# Rothamsted Report for 1967

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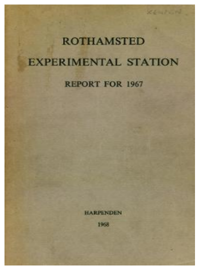


## Experiments With Ley and Arable Farming Systems

**D. A. Boyd**

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# EXPERIMENTS WITH LEY AND ARABLE FARMING SYSTEMS

D. A. BOYD*

Assessing the value of leys in an arable system raises economic and management problems most of which are beyond the scope of field experiment, but one important aspect of ley farming—the degree to which leys can increase the yield of subsequent arable crops—can be evaluated only by experimental methods. Two long-term experiments, one begun at Woburn as long ago as 1937 and the other begun in 1949 at Rothamsted, were designed to answer this question; although ley farming is no longer as controversial an issue as at their inception, the experiments are contributing much to our understanding of the value of organic and inorganic residues in the soil, and to soil fertility problems in general.

The two experiments (and also the Ley Fertility experiments, started in the early 1950s on six of the National Agricultural Advisory Service's Experimental Husbandry Farms—see Harvey (1963)) are of a basically similar design, comparing the effect on the yield of arable test crops of three years of ley or three years of arable cropping. The Woburn experiment differs from the later ones in having only two test crops—the others have three.

Results of the Woburn experiment up to 1956 were discussed by Mann and Boyd (1958), and this report describes its subsequent history up to 1967. Results of the Rothamsted experiment were given in the Annual Reports for 1961 and 1964; yields from a changed cropping scheme are described later in this report.

## The Woburn Ley–Arable Rotation Experiment 1956–67

In the Woburn Ley–Arable experiment there are two ley and two arable sequences whose effects are measured by test crops of sugar beet and barley (Table 1). There is one block for each year of the five-year cycle, and each block contains eight main plots, two per rotation. Half the plots (the "Continuous" series) follow the same rotation throughout the life of the experiment; the other half (the "Alternating" series) have ley and arable sequences alternately. The comparison between the continuous and alternating series takes the place of the two-fold replication found in the Rothamsted and N.A.A.S. experiments.

The main plots are split to test FYM at 15 ton/acre, applied to the same plots of the first test crop for the duration of the experiment.

Until 1956 the first test crop and the first treatment crop of the arable sequences were potatoes, and this frequent cropping with potatoes had

* The following were responsible for the experiments and for the preparation of this report, under the chairmanship of the author: G. W. Cooke, G. V. Dyke, D. S. Hooper, A. E. Johnston, J. R. Moffatt, Diana M. Parrott, G. A. Salt, D. B. Slope and C. A. Thorold. R. G. Warren, now retired, also contributed greatly to the experiments.



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already increased the population of potato cyst-nematodes when the first partial crop failure occurred in the arable treatment crop of potatoes in 1955. The first test crop was then changed to sugar beet, and the former third treatment crop of the arable (roots) sequence from sugar beet to carrots. From 1958 onwards there were serious infestations of lucerne

**TABLE 1**

*Cropping scheme over five years, Woburn, 1956–67*

| Year: | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| | Treatment crops | | | Test crops | |
| Rotation | | | | | |
| Grazed ley | 3 year grazed ley | | | Sugar beet | Barley |
| Lucerne Sainfoin | 3 year lucerne* cut for hay | | | Sugar beet | Barley |
| Arable (Hay) | Potatoes | Rye | Seeds hay | Sugar beet | Barley |
| Arable (Roots) | Potatoes | Rye | Carrots | Sugar beet | Barley |

* Replaced by sainfoin from 1964.

stem eelworm (*Ditylenchus dipsaci*) in second- and third-year lucerne; the initial introduction was probably on the seed. Attempts at control by partial soil sterilisation proved ineffective, and from 1964 onwards common sainfoin (*Onobrychus sativa*) was grown instead.

## Results of test cropping

***First test crop—sugar beet.*** In their analysis of the results up to 1955, when potatoes were the first test crop, Mann and Boyd presented evidence that potassium, and possibly other elements, such as magnesium, were being depleted; they also considered that the arable plots were seriously short of nitrogen.

To find out whether shortage of N and K was adversely affecting yields in some rotations, the sub-plots testing O *v.* FYM were split into four sub-sub-plots to test two amounts of N and of K; dressings of 0·72 cwt N/acre and 0·90 cwt $K_2O$/acre were compared with double these amounts. Average results for the years 1956–61 are given in full in the Appendix (Table A) and are summarised in Table 2.

**TABLE 2**

*Mean yields of sugar beet and responses to FYM and to extra N and K fertiliser, Woburn, 1956–61*

(total sugar, cwt/acre)

| | Grazed ley | Lucerne | Arable (Hay) | Arable (Roots) | Mean |
|---|---|---|---|---|---|
| Mean yield | 56·6 | 52·3 | 48·6 | 52·5 | 52·5 |
| Response to: | | | | | |
| FYM | 6·8 | 9·4 | 12·5 | 14·6 | 10·8 |
| Extra N | −2·8 | −3·0 | −2·4 | 0·1 | −2·0 |
| Extra K | 2·7 | 2·3 | 2·2 | −0·4 | 1·7 |

Rates of N: 0·72 and 1·44 cwt N/acre
Rates of K: 0·90 and 1·80 cwt $K_2O$/acre
Rate of FYM: 15 ton/acre

Although the change of test crop gave freedom from the effects of cyst-forming nematodes, the large effects of rotation and large responses to FYM observed in the potato yields for 1950–55 were as much or more in



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evidence with sugar beet. On the "continuous arable" sequence, FYM increased yields of total sugar by 18 cwt/acre, more than 40%, whereas on the "continuous ley" sequence the increase was only 6 cwt/acre, or 10%; after lucerne results were intermediate between these extremes. The arable (hay) rotation yielded somewhat less than the other arable sequence, and responses to FYM were smaller.

Contrary to expectation, there was little or no increase in sugar yield from the extra N and K applied to the arable (roots) sequence; indeed, extra N or K (but not both) tended to decrease yields. Extra nitrogen consistently decreased the yields after lucerne and grazed ley and lucerne and arable (hay), whereas K somewhat increased them. From the quite small effects of K, it could reasonably have been concluded that the large differences in yield between the test crops of the ley and arable rotations, and between the arable plots with and without FYM, were not caused by shortage of K. However, results of soil analysis between 1958 and 1960 showed clearly that there were substantial differences in amounts of available K and that, despite the evidence from the K-test on the sugar-beet test crop, these were large enough to account for much of the observed difference in crop yield of the different rotations and of plots with and without dung. The puzzle was resolved by Warren and Johnston, who made a small experiment with sugar beet on land near by, in which they tested the effects of applying as much K as fertiliser as was applied in the FYM, and the fertiliser was either broadcast or dug-in with and without extra N (Cooke, 1961). Although their site was richer in K than the plots of the arable rotations of the Ley–Arable experiment, they found that K dug-in increased root yields by 2·7 ton/acre, whereas broadcast K gave increases of only 1·1 ton/acre, indicating that yields in the Ley–Arable experiment were bigger with FYM than with fertilisers because the FYM contained large amounts of K that had been ploughed in. In the Warren and Johnston experiment broadcast NK fertilisers checked germination and retarded growth of the seedlings, and there were probably similar effects in the Ley–Arable experiment.

It was decided to equalise the K status of the different rotations, and of plots with and without FYM, by giving large corrective dressings of K to each block as it came into the sugar-beet test crop. These dressings ranged from nil, on the ley plots receiving FYM, to 6 cwt $K_2O$/acre on the most deficient treatments, the lucerne and arable plots without FYM. Extra K was applied to the plots without FYM, equivalent to the total amount in the FYM; this was a rich pig dung, and from 1962 to 1966 the average amount of K applied each year was 3·6 cwt $K_2O$/acre. The FYM and its K-equivalent, plus one-half of the corrective K, was ploughed in for the sugar-beet crop in the preceding autumn or winter. The other half of the corrective K dressing, plus the basal dressing of 0·90 for all sugar-beet plots was applied on the plough furrow in early February. The tests of extra N and K continued, with the fertilisers applied on the seed-bed but well worked in.

The mean yields of sugar beet for the years 1962–64 are given in detail in Appendix Table B and are summarised in Table 3. Making good the K deficiency decreased the effect of FYM from more than 10 to less than 4



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cwt sugar/acre. For all rotations except lucerne, responses to K were less than in previous years. Responses to N differed between the rotations, the extra 0·72 cwt N/acre decreasing yields after ley but slightly increasing them on the arable plots. Smaller yields from the arable (hay) rotation, in which the seeds ley immediately precedes sugar beet, were thought to be associated with the small amounts of N applied to the leys and to delay in ploughing.

**TABLE 3**

*Mean yields of sugar beet and response to FYM and to extra N and K fertiliser, Woburn, 1962–64*

(total sugar, cwt/acre)

| | Grazed ley | Lucerne | Arable (Hay) | Arable (Roots) | Mean |
|---|---|---|---|---|---|
| Mean yield | 60·6 | 58·8 | 54·2 | 61·0 | 59·2 |
| Response to: | | | | | |
| FYM | 0·9 | 3·7 | 4·3 | 5·7 | 3·9 |
| Extra N | −2·4 | −1·8 | 1·8 | 0·3 | −0·7 |
| Extra K | 0·9 | 2·3 | 0·7 | −1·1 | 0·7 |

Rates of N: 0·72 and 1·44 cwt N/acre
Rates of K: 0·90 and 1·80 cwt $K_2O$/acre
Rate of FYM: 15 ton/acre

By further subdividing the plots in 1962 and again in 1963 the opportunity was taken to test the effect of magnesium (nil *v.* 500 lb/acre $MgSO_4.7H_2O$ applied on the plough furrow). There were small responses to Mg, especially with N but without FYM, and so from 1964 onwards a basal dressing equal to the amount tested was applied annually for sugar beet.

Soils derived from the Lower Greensand have the reputation of being unresponsive to P, but there was evidence from other experiments at Woburn that more P might be needed, so in 1964 a test of 1·5 cwt $P_2O_5$/acre, in addition to the basal dressing of 0·9 cwt $P_2O_5$/acre, was made on split plots, in the same manner as Mg was tested in the two previous years. Extra P had little effect except on the arable (roots) rotation, where it increased yields by 4·5 $\pm$ 2·47 cwt/acre. As it was not wished to make further tests of P, the basal dressing was then increased from 0·9 to 2·0 cwt $P_2O_5$/acre, half applied on the plough furrow and half in the seed-bed.

The test of only two amounts of N in the years 1962–64 could not indicate precisely the optimal N dressing after the different rotations, and from 1965 to 1967 four amounts were tested, as on the Rothamsted Ley–Arable experiment. The amounts tested differed according to rotation (Table 4). The 1962–64 results suggested that most N would be needed by sugar beet in the arable (hay) rotation, less by the arable (roots) rotation and least by the two ley rotations. Where sugar beet followed a ley, yields of total sugar increased by 4–5 cwt/acre when N was increased from 0·35 to 0·70 cwt/acre, but there was no response to larger dressings; with FYM there was little or no increase in yield with more than 0·35 cwt N/acre. As expected, sugar beet in the arable rotations needed more N; the optimum was between 1·05 and 1·40 cwt/acre according to whether or not FYM was used.



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Contrary to expectation, the N requirements of sugar beet in the two arable rotations were similar, and the same amounts could well have been applied to both.

With optimal N, the best yields for the period 1965–67 were given by the lucerne/sainfoin rotation, which yielded 5 cwt/acre more than the

**TABLE 4**

*Mean yields of sugar beet, Woburn, 1965–67*

(total sugar, cwt/acre)

| | cwt N/acre | | | | | |
|---|---|---|---|---|---|---|
| | 0·35 | 0·70 | 1·05 | 1·40 | 1·75 | 2·10 |
| Without FYM | | | (±1·37)* | | | |
| Grazed ley | 61·4 | 66·1 | 65·4 | 65·8 | — | — |
| Lucerne/Sainfoin | 66·4 | 70·6 | 70·5 | 71·3 | — | — |
| Arable (Hay) | — | — | 66·9 | 69·6 | 66·2 | 68·0 |
| Arable (Roots) | — | 59·2 | 64·8 | 65·7 | 66·4 | — |
| With FYM | | | | | | |
| Grazed ley | 65·9 | 64·9 | 66·6 | 63·5 | — | — |
| Lucerne/Sainfoin | 72·9 | 74·0 | 74·2 | 72·2 | — | — |
| Arable (Hay) | — | — | 69·3 | 69·1 | 70·0 | 68·9 |
| Arable (Roots) | — | 66·3 | 69·5 | 72·8 | 69·8 | — |

* For use in horizontal comparisons.

grazed-ley rotation without FYM, and 8 cwt/acre more with FYM. The large value of the organic residues to the first crop after lucerne has also been shown at Rothamsted; in addition, at Woburn the free-living nematodes *Longidorus* and *Trichodorus* were particularly numerous in plots that had been 3 years in grazed ley, and this may at least in part explain the comparatively small yields. The two arable rotations gave fairly similar yields, a few cwt/acre less than lucerne/sainfoin.

Summarising the twelve years' results, there have been large increases in mean yield from 52 cwt sugar/acre in the first 6 years to almost 70 cwt/acre in 1965–67. Large effects of FYM obtained in the first 6 years can mainly be ascribed to nutrient deficiencies made good by giving the corrective dressings of K, by dressings of Mg and by increased dressings of P. Although, given enough N for maximum yield, responses to FYM in the period 1965–67 were much less, there was still some effect of FYM not obtainable by fertilisers alone. This was small in the grazed ley and arable (hay) rotations, but considerable after lucerne (3·6 cwt sugar/acre) and after arable (roots) (5·6 cwt sugar/acre).

***Second test crop—barley.*** The sub-plot tests of fertilisers made on the first test crop prevented similar tests on the following barley crop; however, from 1968 onwards the order of test cropping will be changed to allow a test of four amounts of N for barley.

Because of increased fertiliser dressings, better varieties and general improvements in husbandry, barley yields have much increased during the experimental period; the average was less than 20 cwt/acre in the 1940s, about 25 cwt in the early 1950s, more than 30 cwt/acre in the period 1956–61 and about 40 cwt/acre since 1962.

Throughout, the ley rotations have tended to yield a few cwt more than



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the arable rotations. The first-year residues of FYM were most effective in the early 1950s, but decreased when the fertiliser dressings were increased (Table 5).

**TABLE 5**

*Mean yields of barley, Woburn (grain, cwt/acre)*

| | Grazed ley | | Lucerne/ Sainfoin | | Arable (Hay) | | Arable (Roots) | | Mean |
|---|---|---|---|---|---|---|---|---|---|
| | O | D | O | D | O | D | O | D | |
| 1942–56 | 22·5 | 23·4 | 23·0 | 24·4 | 19·4 | 22·4 | 19·8 | 22·1 | 22·1 |
| 1957–61 | 32·1 | 31·8 | 30·7 | 31·9 | 29·2 | 31·5 | 29·7 | 32·6 | 31·2 |
| 1962–67 | 41·7 | 41·0 | 42·4 | 42·9 | 39·2 | 41·6 | 38·5 | 40·1 | 40·9 |

Standard errors:

| | (i) | (ii) |
|---|---|---|
| 1942–56 | 0·53 | 0·47 |
| 1957–61 | 0·98 | 0·50 |
| 1962–67 | 0·59 | 0·50 |

(i) = For use in comparisons involving different rotations
(ii) = For use in comparisons within the same rotation

O = No FYM
D = 15 ton/acre FYM to 1st test crop

## Yields of the treatment crops

***Arable treatment crops—potatoes.*** Following the crop failure in 1955, samples taken in 1956 showed that most of the blocks contained one or more plots in which the infestation with potato cyst-nematode was great enough to decrease yield. At the request of the Nematology Department, potatoes were retained as a treatment crop, but at the same time the amount of fertilisers applied to potatoes was about doubled. With these larger amounts of fertiliser, yields of more than 10 ton/acre were obtained (Table 6) even on the "continuous arable" treatments, those most subject to potato cyst-nematode. However, taking potato crops every 5 years was still frequent enough to allow potato cyst-nematode populations to

**TABLE 6**

*Mean yields of arable treatment crops, Woburn (1st and 2nd year)*

| | Previous cropping: | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Grazed ley | | Lucerne/ Sainfoin | | Arable (Hay) | | Arable (Roots) | |
| | O | D | O | D | O | D | O | D |
| Potatoes | | | | | | | | |
| 1943–56 | 11·2 | 12·6 | 9·8 | 12·1 | 9·4 | 11·3 | 9·4 | 10·9 |
| 1957–61 | 14·2 | 15·9 | 13·1 | 14·1 | 11·5 | 12·3 | 11·1 | 12·3 |
| 1962–67 | 12·5 | 14·6 | 10·4 | 12·6 | 6·5 | 7·6 | 6·0 | 7·5 |
| Rye | | | | | | | | |
| 1949–56 | 32·7 | 33·3 | 33·0 | 33·3 | 30·3 | 32·3 | 29·6 | 31·4 |
| 1957–61 | 32·9 | 33·4 | 34·1 | 32·4 | 29·5 | 32·0 | 30·7 | 31·0 |
| 1962–66 | 36·4 | 35·6 | 36·6 | 35·4 | 32·0 | 33·2 | 35·2 | 34·8 |

Potatoes: total tubers, ton/acre
Rye: grain, cwt/acre. Crop failed 1967

O: No FYM
D: 15 ton/acre FYM to 1st test crop



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increase, especially in blocks III–V, resulting in poor yields on plots of the "continuous arable" series in 1963–65. Despite the introduction of the resistant variety Maris Piper and comparatively few potato cyst-nematodes on blocks II and I, yields from the arable plots in 1966 and 1967 were still small. There is a possibility that free-living nematodes may also be causing damage to the potato roots. In 1967 the fungus *Verticillium* was found in July infecting 38% of stems of the continuous arable (roots) series but only 6% of the alternating series, whereas *Rhizoctonia* was equally widespread in both series. To what extent interaction between fungi and free-living nematodes has contributed to these poor yields is not known, and a special investigation is planned for 1968. (See also the report of the Nematology Department (p. 152) and Plant Pathology Department (p. 132).)

***Rye.*** Except for failure in 1967 because of poor seed-bed conditions, the second arable treatment crop, winter rye, yielded consistently well, with the average yield in any 5-year period exceeding 30 cwt/acre. The alternating series yielded slightly more than the continuous; there was little effect from FYM applied 3 years previously (Table 6).

***Carrots.*** The two arable sequences differ only in respect of their third treatment test crop; on the change of test crop in 1956, sugar beet was replaced as the third treatment crop in the arable (roots) rotation by carrots. Partly because of failure to control motley dwarf in some years and the loss of a first sowing in 1960, mean yields (Table 7) were small in most

**TABLE 7**

*Mean yields of arable treatment crops, Woburn (3rd year)*

Seeds Hay (dry matter, cwt/acre)

| | Ley | | Arable | |
|---|---|---|---|---|
| | O | D | O | D |
| 1945–56 | 58·7 | 66·2 | 52·8 | 58·4 |
| 1957–61 | 59·7 | 67·2 | 51·3 | 58·0 |
| 1962–67 | 77·7 | 80·9 | 75·4 | 77·8 |

Carrots (roots, ton/acre)

| | Ley | | Arable | |
|---|---|---|---|---|
| | O | D | O | D |
| 1956–61* | 8·3 | 10·2 | 7·0 | 8·6 |
| 1962–67 | 22·8 | 24·0 | 20·7 | 22·2 |

* Mean of 5 years; crop failed 1957.

O = No FYM
D = 15 ton/acre FYM to 1st test crop

years up to 1962, when the manuring was changed to include P and more K. After changing the variety to Autumn King in 1964, mean yields exceeding 30 ton/acre were obtained in 1965 and 1967. As for rye, differences between the alternating and continuous series and residual effects of FYM were usually small.

***Seeds hay.*** The mixture of S.24 ryegrass, late-flowering red clover and alsike is undersown in the rye. There is usually a good first cut but little aftermath.



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Among the changes introduced in 1956, more N and K were provided for the seeds hay; in 1962 the K dressing was much increased and P fertiliser was also given. Hay yields of the "continuous" plots increased from between 50 and 60 cwt dry matter/acre in the period 1955–56 to 75–80 cwt dry matter/acre in 1962-67, and the difference between the alternating and continuous series and the residual effect of FYM, formerly substantial, is now small (Table 7).

***Ley treatment crops.*** Despite increased fertiliser dressings, yields from the 2nd-year and 3rd-year lucerne crops were much affected by the incidence of stem eelworm (*Ditylenchus dipsaci*) from 1958 onwards (Table 8). The sainfoin, which replaced lucerne, has not been free from troubles, and the plots carrying third-year sainfoin in 1966 had to be resown in August 1965 and again in spring 1966.

**TABLE 8**

*Mean yields of ley treatment crops, Woburn*

| | 1st year | | 2nd year | | 3rd year | |
|---|---|---|---|---|---|---|
| | O | D | O | D | O | D |
| Lucerne/Sainfoin (cwt dry matter/acre) | | | | | | |
| Lucerne 1944–56 | 14 | 17 | 52 | 59 | 60 | 66 |
| Lucerne 1957–64 | 22 | 31‡ | 40 | 52 | 40 | 44* |
| Sainfoin 1965–67 | 26 | 27§ | 50 | 48 | 44 | 46† |

| | Sheep days/acre | | |
|---|---|---|---|
| | 1st year | 2nd year | 3rd year |
| Grazed ley | | | |
| 1944–56 | 1006 | 1871 | 1796 |
| 1957–61 | 1115 | 1862 | 1729 |
| 1962–67 | 1530 | 2160 | 1845 |

* Because of lucerne stem eelworm (*Ditylenchus dipsaci*) the plots were fallowed in 1959 and no yields were taken in 1960.
† In 1965 and 1966 the crop was resown in spring.
‡ 1957–63.
§ 1964–67.

The grass/clover ley is grazed rotationally by one or two teams of sheep; there are usually four to eight sheep per team. The plots are topped after grazing, but the amounts uneaten are usually small. The sheep days per acre averaged 1561 for 1944–61 and 1845 for 1962–67, equivalent to about 21 and 25 cwt starch equivalent per acre (reckoning $1\frac{1}{3}$ lb starch equivalent per sheep day) (Table 8).

## The Rothamsted Ley–Arable Rotation Experiment

Like the Woburn experiment, the Rothamsted Ley–Arable experiment consists of four contrasted rotations whose effects are measured by the yield of arable test crops common to all rotations. The 6-year cycle has three "treatment" crops—ley or arable, followed by three test crops (Table 9). Of the four rotations compared, three have a ley sequence and the other a sequence of arable crops.

The experiment is on two fields—Fosters, an old arable field, and



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Highfield, formerly in permanent grass. On both fields there are plots of permanent grass sown down when the experiment began in 1949–51 and, on Highfield, plots of the original permanent grass sward. The two fields are almost a mile apart, but on a similar soil (Batcombe Series).

**TABLE 9**

*Cropping scheme over six years, Rothamsted, 1962–67*

| | Treatment Crops (1st, 2nd and 3rd years) | Test Crops 4th year | Test Crops 5th year | Test Crops 6th year |
|---|---|---|---|---|
| Rotation Treatments | | | | |
| Lucerne | 3-year lucerne cut for hay | Wheat | Potatoes | Barley |
| Grass/Clover Ley | 3-year grass/clover ley without N | Wheat | Potatoes | Barley |
| Grass Ley | 3-year pure grass ley with N | Wheat | Potatoes | Barley |
| Arable | Ryegrass ley for hay, sugar beet, oats | Wheat | Potatoes | Barley |
| Other treatments | | | | |
| .................... | Permanent Grass (Original Sward)* | ......... | ......... | ......... |
| .................... | Permanent Grass (Reseeded 1949–51) | ......... | ......... | ......... |

* On Highfield only.

Initially, in addition to the lucerne there were two grass/clover leys, one grazed by sheep and receiving little N, and the other given more N was cut repeatedly at the silage stage. In 1962 the grazed ley was replaced by a different grass/clover sward (S.51 Timothy, S.215 Meadow Fescue, S.100 White Clover) grown with ample PK fertiliser but without N, and grazing was discontinued.

The other ley was changed to an all-grass ley receiving moderately large dressings of N—0·6 cwt N/acre for each cut. Pure S.37 Cocksfoot was sown in 1962 and 1963; because of severe virus infection and winter-killing of cocksfoot ley, Timothy-Meadow Fescue (without clover) was sown from 1964 onwards. Both leys are now cut by forage harvester at the early silage stage.

This report describes the results obtained with the test crops following these leys. As only one such barley crop has yet been taken, results of tests of the old-style treatment crops are also given for barley.

**Yields of the test crops**

***First test crop—wheat* (*1965–67*).** Four amounts of spring N were tested on wheat (see Table 10) in steps of 0·3 cwt N/acre on Highfield (0·4 cwt N/acre for the arable rotation) and of 0·4 cwt N/acre on Fosters (0·53 cwt N/acre for the arable rotation). There was also a test of autumn nitrogen—0·6 cwt N/acre on both fields.

In the previous three years, 1961–64, the mean yield of Cappelle wheat with comparable amounts of N was slightly more on Highfield than on Fosters, but in the period 1965–67 maximum yields were about 5 cwt/acre more on Fosters. The nitrogen requirements of crops grown on Highfield were, at first, much less than those on Fosters because N in the organic matter from the old turf was mineralised. Even now, more than 15 years after the original ploughing, less N is needed to achieve maximum yield, and the response to N is less.



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Previous results showed that, for wheat, the kind of rotation—ley or arable—greatly influenced both the yield without N and the response to N, but that, with optimal N, yields in all rotations were much the same. The present results are similar. With optimal N there were again quite small yield differences between the rotations (Table 10). As before, N responses differed between the rotations, and were much greater for the arable rotation, whereas on average differences between the ley rotations were only small. On Fosters, in spring 1965, wheat in the all-grass ley rotation (the ley was resown with Italian ryegrass in spring 1964) was attacked by stem-boring larvae and yields were decreased by 5–6 cwt at each rate of N; but for this, the means of this treatment in Table 10 would have been some 2 cwt greater.

**TABLE 10**

*Wheat, Rothamsted: effect of N and rotations, 1965–67*

(mean yield of grain, cwt/acre)

| Cwt N/acre Autumn | Cwt N/acre Spring | Lucerne | Grass/ Clover Ley | Grass Ley | Cwt N/acre Autumn | Cwt N/acre Spring | Arable |
|---|---|---|---|---|---|---|---|
| Highfield | | | | | | | |
| — | — | 45·3 | 46·7 | 46·3 | — | — | 34·4 |
| — | 0·30 | 49·5 | 50·8 | 51·5 | — | 0·40 | 51·2 |
| — | 0·60 | 52·1 | 52·1 | 49·5 | — | 0·80 | 53·4 |
| — | 0·90 | 46·7 | 48·7 | 49·2 | — | 1·20 | 51·6 |
| 0·60 | — | 53·3 | 54·8 | 46·2 | 0·60 | — | 46·6 |
| 0·60 | 0·30 | 43·2 | 55·9 | 48·0 | 0·60 | 0·40 | 52·2 |
| 0·60 | 0·60 | 46·3 | 44·5 | 49·1 | 0·60 | 0·80 | 49·0 |
| 0·60 | 0·90 | 36·1 | 44·9 | 44·2 | 0·60 | 1·20 | 47·7 |
| Mean | | 46·6 | 49·8 | 48·0 | | | 48·3 |
| Autumn | Spring | | | | Autumn | Spring | |
| Fosters | | | | | | | |
| — | — | 53·5 | 46·3 | 48·0 | — | — | 32·7 |
| — | 0·40 | 59·6 | 56·1 | 54·0 | — | 0·53 | 51·8 |
| — | 0·80 | 59·3 | 55·7 | 55·4 | — | 1·06 | 57·8 |
| — | 1·20 | 56·4 | 54·5 | 51·7 | — | 1·60 | 56·6 |
| 0·60 | — | 57·2 | 56·4 | 53·4 | 0·60 | — | 46·5 |
| 0·60 | 0·40 | 59·4 | 57·8 | 57·3 | 0·60 | 0·53 | 57·0 |
| 0·60 | 0·80 | 55·5 | 55·1 | 54·6 | 0·60 | 1·06 | 57·5 |
| 0·60 | 1·20 | 53·2 | 51·8 | 52·2 | 0·60 | 1·60 | 55·3 |
| Mean | | 56·8 | 54·2 | 53·3 | | | 51·9 |

In the period 1961–64 yields were rather small, in part attributable to damage by stem-boring larvae, and responses to N by wheat after the grass/clover leys were especially large. A test of nitrogen applied in autumn was introduced because it was thought the decaying residues from the grass leys might be fixing nitrogen and that the lucerne might be enriching the subsoil with nitrogen. Autumn N much increased the yield of plots not receiving N, especially in the arable rotation, where the increase was about 12 cwt/acre on Highfield and 14 cwt/acre on Fosters; however, the increase was less than would be expected from the same amount of N applied in spring.

On Fosters, assuming that leys provide 0·50 cwt N/acre and that the efficiency of autumn N is 50% of that of spring N, the mean yields with and



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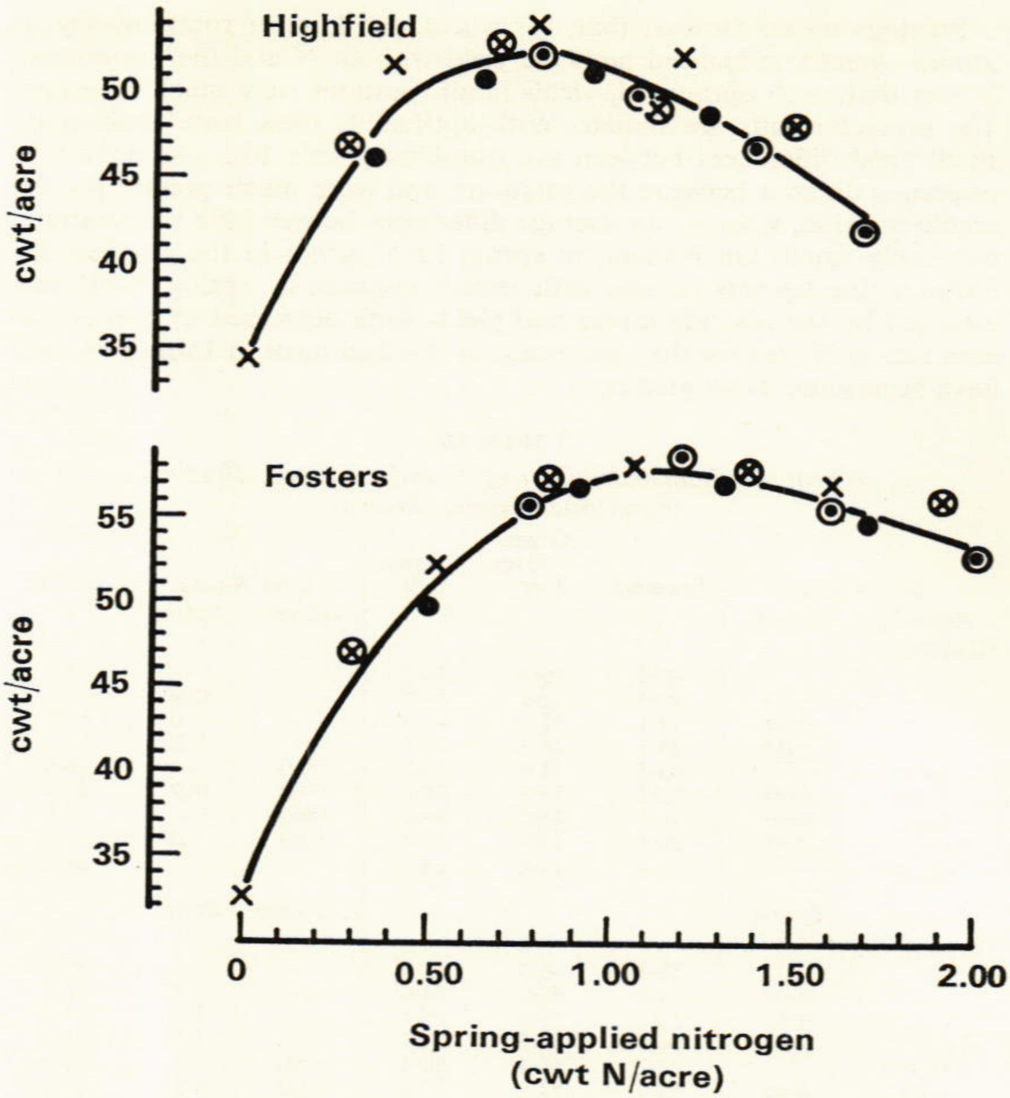


Fig. 1. Mean yields of wheat, Rothamsted 1965–67

Key to rotations: × Arable, no autumn N
⊗ Arable, with autumn N
● Ley, no autumn N
◉ Ley, with autumn N

without autumn nitrogen of the three ley rotations and of the arable rotation fall on or near a single response curve relating yield and spring N (Fig. 1). With each amount of N, lucerne yielded slightly more than the other rotations; allowing for the smaller crop from the all-grass ley rotation, the remaining variation in yield is no more than would be expected from experimental error.

On Highfield the relationship between yield and nitrogen from leys and from autumn- and spring-applied fertiliser was less simple than on Fosters,



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with unexplained differences between the yields and nitrogen responses of the different rotations; there were also large block differences and unusually large plot errors arising in part from lodging and bird damage. For Highfield, as for Fosters, the assumption that for wheat in the arable rotation autumn N was about half as efficient as spring N accounts for much of the differences between the yields with different amounts of autumn and spring N. Without N, all three leys yielded poorly on Highfield; to equate the response curve for leys without autumn N to that of the arable rotation, they must have provided less N than on Fosters, about 0·35 cwt N/acre. With autumn N, by contrast, spring N was not needed for maximum yield after leys; comparison of the mean yields after the three leys with the yields in the arable rotation, suggests that, in terms of spring-applied N, the combined effect of leys and of winter N was equal to 0·8 cwt or more spring N/acre, i.e. at least as much as on Fosters. Compared with the other leys, lucerne was relatively less effective than on Fosters, mainly because of particularly poor yields in 1965.

***Second test crop—potatoes (1966–67).*** Potatoes yielded more than 20 tons on both fields in both years. There were only small differences in yield between the four rotations, and between FYM and equivalent fertiliser (Table 11).

**TABLE 11**

*Potatoes, Rothamsted: effect of rotation and of FYM* v. *equivalent fertilisers, 1966–67*

(mean yield of total tubers, ton/acre)

| | Lucerne | Grass/ Clover Ley | Grass Ley | Arable | Mean |
|---|---|---|---|---|---|
| Highfield | | | | | |
| FYM | 22·8 | 23·4 | 23·6 | 22·0 | 22·9 |
| Fertilisers | 22·9 | 23·2 | 23·1 | 22·2 | 22·8 |
| Fosters | | | | | |
| FYM | 21·1 | 20·7 | 20·9 | 20·3 | 20·8 |
| Fertilisers | 21·7 | 21·7 | 21·1 | 20·7 | 21·3 |

***Third test crop—barley.*** Since 1962 there has been a test of four amounts of N for barley, as for wheat, but the response is limited by the residual value of the N applied as fertiliser and FYM to the preceding potato crop. Table 12 gives mean yields for 1962–66, from the old-style treatment crops. The results differ little from those discussed in the Rothamsted Report for 1965. The two fields had almost the same mean yield (48 cwt/acre). Without N, Fosters, the old arable field, yielded about 2 cwt/acre less than Highfield, and about 0·5 cwt N/acre was needed to attain maximum yield, compared with about half that quantity on Highfield. With optimal N, differences in barley yield from the different rotations were small.

Only a single year's results have so far been obtained from the new-style treatment crops; these are summarised in Table 13. On Highfield, but not on Fosters, barley yields seem to have been affected by the contrast of FYM and equivalent fertilisers for potatoes; this residual effect was



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confounded with the cubic term for N to barley, and accounts for the irregular increase in the mean yields with increasing N. It might be expected to appear more strongly on Highfield because smaller amounts were tested there than on Fosters; moreover, in 1967, barley on Highfield needed much more N than in the past. Even with similar amounts of N, yields on Highfield were less than on Fosters; with optimal N, in all the rotations on Fosters yields exceeded 50 cwt/acre.

**TABLE 12**

*Barley, Rothamsted: effect of N and rotation 1962–66*

(mean yield of grain, cwt/acre)

| | cwt N/acre | Lucerne | Grazed Ley | Conserved Ley | Arable | Mean |
|---|---|---|---|---|---|---|
| Highfield | — | 46·7 | 48·6 | 44·8 | 44·2 | 46·0 |
| | 0·1 | 48·2 | 49·8 | 47·8 | 47·0 | 48·2 |
| | 0·2 | 48·6 | 48·9 | 48·6 | 48·4 | 48·6 |
| | 0·3 | 47·8 | 48·4 | 50·0 | 46·8 | 48·3 |
| | Mean | 47·8 | 48·9 | 47·8 | 46·6 | 47·8 |
| Fosters | — | 45·9 | 46·6 | 44·8 | 42·2 | 47·0 |
| | 0·2 | 49·0 | 49·4 | 47·2 | — | (47·8) |
| | 0·4 | 49·0 | 48·6 | 48·2 | 47·9 | 48·7 |
| | 0·6 | 48·8 | 48·2 | 47·7 | 49·2 | 48·0 |
| | 0·8 | — | — | — | 48·3 | — |
| | Mean | 48·2 | 48·2 | 47·0 | (46·2) | 47·9 |

**TABLE 13**

*Barley, Rothamsted: effect of N and rotation 1967*

(mean yield of grain, cwt/acre)

| | Cwt N/acre | Lucerne | Grass/ Clover Ley | Grass Ley | Reseeded Grass | Arable | Mean |
|---|---|---|---|---|---|---|---|
| Highfield | — | 36·4 | 41·5 | 39·2 | 51·6 | 33·4 | 40·4 |
| | 0·1 | 43·5 | 43·9 | 37·3 | 54·8 | 40·0 | 43·9 |
| | 0·2 | 42·8 | 42·5 | 44·6 | 45·8 | 42·9 | 43·8 |
| | 0·3 | 47·4 | 45·6 | 47·0 | 47·8 | 46·6 | 46·8 |
| | Mean | 42·5 | 43·4 | 42·0 | 50·0 | 40·7 | 43·7 |
| Fosters | — | 47·9 | 49·0 | 45·8 | 53·8 | 41·4 | 47·6 |
| | 0·2 | 51·5 | 52·0 | 52·9 | 55·6 | — | (51·6) |
| | 0·4 | 54·6 | 52·3 | 53·3 | 54·1 | 49·8 | 52·8 |
| | 0·6 | 53·1 | 50·0 | 51·6 | 52·3 | 56·5 | 52·9 |
| | 0·8 | — | — | — | — | 54·1 | — |
| | Mean | 51·8 | 50·8 | 50·9 | 54·0 | (48·4) | 51·2 |

Plots ploughed out from reseeded permanent grass in 1965 and put through the test cropping sequence were cropped with barley in 1967. The yields (Table 13) make an interesting contrast with those following the 3-year leys. On Fosters they yielded slightly more and on Highfield very much more than the leys; on both fields little or no N was needed for maximum yield.

**Yields of the treatment crops.** At Rothamsted the arable treatment crops do not, as at Woburn, give comparisons of the effects of ley and arable rotations. Average yields of the treatment crops for the years 1964–66 are given in Table 14.



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**TABLE 14**

*Mean yields of treatment crops, Rothamsted 1964–66*

| | Highfield | Fosters |
|---|---|---|
| Leys, reseeded and permanent grass (cwt dry matter/acre/year) | | |
| *With nitrogen* | | |
| All-grass ley | 75 | 69 |
| Reseeded grass | 91 | 91 |
| Permanent grass | 91 | — |
| *Without nitrogen* | | |
| Clover/grass ley | 53 | 52 |
| Reseeded grass | 46 | 58 |
| Permanent grass | 45 | — |
| Lucerne | 62 | 61 |
| Arable treatment crops | | |
| One-year ley (cwt dry matter/acre) | 83 | 80 |
| Sugar beet (cwt total sugar/acre) | 71 | 64 |
| Oats (cwt grain/acre) | 37 | 48 |

With 0·6 cwt N/acre for each cut, the largest yields of herbage dry matter were given by the reseeded and permanent grass, about 90 cwt/acre; this was more than from the grass ley, partly because of the smaller production in the seeding year (the leys are not undersown), but also because the leys yielded less in their 3rd year. Without N, yields of the leys and reseeded and permanent grass were between 45 and 60 cwt dry matter/acre. Lucerne yielded more than the clover/grass ley but less than the all-grass ley. The arable treatment crops yielded well, the average yield of total sugar being about the same as at Woburn.

Differences between the crops on Highfield and Fosters were fairly small; one of the largest differences, for oats in 1965, was because on Highfield bird damage led to failure of the first sowing, but there was again a large and unexplained difference in oat yields in 1967. By contrast, sugar beet yielded 10% more on Highfield. The dense grass sward of the reseeded and permanent grass plots on Highfield has prevented clover from coming in; its absence probably accounts for the smaller yields without N on these plots compared with reseeded grass without N on Fosters, where the sward has always been more open and now has some clover.

## Discussion

The ley–arable rotation experiments were designed to find out whether the yield of arable crops was improved when they form part of a ley rotation instead of a purely arable one. Results of both the Rothamsted and Woburn experiments show that gains from a ley rotation are usually small or non-existent. Indeed, so much P and K is taken off cut leys that unless the loss is made good by additional dressings, soil reserves are so depleted that yields of succeeding arable crops are diminished.

Provided that the arable rotation is designed to avoid the build-up of soil-borne pests and diseases, and that adequate nutrients are applied to make good the amounts removed by cropping, the value of a ley to the subsequent arable crops can be assessed at little more than the cost of the



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extra fertiliser N required to achieve optimal yields without a ley. At Rothamsted this was about 0·5 cwt N/acre for the first crop, wheat (less on Highfield where no autumn N was applied) and about 0·2 cwt N/acre for the third crop, barley; the total might amount to no more than 1 cwt N/acre. At Woburn 1st-year effects were a little greater, 2nd- and 3rd-year effects were not measured.

The failure of leys greatly to increase the yield of the following crops implies that they must be judged on the amount and quality of their fodder production compared with that obtained from permanent grass, and on their value as alternative crops to control soil-borne pests and diseases.

Under small-plot grazing conditions, in the years up to 1962, estimated production of used starch-equivalent (SE) from both leys and permanent grass at Rothamsted was poor—about 15 cwt SE/acre/year—but little fertiliser N was used, and the contribution from clover was slight. However, since 1962 dry matter produced by the grass leys with N was still no greater than that from similarly treated permanent grass.

At Woburn the grazed leys have been more productive than the former grazed leys at Rothamsted, and since 1962 the used SE has reached 25 cwt SE/acre/annum. However, this has been achieved only by having a reserve of grassland elsewhere in the farm to fall back on in dry weather. At current prices the value of the sheep grazing is much less than the return from the arable crops, with yields of 20 tons sugar beet and carrots, 40 cwt barley, 33 cwt rye.

Although the results do not necessarily apply to all soils and farms, there is good reason to consider they apply widely. How far this is so should be known in the course of 1968, when detailed results of the six experiments on N.A.A.S. Experimental Husbandry Farms should be reported.

**Future of the experiments.** From 1968 the test cropping of both experiments will be changed. At Rothamsted potatoes will be the first test crop in place of wheat, and at Woburn barley will become the first test crop in place of sugar beet. The Rothamsted experiment will be discontinued in 1971, although one or more blocks will be kept for long-term soil studies. The future of the Woburn experiment has yet to be decided.

**Conclusion.** Including leys in an arable rotation does not greatly increase yields of the arable crops, provided that the arable cropping is designed to minimise losses from soil-borne pests and diseases and that enough fertiliser is given to make good the nutrients taken off and allowance is made for the additional N provided by the leys.

## References

Boyd, D. A. *et al* (1962) *Rep. Rothamsted exp. Stn* for 1961, 173–180.
Boyd, D. A. (1966) *Rep. Rothamsted exp. Stn* for 1965, 216–221.
Cooke, G. W. (1961) *Rep. Rothamsted exp. Stn* for 1960, 48.
Harvey, P. N. (1963) *Progress Report N.A.A.S. Experimental Husbandry Farms and Experimental Horticulture Stations*, London: H.M.S.O., pp. 1–5.
Mann, H. H. & Boyd, D. A. (1958) *J. agric. Sci.* **50**, 297–306.



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## APPENDIX

### TABLE A

*Mean yields of total sugar, Woburn 1956–61*
(cwt sugar/acre)

| | Previous cropping | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Grazed ley | | Lucerne | | Arable (Hay) | | Arable (Roots) | |
| Treatment | Cont. | Alt. | Cont. | Alt. | Cont. | Alt. | Cont. | Alt. |
| | | | | (±1·70)* | | | | |
| — | 58·5 | 49·4 | 45·9 | 50·4 | 42·7 | 44·1 | 42·9 | 49·0 |
| D | 62·3 | 56·3 | 56·9 | 57·1 | 52·4 | 57·0 | 60·3 | 62·6 |
| N | 53·1 | 46·1 | 42·3 | 47·9 | 38·8 | 38·7 | 41·7 | 46·3 |
| DN | 62·6 | 54·3 | 53·5 | 55·0 | 53·5 | 51·7 | 62·1 | 56·6 |
| K | 61·7 | 52·4 | 47·2 | 51·8 | 42·2 | 46·4 | 40·9 | 46·2 |
| DK | 64·5 | 59·1 | 60·6 | 60·4 | 56·9 | 55·4 | 61·4 | 56·3 |
| NK | 57·2 | 47·7 | 45·5 | 49·7 | 42·0 | 42·7 | 45·3 | 49·5 |
| DNK | 65·1 | 56·2 | 56·2 | 56·0 | 53·6 | 57·0 | 60·3 | 58·6 |

* For use in comparisons within the same rotation and the same level of D

D = 15 tons FYM
Rates of N: 0·72 and 1·44 cwt N/acre
Rates of K: 0·90 and 1·80 cwt $K_2O$/acre

### TABLE B

*Mean yields of total sugar, Woburn 1962–64*
(cwt sugar/acre)

| | Previous cropping | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Grazed ley | | Lucerne | | Arable (Hay) | | Arable (Roots) | |
| Treatment | Cont. | Alt. | Cont. | Alt. | Cont. | Alt. | Cont. | Alt. |
| | | | | | (±2·21)* | | | |
| — | 63·4 | 59·0 | 54·4 | 57·2 | 47·4 | 52·8 | 54·2 | 61·0 |
| D | 62·5 | 59·9 | 63·1 | 60·7 | 56·6 | 55·4 | 63·2 | 65·6 |
| N | 60·9 | 55·7 | 54·2 | 53·7 | 50·7 | 56·1 | 58·2 | 60·3 |
| DN | 62·7 | 57·0 | 59·6 | 59·0 | 56·5 | 56·2 | 67·8 | 61·5 |
| K | 68·5 | 55·8 | 57·8 | 59·8 | 48·4 | 52·7 | 55·3 | 62·9 |
| DK | 61·8 | 63·7 | 63·9 | 61·4 | 58·5 | 57·6 | 60·7 | 63·9 |
| NK | 60·7 | 56·8 | 57·5 | 61·8 | 52·2 | 56·9 | 55·9 | 57·1 |
| DNK | 60·8 | 60·1 | 60·7 | 57·7 | 55·7 | 55·0 | 64·1 | 63·5 |

* For use in comparisons within the same rotation and the same level of D

D = 15 tons FYM
Rates of N: 0·72 and 1·44 cwt N/acre
Rates of K: 0·90 and 1·80 cwt $K_2O$/acre



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