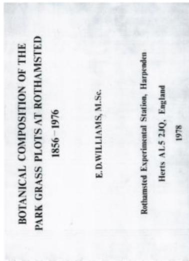
ROTHAMSTED RESEARCH

Botanical Composition of the Park Grass Plots at Rothamsted 1856-1976


BOTANICAL COMPOSITION OF THE
PARK GRASS PLOTS AT ROTHAMSTED
1856 - 1976

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Full Table of Content

Association Between Botanical Composition and Yield

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layers may bring about fairly large changes in the botanical composition. For example, the changes in botanical composition on Plot 18*c* were associated with only 0.2 pH unit increase in the uppermost 7.5 cm of soil in 1971, although the pH of the 'mat' of partially decomposed organic matter was raised from 3.9 to 6.3 (Johnston, 1972). The effects of recent lime on the botanical composition of the swards has, in general, been more consistent than on yield since it has been less subject to seasonal variations. Also, although in 1973 recent lime on 11^1 increased yield of sub-plot *c* compared to *d* by only about 20%, but by as much as 70% on 11^2, changes in botanical composition were similar. The reduction in the acid-tolerant grasses and replacement by other species was accompanied by large increases in yield, especially at the first cut on sub-plot *c*. However, changes in the proportion of grasses already present e.g. on sub-plot 11^2b had little effect on yield, although pH was raised from 4.7 to c.6.0 in the uppermost 22.5 cm.

Although the unlimed sub-plots of plots 4^2, 9 and 10 were very similar, consisting of c.70% *Anthoxanthum*, and although this was decreased to 5-10% by lime, the species was replaced by different amounts of different species on the different sub-plots. On 4^2c *Anthoxanthum* was replaced mainly by *Festuca rubra* on 9*c* by *Holcus* and on 10*c* by both. It is clear therefore that a prediction of the effects of lime entails not only knowledge of the existing flora and extent of pH change but also previous fertiliser application or nutrient status of the soil as well as the proximity of other species. The presence of *Festuca rubra* on K-deficient soil in the pH range 4.7-5.5 on the Park Grass plots confirms this association on other soils and under other management conditions (*e.g.* Castle & Holmes, 1960; Murphy, 1960; Heddle, 1967; Smith, Elston & Bunting, 1975; Arnold, Hunter & Gonzalez-Fernandez, 1976). The relatively small effect of lime under the new scheme on % *Agrostis* on plots receiving N_2 is similar to the effects at the start of light lime on Plot 19, where there was also no reduction during the first 8 years although there were large reductions later. It is, however, not clear why lime should increase the amount of *Holcus* on sub-plots 9*c* and 10*c* whilst decreasing it on 11^1c and 11^2c.

It is now abundantly clear that, although some species are plentiful in very acid conditions whilst others are absent, great caution needs to be exercised in categorising species simply into those that are discouraged or encouraged by liming. The distribution of species is influenced by the relative preferences and tolerances of other species and also the influence of lime depends on the pH range and extent of change and on what other nutrients are applied. For example, although *Holcus* dominates the unlimed acid sub-plots of 11^1 and 11^2 this may not be because it prefers acid conditions *per se* but because it is better able to survive and is not subjected to competition from other species in such conditions. There have been some instances, as already noted, where the amount of *Holcus* has been increased by lime on Park Grass. Similarly, *Rumex,* which may appear to prefer acid conditions, also grows well on limed soils but is subject to increased competition there (Brenchley, 1935).

ASSOCIATION BETWEEN BOTANICAL COMPOSITION AND YIELD

Although the experiment was set up as an agricultural investigation and the treatments induced large changes in yield these were soon associated with conspicuous changes in botanical composition. However, the fact that complete fertilisers (N_3PK) increased yield three-fold even in the first year suggests that this was achieved by the response of species already present at the outset,

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since it is unlikely that large changes would have occurred in the botanical composition during the first year. As the unmanured plot became increasingly impoverished, *Lolium* and *Holcus* decreased to very minor components and *Agrostis* and *Festuca* became the main grasses; other species have been abundant. It is possible that through growing slowly the species may make small demands on the environment and/or that they may be very efficient in the use of mineral nutrients. The presence of large numbers of low-growing dicotyledonous species may also be a form of adaptation to the fertiliser and management regime – only a small part of this vegetation would be removed during harvest, perhaps enabling nutrients to be conserved and recycled within the community.

The larger yield on the plot given PKNaMg than on the unmanured plot has for most of the time been associated with more *Dactylis* and legumes and the still larger yield on the limed half of this plot, with even more vigorous growth of *Lathyrus* and also *Arrhenatherum* and *Alopecurus*. However, when yields of hay in individual years between 1900-1950 are plotted against % legumes in those years on both unlimed and limed half plots there appears to be no correlation between yield and legume content. Brenchley (1935), however, using data from four selected years postulated a correlation between the two parameters but it is clear that although high yields in particular years may be associated with much legume, there are many other years where large yields are associated with little legume and small yields with much legume. When potassium was omitted from this treatment, yield declined to about 50% of that with K, legumes became less frequent and latterly *Leontodon* and *Plantago* more frequent. On the plot given the smallest amount of ammonium sulphate without P and K, and where *Agrostis* has been dominant since c. 1940, yield has been smaller than on the unmanured plots. However, it cannot be deduced from this that *Agrostis* is a low-yielding species *per se* since its presence on this plot may merely reflect that it is better able to survive under these conditions than its competitors. The species was in fact, especially in the early years of the experiment, also associated with plots of higher fertility and is also frequent now on plots receiving N_2. The plot given N_2PKNaMg yielded about 4.0 t ha^{-1} of hay during the first 30 years but yield then declined progressively to about 2.8 t ha^{-1} during the 1950's. This decline was associated, at least during the first quarter of the century, with larger amounts of and subsequent dominance by *Holcus* for another thirty years before *Anthoxanthum* became dominant. The variations in yield on the limed half from the 1920's to the 1940's were not associated with any changes in botanical composition.

Omitting K from this treatment (i.e. N_2PNaMg) resulted in a sharp decline in yield which was associated with a decrease in *Poa trivialis* and *Dactylis* and increases in *Alopecurus, Arrhenatherum* and *Festuca* which continued until about 1920. Afterwards yield continued to decline while *Holcus* was dominant during the next 15 years or so and then while *Anthoxanthum* and *Agrostis* were the main constituents. Yield on the limed half-plot declined only very slowly and this was associated during the mid-40's to mid-50's with an increase in *Festuca* and a decrease in *Alopecurus*. On the N_3PKNaMg plots (11^1 and 11^2) Cashen's statistical analysis (1947) suggested that there was no significant falling off in yield during the first fifty years. Whilst this is probably true for the plot receiving N_3PKNaMgSi it is less likely to be so for Plot 11^1 (N_3PKNaMg). Examination of ten-year means for yields of this plot showed a gradual but consistent decrease from the outset: statistical analyses of the first fifty

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years were probably distorted by the abnormally high yields during the fifth decade. After the rapid increase and subsequent dominance of *Holcus* appreciable decreases in yield occurred. Although the larger yields on the limed halves were associated with *Alopecurus* and *Arrhenatherum*, changes in yield with time could not be correlated with changing botanical composition.

On plot 17, receiving sodium nitrate, yield has declined continuously although botanical composition has been relatively stable. However, on Plot 14, receiving the larger amount of sodium nitrate and PKNaMg, moderately stable yields have been associated with relatively stable botanical composition.

Although evidently it is possible to associate differences in yield on the Park Grass plots with differences in botanical composition and to outline changes in yield with time in relation to concurrent botanical changes it is clear that the relationship between yield and botanical composition is very complex and it is very difficult to establish causal relationships between the two. The complexity of the situation is due to the large number of species present, insufficient botanical data for some periods (e.g. 1877 to 1903), difficulties of estimating hay yield accurately on low-yielding plots and of satisfactorily eliminating the effects of variable and changing weather conditions. In addition, until 1960 estimates of yield were also affected by weather during hay-making. Another reason for the difficulty in correlating yield and botanical composition is that both are affected by a third factor, the fertiliser treatment and hence nutrient status of the soil. Yield is the indirect consequence of the effects of the fertiliser treatments on the responses and interactions or competition of the species present and depends on the fact that whereas some species may have very specific requirements and do not seemingly respond to increased fertility others may be less specific in their requirements and be able to respond to increased fertility.

Despite these difficulties it is nevertheless possible to characterise the extreme situations. In general, low-yielding plots, e.g. the unmanured and the PNaMg plots, have large numbers of low-growing dicotyledonous species together with unproductive grasses, or where conditions are acid and P and/or K are deficient, only acid-tolerant grasses are present, whereas the higher-yielding plots are now dominated by *Alopecurus* and *Arrhenatherum*. However, plots with roughly similar botanical composition may yield differently whilst others with similar total yields have very different botanical compositions.

RELATIONSHIP BETWEEN FERTILISER TREATMENT AND BOTANICAL COMPOSITION

The experiment is best known for the way in which the different fertiliser regimes have changed the presence and balance of species on the different plots. The subject has been comprehensively presented in many previous publications (Lawes, Gilbert & Masters, 1882; Brenchley, 1924; Brenchley & Warington, 1958) and need not be repeated here.

However, it must be emphasised that conclusions about the preferences of individual species and their response to various factors should take account of other factors involved and also of changes that have occurred with time. The distribution of species is not governed solely by the response to the presence or absence of one particular nutrient although data from Park Grass can be used to pinpoint some of the major determinants within a given situation. Additionally, the frequency of a given species may be determined as much by the response through competition of

12 R