' make up 17% of the yield on 1c and 6% on 9c and 18c.

As might be expected, increasing the rate of liming on sub-plots b has had less effect on botanical composition than liming sub-plots c, which were previously unlimed. Increasing the pH on sub-plots b has in general favoured Arrhenatherum at the expense of Alopecurus. The changes have been largest on the most acid plot i.e. one which receives most ammonium sulphate without silica; on the potassium-deficient plot where the required increase in pH has been small and little lime has been added there has been no change in the vegetation. Lathyrus pratensis has been encouraged with increased lime on the plot given the intermediate amount of nitrogen and complete minerals.

Effects on individual species

This experiment indicates tolerances or preferences of individual species for some combination of fertilisers and soil acidity, but competition between species must also affect the results (Thurston et al., 1976). Experiments on isolated plants as described at the British Ecological Society Symposium in 1968 by Goodman for Lolium perenne (perennial ryegrass) and demonstrated by Snaydon for Anthoxanthum odoratum plants obtained from the Park Grass plots are necessary to determine the factors involved and their relative importance (See Appendix). Anthoxanthum is now dominant on all unlimed plots receiving N2 + P i.e. 4<sup>2</sup>, 9 and 10. The effect of treatment on some species has already been indicated in discussing the plant communities e.g. all grasses are encouraged by nitrogen. Agrostis tenuis tolerates acidity and also potassium and

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SLIDES

phosphorus deficiency. Holcus lanatus also tolerates acidity but requires phosphate and potash and benefits from much nitrogen, and Anthoxanthum odoratum requires phosphorus but tolerates acidity and potassium deficiency. Alopecurus pratensis requires complete fertilisers and will not grow on very acid soil. Leguminosae do not need nitrogenous fertilisers but benefit from phosphorus and potassium. Festuca rubra is abundant on plots of pH 5.0 to 5.5 where potassium is not given.

Taraxacum officinale is very abundant only on plots that are less acid than pH 5.3 and receive potassium. Occasional plants occur on no-potassium or moderately acid plots, but it is not known whether these individuals are more tolerant than the species as a whole, or whether they are in spots where soil conditions are more favourable to them than on the rest of the plot. Different combinations of dandelion species occur on different plots.

Rumex acetosa tolerates phosphorus deficiency in very acid soil. After a drought or severe frost has killed most of the Agrostis on such a plot, R. acetosa may be the only living plant. Probably depth of rooting is responsible for the difference between Agrostis and Rumex.

Fritillaria meleagris flowers every year on one plot where it was probably planted, but does not spread to other plots.

Effects on the distribution of fauna etc.

Changes in flora, caused by treatments, affect the fauna of the plots (Edwards et al., 1975, 1976). Acid soil is unfavourable to earthworms, as may be seen from the distribution of worm-casts. When moles invade the field they throw up mole-hills

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26 and 27

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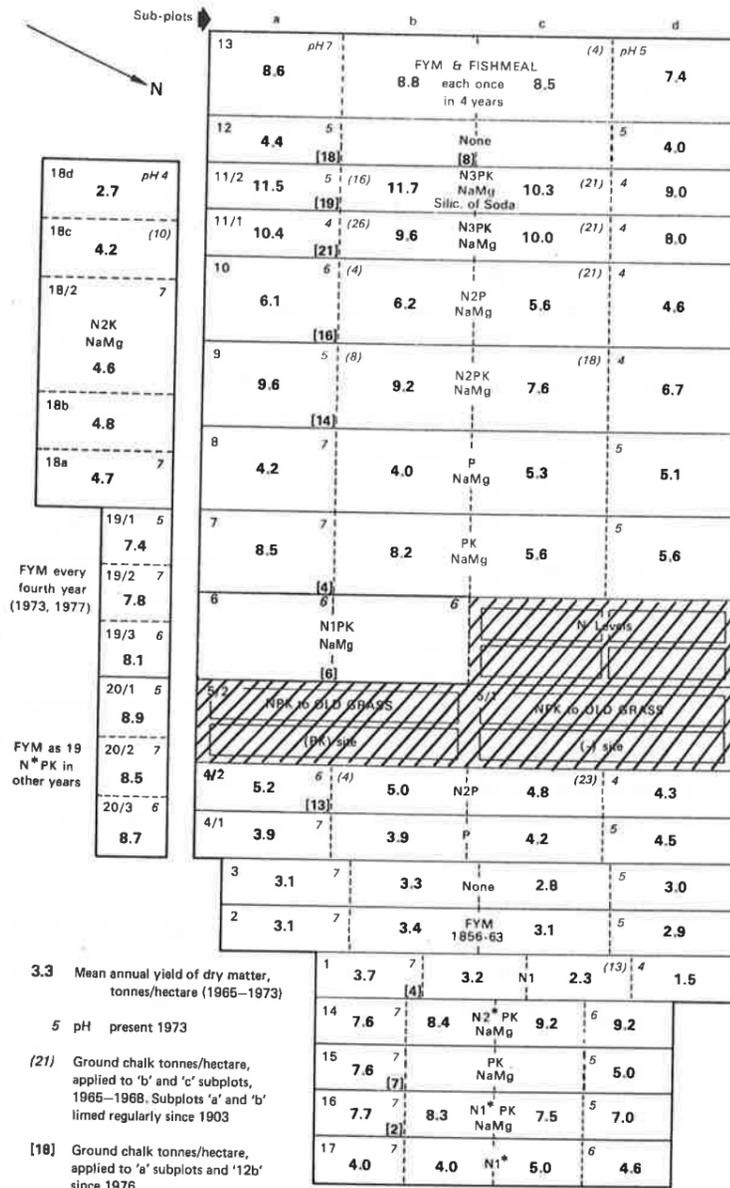
- SLIDES
- 6 only on the plots where earthworms are abundant. Swallows tend to fly mostly over the plots where Umbelliferae are flowering e.g. 7 and 11 limed, because the inflorescences attract flies.
- 33 A large fairy ring caused by the fungus Marasmius oreades persisted and slowly enlarged for many years.

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- See also yields and occasional botanical or chemical notes in Rothamsted Experimental Station Annual Report, and Yields of the Field Experiments, both published annually.
- Note: The Latin names of species in this paper are those used in Clapham, Tutin and Warburg (1962) Flora of the British Isles (2nd edition) Cambridge University Press and are not always the same as those used in the papers and publications listed above.

**PARK GRASS**  
Hay each year since 1856



Plan 1. Diagram of the Park Grass plots. The plots are numbered in the left hand corner. Numbers in bold type = mean annual yield of dry matter tonnes per hectare (1965-73). Numbers in italic type = pH in 1973. Numbers in curved brackets = ground chalk tonnes per hectare applied to 'b' and 'c' subplots 1965-68, sub-plots 'a' and 'b' limed regularly since 1903, square brackets applied to 'a' and '12 b' sub-plots since 1976. The shaded area is used for micro-plot experiments.

Inorganic treatments

Nitrogen (applied annually in spring)

N<sub>1</sub>, N<sub>2</sub>, N<sub>3</sub>, ammonium sulphate supplying 48, 96, 144 kg N ha<sup>-1</sup> (43, 86, 129 lb N acre<sup>-1</sup>).

N<sub>1</sub>\*, N<sub>2</sub>\* sodium nitrate supplying 48, 96 kg N ha<sup>-1</sup> (43, 86 lb N acre<sup>-1</sup>). 96 kg N ha<sup>-1</sup> is equivalent to 462 kg ammonium sulphate ha<sup>-1</sup>. (412 lb acre<sup>-1</sup>) or 617 kg sodium nitrate ha<sup>-1</sup> (550 lb acre<sup>-1</sup>).

Minerals (applied annually in winter)

P 407 kg superphosphate supplying 34 kg P ha<sup>-1</sup> (30 lb P acre<sup>-1</sup>)

K 560 kg potassium sulphate supplying 224 kg K ha<sup>-1</sup> (200 lb K acre<sup>-1</sup>)

Na 112 kg sodium sulphate supplying 16 kg Na ha<sup>-1</sup> (14 lb Na acre<sup>-1</sup>)

Mg 112 kg magnesium sulphate supplying 11 kg Mg ha<sup>-1</sup> (10 lb Mg acre<sup>-1</sup>)

Sodium silicate 448 kg of water-soluble powder ha<sup>-1</sup> (400 lb acre<sup>-1</sup>)

Organic treatments (applied every 4th year)

Dung 35 tonnes farmyard manure ha<sup>-1</sup> (14 tons acre<sup>-1</sup>) (bullocks)

Fish meal to supply 96 kg N ha<sup>-1</sup> (86 lb N acre<sup>-1</sup>) (about 750 kg meal ha<sup>-1</sup> or 6 cwt acre<sup>-1</sup>)

APPENDIX

Genetic Change Within Species

by

Dr. R. W. Snaydon

(Department of Agricultural Botany, University of Reading)

Lawes and Gilbert started the Park Grass Experiment in 1856, just two years before Darwin and Wallace first published their theory of evolution by natural selection. It is therefore apt that the experiment now provides us with such a unique opportunity to test Darwin's theory. Have the various fertiliser and liming treatments caused any genetic changes within plant species over the last 120 years? Are the changes adaptive? How quickly do the changes occur? How sharp are the differences at the boundaries of plots? We have tried to answer some of these questions by studying one grass species, *Anthoxanthum odoratum* (sweet vernal grass), in detail.

*Anthoxanthum odoratum* occurs on almost every plot of the experiment and dominates some plots (e.g. plots 4/2U\*, 9U). We have collected plants of *A. odoratum* from a number of contrasting plots and grown them, as spaced plants, for several years at Reading. The plants have been measured to see whether they differ in height, yield, disease susceptibility, flowering date, leaf size, etc. They have also been tested to see whether they differ in response to mineral nutrients. These studies show (see references) that plants collected from the various fertiliser and liming treatments differ in a number of ways. There were also considerable differences between plants collected from a single plot. The differences between plots must have evolved in the last 120 years.

Plants collected from plots with tall vegetation (e.g. 9L\* and 4/2L) were generally taller (Fig. 1a) than those from plots with short vegetation (e.g. 3U and 1U). Similarly plants from heavily yielding plots (e.g. 9L and 9U) yielded more dry matter (Fig. 1b) than those from low yielding plots

\*For explanation see page 20.

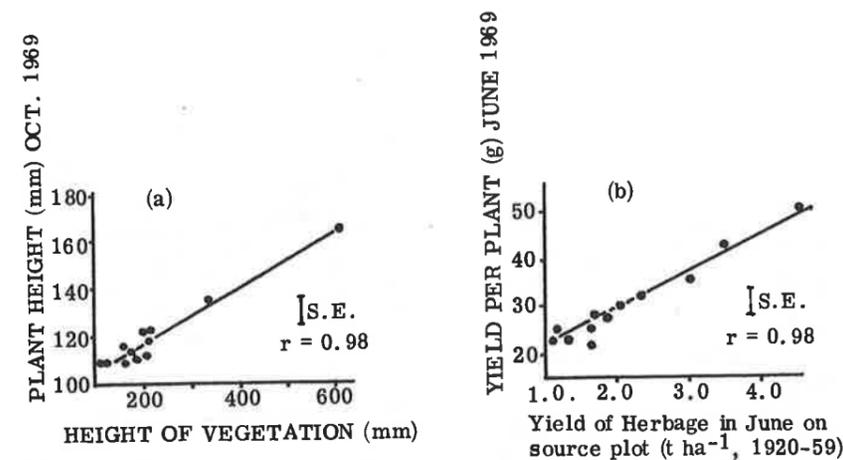


Fig. 1. Relationships between morphological characters of twelve populations of *Anthoxanthum odoratum*, collected from the Park Grass Experiment and grown in a spaced trial, and environmental conditions on their source plots. (a) Plant height in October, (b) Dry weight yield per plant in June.

(e.g. 3L and 3U). There were also differences in flowering date, mildew susceptibility, seasonal pattern of growth, leaf size and other characters. Most of the differences could be associated with conditions on the plots where the plants were originally collected. Less detailed studies have shown equivalent differences in other species, e.g. *Lolium perenne* (perennial ryegrass), *Dactylis glomerata* (cocksfoot) and *Holcus lanatus* (Yorkshire fog).

Plants of *A. odoratum* also differed in response to soil nutrients and toxins. Plants from acid unlimed soils, which are deficient in calcium, needed less calcium than those from limed plots (Fig. 2a). They were also more resistant to the high levels of aluminium (Fig. 2b), which are usually present in acid soils. Plants from the various plots also differed in response to phosphorus, and potassium, but not to nitrate or magnesium.

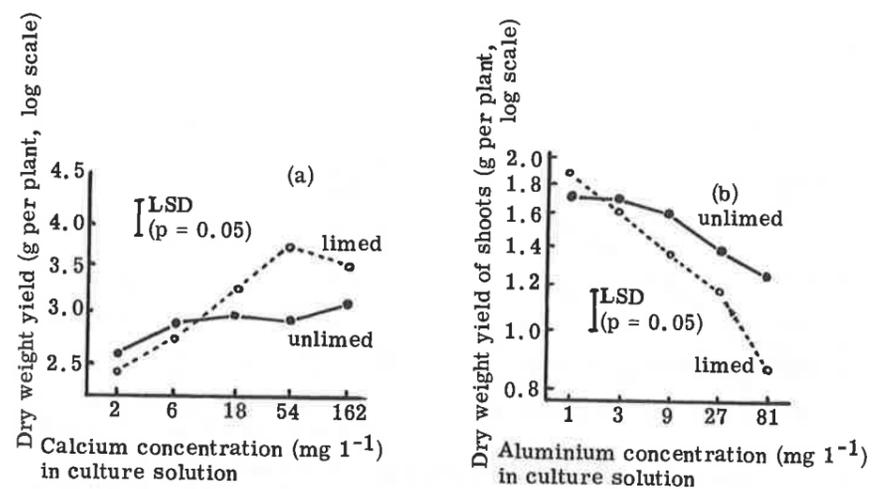


Fig. 2. The effect of calcium concentration (a), and aluminium concentration (b), on the dry weight yield of *Anthoxanthum odoratum* plants, collected from limed and unlimed plots of the Park Grass Experiment, when grown in sand culture at Reading.

It seems that the various fertiliser and liming treatments have changed the size and shape of plants and their response to soil conditions, usually making them better suited to the conditions of their native plot. The most likely explanation of these changes, as Darwin suggested, is that there has been natural selection of the plants best suited to each plot. We have tried to test this by collecting plants from six contrasting plots, growing them at Reading for several years, and then transplanting them back into both their native plots and contrasting plots. Plants transplanted back into their 'native' plots survived about twice as long as those transplanted into contrasting 'alien' plots (Fig. 3). The surviving plants also produced 50%

more dry matter in their native plots. This confirms that plants are better suited to the conditions of their native plots. It also suggests that natural selection eliminates the less well suited plants and favours the best suited plants on each plot.

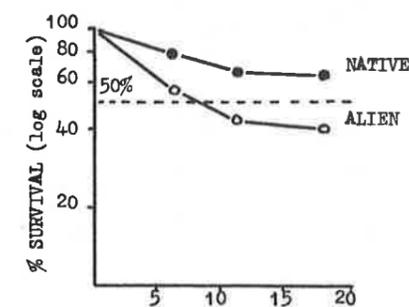


FIG 3. MONTHS AFTER PLANTING

The new liming treatments that were started in 1965 give us an opportunity to see how quickly genetic differences can develop. We collected plants from newly limed plots and adjacent unlimed plots in 1972. When the plants were grown at Reading, there were significant differences in height, yield and other characters. The differences were greatest on the plots where liming had most effect on the vegetation. Obviously changes can occur in less than 10 years.

The boundaries between plots of the Park Grass experiment are very sharp (slides 3 and 20). Are the genetic differences within plant species equally sharp? Intense natural selection would tend to cause sharp differences but cross-pollination and seed scattering would tend to blur the differences. We have collected plants and seeds at intervals across the boundary between plots 8L and 9L, where soil conditions and the vegetation change sharply (Fig. 4a and b). When grown at Reading, plants collected only short distances apart at the boundary differed in height, yield

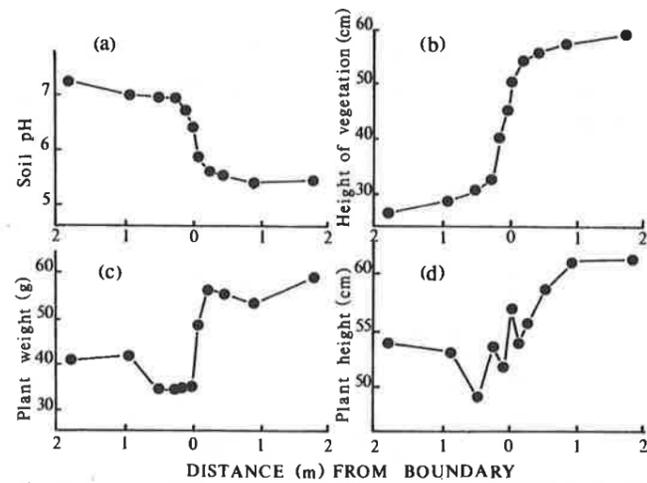


Fig. 4. The sharp differences in soil pH (a), and the height of vegetation (b), that occur at the boundary between two plots (8L and 9L) of the Park Grass Experiment. Plants of sweet vernal grass, collected at intervals across this boundary, differed in yield (c), and height (d), when grown for two years at Reading.

(Fig. 4c and d) and other characters. The differences between plants were almost as sharp as the differences in environmental conditions. By comparing plants with other plants grown from their seed, it seems that cross-pollination is only important within about 2m of the boundary (Fig. 5).

Changes in genetic structure of plant species can apparently occur very rapidly. If there is only limited variation within a species, the species will be restricted to a few environments. If there is wide variation within the species then it will occur in many environments, but different types of plants (ecotypes) will occur in each environment. These considerations have important implications in the breeding and management of pasture plants and also in nature conservation.

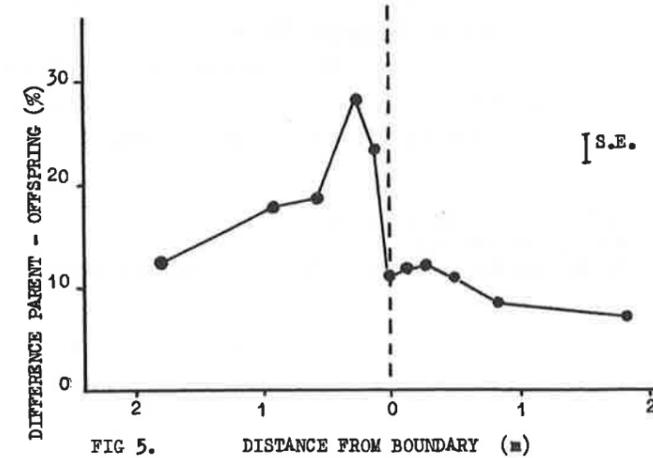


FIG 5. DISTANCE FROM BOUNDARY (m)

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\* L (limed) now divided into sub-plots a and b  
U (unlimed) now divided into sub-plots c and d  
(new liming treatments had not been applied at the date of sampling)

Latin and common names of species mentioned in this text as in Clapham, Tutin and Warburg, Flora of the British Isles, 2nd edition, and not necessarily the names used for these plants in the references cited.

Agrostis tenuis	common bent-grass
Alopecurus pratensis	meadow foxtail
Anthoxanthum odoratum	sweet vernal grass
Arrhenatherum elatius	false oat-grass
Briza media	quaking-grass
Cerastium holosteoides	common mouse-ear chickweed
Chamaenerion angustifolium	rosebay willow-herb
Dactylis glomerata	cocksfoot
Dactylorhiza fuchsii	common spotted orchid
Festuca rubra	red fescue
Fritillaria meleagris	fritillary
Holcus lanatus	Yorkshire fog
Lathyrus pratensis	meadow vetchling
Listera ovata	twayblade
Lolium perenne	perennial ryegrass
Lotus corniculatus	birdsfoot trefoil
Ophioglossum vulgatum	adder's tongue
Potentilla reptans	creeping cinquefoil
Primula veris	cowslip
Rumex acetosa	sorrel
Taraxacum officinale	dandelion
Trifolium pratense	red clover
Trifolium repens	white clover

29. Bugle (*Ajuga reptans*). 24.4.57  
Occurs mainly on plots with short vegetation, especially the unmanured. (See Slides 4 and 7 for habitat in different months).
30. Fritillary (*Fritillaria meleagris*). 10.5.55  
Flowers every year on the corner-plot, 17 Unlimed (sodium nitrate only) and may have been planted. It is rarely seen elsewhere. The number of flowers on the plot varies from one year to another. Our records show them from 1922, but an apocryphal story ascribes their planting on this field near the Manor (see Slide 25) to Lady Lawes, wife of the founder of Rothamsted.
31. Dactylorhiza fuchsii. June 1964.  
First recorded June 1963, on two plots with fairly short vegetation. Also flowered in 1964 and 1965, but not seen in the next 4 years.
32. Listera ovata. June 1964.  
Occurs on one of the Unmanured plots. First recorded June 1964.
33. Fairy ring. 29.3.57  
Caused by toadstool fungus (*Marasmius oreades*). This ring on Plot 19 has since disappeared.
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2. Aerial photograph (looking S.W.) 27.6.64  
Same way round as plan (Slide 1).  
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Cutting (by forage harvester) has just begun, see marks on plots 18, 19, 20 on left.
3. Plots 12 left and 11 - 1 right. 21.8.64  
Left - unmanured.  
Right, (back) - PKNaMg and ammonium sulphate, unlimed.  
Right, (front) - PKNaMg and ammonium sulphate, limed.  
Regrowth after first cut. Note sharp, straight boundaries between plots, due to accurate application of fertilisers

3. and to their differential effect on species. Nutrients do not move laterally, contrast arable experiments e.g. Hoos barley where cultivations have caused lateral movements of 3 m or more.
4. Plot 12 (unmanured). 21.8.64  
Close-up of left side of Slide 3.  
All species present on Park Grass are found on unmanured plots, but plants of each are small and few. No dominant species. This is believed to represent the original vegetation of the whole area before the experiment began. About 60 species. Other plots have different proportions of fewer species. Hay yield very light as vegetation is so short. (See Slide 7 for same plot in different month).
5. Plot 11 - 2 Unlimed. 21.8.64  
Complete fertilisers, much N as ammonium sulphate, unlimed. A pure stand of Yorkshire fog (Holcus lanatus) selected out of the mixture of 60 species solely by fertilisers and lack of lime. Close-up of plot at back right of Slide 3. See also Slides 10 and 12. One of the heaviest hay yields, but unpalatable.
6. Plot 11 - 2 Limed. 21.8.64  
Complete fertilisers and lime. Much N as ammonium sulphate. Right front of Slide 3; only difference from Slide 5 is addition of lime. One of the heaviest hay yields. More diverse flora than 11 - 2 Unlimed and includes good agricultural grasses. Cocksfoot (Dactylis glomerata), meadow foxtail (Alopecurus pratensis) and some weeds especially Umbelliferae. Flies settle on these and swallows are often seen in summer flying mainly over plots with flowering Umbelliferae.

7. Plot 12 (Unmanured) with Cowslip etc. 10.5.65  
Demonstrates diverse flora including low-growing plants, some rare locally e.g. cowslip (Primula veris) which are stamped out by competition from taller species on more fertile plots. (See Slide 4 for different month on same plot and Slides 29, 30, 31, 32, 34 for other interesting species).
8. Plot 11 - 2 Limed. 10.6.65  
PKNaMg and lime, with much nitrogen as ammonium sulphate. Before hay cut. See Slide 6 for re-growth after first cut, and comments on flora.
9. Plot 14 Unlimed. 2.6.66  
PKNaMg with nitrogen as sodium nitrate.  
Similar in vegetation and yield to Plot 11 - 2 Limed (Slides 6 to 8) but sufficiently alkaline without lime to support agriculturally valuable grasses e.g. cocksfoot (Dactylis glomerata) and also Umbelliferae.
10. Seedlings of Yorkshire fog (Holcus lanatus) on Plot 11 Unlimed. 24.4.65  
Complete fertilisers; high nitrogen as ammonium sulphate. No lime. Most Holcus plants die in winter and are replaced by seedlings. A change from hay-making to forage-harvesting would drastically affect the vegetation on this plot. See also Slides 5, 12, and 25.
11. Plot 4 - 2 Unlimed. 5.8.61  
Nitrogen (as ammonium sulphate) and phosphate only.  
Water lying on top of dry peat-layer after summer rain.  
Peat layers develop on other Unlimed plots too, e.g. 11 - 2 (see also Slides 12 and 16).

12. Plot 11 - 2 Unlimed. 6.6.59  
Complete fertilisers. Much nitrogen as ammonium sulphate. Yellow patches, which are exceptional, are due to local loosening of peat mat from mineral soil below. Seedlings (Slide 10) root in peat while it is moist, but if it is loosened by harrowing, roots do not penetrate to the underlying clay, and when the peat dries out, the young plants suffer. See Slide 16).
13. Plot 10 Unlimed. 19.11.56  
Nitrogen as ammonium sulphate. PNaMg (no potassium). Sweet vernal grass (Anthoxanthum odoratum) yellowed by frost. (K deficiency may be contributory factor).
14. Plots 9 and 10 Unlimed. 2.6.66  
Both receive PNaMg and N as ammonium sulphate. With K on left and without on right. Sweet vernal grass (Anthoxanthum odoratum) dominant on both plots, but taller with potassium on Plot 9. (Contrast right side with Slide 15).
15. Plot 10 Limed. 11.6.65  
Contrast Slide 14 right. More varied vegetation, including Sorrel (Rumex acetosa) which tolerates K-deficiency when lime is given.
16. Plot 4 - 2 Unlimed. 23.4.65  
Nitrogen as ammonium sulphate, phosphate (no K, Na or Mg). Peat lifted. Chain harrowed 11 February; rolled 12 February; N applied 10 March. (See Slides 11, 12 and 18).

17. Plot 4 - 2 Limed. 24.4.65  
Contrast Slide 16. Lime prevents formation of peat layer and also encourages growth of grass.
18. Plot 4 - 2 d. (Unlimed). 9.6.67  
Nitrogen (as ammonium sulphate) and phosphate only. Note growth 7 weeks later than Slide 16. Mainly sweet vernal grass (Anthoxanthum odoratum) which tolerates potassium deficiency (Slide 14) and acidity.
19. Plots 11 - 1 c. and 11 - 1 d. 18.4.69  
Complete fertilisers, much N as ammonium sulphate. Unlimed at back, new liming (started 1965) in front. Vegetation is more varied and growth starts earlier in the year on limed than on unlimed area. Unlimed all dead Yorkshire fog (Holcus Lanatus). Limed has tussocks of meadow foxtail (Alopecurus pratense), cocksfoot (Dactylis glomerata), rough-stalked meadow-grass (Poa trivialis), cow-parsley (Anthriscus sylvestris), dandelion (Taraxacum officinale) and sorrel (Rumex acetosa).
20. Plots 1 Unlimed and 14 Unlimed. 10.6.65  
Plot 1 (foreground), ammonium sulphate only.  
Plot 14 (background) PKNaMg, N as sodium nitrate.  
Note striking contrast in general appearance and also sharp boundary between the two plots. (See also Slide 9 for Plot 14 with details of vegetation). Plot 1 is acid and receives unbalanced fertilisers. Common bent (Agrostis tenuis) predominates.

21. Plot 1 Unlimed. (plot 14 Unlimed left foreground and Plot 1 Limed left background). 3.9.55  
Ammonium sulphate only.  
Bronze colour of grass exceptionally noticeable.  
July and August rainfall 26.9 mm compared to long-term mean 131 mm. Yield 0.23 t ha<sup>-1</sup> "hay" on 28 June and 0.23 t ha<sup>-1</sup> on 16 Sept. Contrast slide 20 taken earlier in a more normal season.
22. Plot 1 Unlimed. 20.2.59  
Ammonium sulphate only.  
Molehills in paths but none on this half-plot - soil on plot too acid for earthworms, which attract moles.
23. Plot 18 Unlimed. 15.6.56  
Acid and P-deficient.  
The whitish colour of grass is exceptional. (April and May rainfall 45.2 mm compared with long-term average 104.4 mm).  
First crop, cut 12 July, gave only 0.1 t ha<sup>-1</sup> hay, an exceptionally poor yield. Sorrel (*Rumex acetosa*) survives even under these severe conditions.
24. Plot 18 - 2 with Dandelions (*Taraxacum officinale*). 13.5.63  
Ammonium sulphate, KNaMg, (no phosphate) limed.  
No dandelions on Plot 18 Unlimed on left or on Plot 10 (no K) behind i.e. dandelions only flourish with sufficient K and above about pH 5.6.

25. Aerial photograph (from South). 12.5.55  
i.e. 6 weeks earlier than Slide 2 and from opposite end of the field; showing dead areas (Unlimed halves of ammonium sulphate. Plots 11 - 2, 11 - 1, 10, 9, 4 - 2, 1 etc.). Dandelions showing faintly on limed halves of Plots 18, 19, 20 and 7 (all with potassium). Note dark green of limed halves of 11 - 2, 11 - 1, 10 (much N). Plots 9 Limed and 4 - 2 Limed are not particularly dark green. (Rothamsted Manor House in background).
26. Plot 7 Limed. 15.6.56  
PKNaMg (but no nitrogen). Limed.  
Red clover (*Trifolium pratense*) encouraged by phosphate and potassium, provides its own nitrogen from nodule-bacteria.  
Grasses not much in evidence. Buttercups (*Ranunculus acris*) prevalent, also large leaves of hogweed (*Heracleum sphondylium*). Patchy distribution of perennials.  
Yorkshire fog (*Holcus lanatus*) in far background is on Plots 10 and 11 Unlimed.
27. Plot 7 Limed. 11.6.65  
As Slide 26 but closer up to show details.  
Note leaves (but not flowers yet) of meadow vetchling (*Lathyrus pratensis*, Leguminosae) in addition to red clover (*Trifolium pratense*).
28. Plot 2 Limed. 15.6.56  
Lime, no fertilisers.  
Red clover (*Trifolium pratense*) present in quantity, but not so lush as on Plot 7 Limed (Slides 26 and 27) where phosphate and potassium are given.

29. Bugle (*Ajuga reptans*). 24.4.57  
Occurs mainly on plots with short vegetation, especially the unmanured. (See Slides 4 and 7 for habitat in different months).
30. Fritillary (*Fritillaria meleagris*). 10.5.55  
Flowers every year on the corner-plot, 17 Unlimed (sodium nitrate only) and may have been planted. It is rarely seen elsewhere. The number of flowers on the plot varies from one year to another. Our records show them from 1922, but an apocryphal story ascribes their planting on this field near the Manor (see Slide 25) to Lady Lawes, wife of the founder of Rothamsted.
31. Dactylorhiza fuchsii. June 1964.  
First recorded June 1963, on two plots with fairly short vegetation. Also flowered in 1964 and 1965, but not seen in the next 4 years.
32. Listera ovata. June 1964.  
Occurs on one of the Unmanured plots. First recorded June 1964.
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