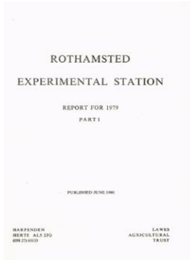
ROTHAMSTED RESEARCH

# Report for 1979 - Part 1

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## Report on Multidisciplinary Activities

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# MULTIDISCIPLINARY ACTIVITIES

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Investigations requiring contributions from several disciplines have increased substantially in number and in effort devoted to them in recent years. Multidisciplinary teams have been formed, drawing on Chemical Liaison Unit, Farm staff, Field Experiments Section, Botany, Entomology, Nematology, Plant Pathology, Physics, Soil Microbiology, Soils and Plant Nutrition and Statistics Departments for their membership, to investigate factors affecting yields of grass, winter wheat and beans. Their efforts are concentrated on multifactorial experiments in which the effects of each of the several main components of a production system can be compared separately and in combination with others, with the objectives of defining and understanding those factors and their interactions that are involved in limiting yield. In particular, we wish to identify and measure the effects of factors that are most critical for yield and that are in the grower's control, so that he can optimise his system by providing the best combination of these factors.

This new Chapter in the Annual Report will bring together, we hope with benefit to the reader, results that hitherto would have been dispersed in the various Departmental reports making a coherent picture difficult to paint. It is not intended to cover all multidisciplinary activities in any one year but to report each at suitable intervals. The reports on winter wheat investigations that are presented concern the first-year results on the Rothamsted and Woburn comparative multifactorial experiments, now at the commencement of their second year, to which attention was drawn earlier (*Rothamsted Report for 1978*, Part 1, 14).

## Factors limiting yields of winter wheat

A multifactorial experiment was sown to winter wheat cv. Hustler in autumn 1978 to study the factors limiting yields of winter wheat, when grown as the first crop after a break (early potatoes). Eight two-level factors were tested (Table 1) in combination of all factors in a half replicated design of 128 plots, with six additional plots to establish a nitrogen response curve, sited on silty clay loam at Rothamsted. The effects of these factors on yield, crop growth, nutrient uptake and incidence of pests and diseases and their interactions were monitored throughout the year. To compare the effect of sites, factors 1–6 of this experiment were tested on sandy lower greensand at Woburn, with basal applications of fungicide and aphicide (reported separately below). Both experiments received a basal application of chlormequat.

### Rothamsted site

***Yield at maturity.*** Grain yields were large by national standards and the best ever obtained at Rothamsted. The mean of all plots was 9·7 t ha$^{-1}$; a third of the plots yielded more than 10 t ha$^{-1}$ and 16 plots yielded more than 11 t ha$^{-1}$. The largest increases were obtained by controlling leaf diseases and aphids in June and July (Table 1). Fungicide and aphicide increased grain size and fungicide also lessened the death of tillers; their combined effects were more than additive and were greater with 250 than with 160 kg N ha$^{-1}$. Consequently the mean yield of plots given fungicide and aphicide was 2·3 t ha$^{-1}$ (27%) greater than that of plots given neither. The only factor to affect the yield of plots treated with fungicide and aphicide was sowing date: the early-sown crop yielded 0·4 t ha$^{-1}$ more than the later-sown one. However, the mean effect of sowing date was less and non-significant. Plots receiving 250 kg N ha$^{-1}$ had smaller grains and yielded 1 t ha$^{-1}$ less than those receiving 160 kg N ha$^{-1}$ in the absence of fungicide and aphicide but yielded



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equally (10·9 t ha$^{-1}$) when both were applied. Early-sown plots receiving three applications of nitrogen had more ears and yielded 0·5 t ha$^{-1}$ more than those receiving a single application. Precision-sown plots also had more ears (10%) than conventionally-sown ones but did not differ significantly in grain yield. Aldicarb slightly increased and irrigation slightly decreased grain yields.

**TABLE 1**

*Factors tested and their effect on grain yield (t ha$^{-1}$). Means of all other factors*

| | Level 1 | Yield | Level 2 | Yield |
|---|---|---|---|---|
| (1) | Stanhay drill—precision<br>Seed spaced 2·54 cm apart in 10 cm rows | 9·68 | Nordsten drill—random<br>Same seed number in 10 cm rows | 9·61 |
| (2) | Sown early<br>21 September | 9·72 | Sown later<br>13 October | 9·57 |
| (3) | Nitrogen rate 1<br>160 kg ha$^{-1}$ | 9.91 | Nitrogen rate 2<br>250 kg ha$^{-1}$ | 9·83 |
| (4) | Nitrogen—single application<br>6 April | 9·50 | Nitrogen—split applications<br>12 March, 6 April, 17 May | 9·79 |
| (5) | Irrigation—125 mm<br>Soil moisture deficit limited to 25 mm | 9·53 | None | 9·76 |
| (6) | Autumn pesticide—aldicarb<br>Applied to seedbed 5 kg ha$^{-1}$ | 9·77 | None | 9·52 |
| (7) | Summer aphicide—pirimicarb<br>0·14 kg ha$^{-1}$ on 26 June and 17 July | 10·30 | None | 8·99 |
| (8) | Fungicide—'Cosmic'<br>4 kg ha$^{-1}$ on 30 May and 26 June | 10·13 | None | 9·16 |

The results of individual sponsors' sampling are reported below. (Banfield, Statistics Department; Dewar, Entomology Department; Lacey, Plumb and Prew, Plant Pathology Department; Thorne, Botany Department; Penny, Soils and Plant Nutrition Department; Williams, Nematology Department)

***Growth and development.*** The experiment was sampled on 20 December, 2 April, 14 May, 25 June/2 July (anthesis of early- and later-sown plots) and 6 August (shortly before all leaves senesced), as well as at maturity on 28 August.

The precision drill produced a crop of more uniform appearance than the conventional drill, with a slightly greater dry weight and number of shoots at most samplings. Sowing was shallower and more uniform with the precision than the conventional drill. Plant establishment (228 plants m$^{-2}$, 61% of seed sown) was unaffected by drill or sowing date, with negligible death of plants between December and April in spite of the severe winter.

The size of the early-sown crop was large in comparison to the later-sown crop during the winter but by anthesis the difference was relatively small (Table 2). The early-sown crop grew faster until mid-May, presumably because it intercepted more light. After mid-May, when light interception would be almost complete in both crops, growth rates were the same (early 16·8, later 16·9 g m$^{-2}$ d$^{-1}$, 14 May–6 August). Ear initiation ('double ridge' stage of apical development) on main shoots occurred on 13 March in the early-sown crop and 4 weeks later in the later-sown. Grain growth began (anthesis) on 26 June and ended (no green tissue remaining) on 20 August in the early-sown crop and the later-sown was only 4 days later. Tillering also differed between sowing dates (Table 2). Observations made between samplings showed that maximum shoot numbers were present in early and late April for the early- and later-sown crops respectively. The later sowing produced more tillers but fewer survived so that final ear number was only 4% greater than with early sowing.

Increasing nitrogen fertilisation from 160 to 250 kg N ha$^{-1}$ increased tillering but



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TABLE 2

*Change with time in total dry weight (g m$^{-2}$), leaf area index and number of shoots m$^{-2}$ of Hustler winter wheat sown on 21 September (E) or 13 October (L). Means of all other treatments*

| | Sowing date | 20 December | 2 April | 14 May | 25 June (E) 2 July (L) | 6 August | 28 August |
|---|---|---|---|---|---|---|---|
| Total dry weight | E | 37 | 65 | 362 | 1097 | 1768 | 1512 |
| | L | 16 | 21 | 259 | 1127 | 1683 | 1533 |
| Leaf area index | E | 0·6 | 0·8 | 6·0 | 10·1 | 2·1 | 0 |
| | L | 0·2 | 0·3 | 4·5 | 9·7 | 3·0 | 0 |
| Number of shoots | E | 1084 | 1283 | 1309 | 623 | 604 | 597 |
| | L | 560 | 831 | 1738 | 625 | 627 | 620 |

decreased survival and ear number was negligibly affected. Splitting the nitrogen application increased ear survival slightly, especially in the early-sown crop. The amount and timing of nitrogen interacted with other factors in their effects on dry weight and leaf area at and after anthesis. Increasing the nitrogen from 160 to 250 kg ha$^{-1}$ on 'healthy' crops increased straw weight and total dry weight at anthesis slightly (6%) and leaf area at anthesis considerably (27%). Splitting the nitrogen application on early-sown crops also had a small beneficial effect on dry weight and leaf area at anthesis.

Fungicide and aphicide affected growth after anthesis; each delayed leaf senescence and so increased green leaf area on 6 August. The effects were larger with irrigation, when each treatment increased the area of green leaf lamina about four-fold.

No irrigation was required until anthesis, when the soil moisture deficit measured by neutron probe was only 25 mm. During July only 10 mm of rain fell and 125 mm irrigation was applied. The maximum deficit reached on the unirrigated plots was 138 mm which would not seriously affect grain yield on this soil. Irrigation was slightly deleterious even with control of pests and diseases. It decreased ear dry weight slightly, increased weight of the stems and leaves by an equal amount and delayed senescence somewhat more than did fungicide or aphicide but without the same beneficial effect. (Thorne and Taylor, Botany Department)

***N and K contents.*** The percentages of N and K were measured in the samples taken for growth analysis and total uptakes calculated from these percentages and the total dry weight of the crop.

The method of drilling had no effect on the percentage or uptake of either nutrient but the time of drilling had very large effects early in the season. In December and April early-sown wheat contained 5·47 and 5·33% N and 3·89 and 3·47% K respectively, slightly more in December but slightly less in April than the later-sown but, because of the large difference in growth, uptakes by the early-sown crop were two or three times as large. R. J. B. Williams measured $NO_3$-N in the stems in December (early sown 560, later sown 270 ppm) and in March (early 740, later 820 ppm). By May % N had fallen to 3·64 in the early- and 4·20 in the later-sown crop; respective values for % K were 3·57 and 4·05. Uptakes were now only about 30% larger by the early-sown crop than by the later-sown crop and ranged from 95 (later-sown smaller rate of N) to 150 kg N ha$^{-1}$ (early-sown larger rate of N). K uptakes for the same crops ranged from 96 to 137 kg K ha$^{-1}$ and so already exceeded the amount given in fertiliser (83 kg ha$^{-1}$). At anthesis % N had decreased to 1·78 and 1·66 in the early- and later-sown crops and % K to 2·13 and 1·19, but uptakes of each at that stage were not significantly altered by sowing date. By 6 August % N (1·12) and % K (1·19) were at a minimum and did not differ with sowing date.



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The first of the divided N dressings (40 kg N $ha^{-1}$ on 12 March) increased % N and % K in April. Uptakes of N (kg $ha^{-1}$) ranged from 11 in the later-sown crop not yet given N to 38 in the early-sown given 40 kg N; corresponding K uptakes were 7 and 25. Without fertiliser N the stems contained only 150 ppm $NO_3$-N but 420 with N. In May, at anthesis and on 6 August the higher rate of N significantly increased % N and % K. At anthesis wheat given 250 or 160 kg N $ha^{-1}$ contained 1·93 and 1·51% N and 2·23 and 1·90% K respectively; amounts of N in the crop (range 158–232 kg N $ha^{-1}$) were about 60% larger than on 14 May and of K (range 197–257) about 100% larger. At harvest % N in the grain was increased by the higher rate of N (from 1·76 to 1·99%) but the timing of the application had no effect. There were positive interactions between N and aphicide and N and fungicide on N and K uptakes by the whole crop on 6 August and also on N uptake by grain at harvest but in neither case were the percentages of N and K affected so that the differences simply reflected the differences in yield. Total uptakes at harvest are not yet known as the straw has not been analysed. (Penny, Soils and Plant Nutrition Department)

***Nematodes.*** Soil was sampled on 18 May and 4 September for plant parasitic nematodes. The only factor to affect nematode numbers (Table 3) in the soil was autumn pesticide

TABLE 3

*The effects of with (A) and without (−) aldicarb on plant parasitic nematodes (nematodes per litre soil). Means of all other treatments*

| | *Pratylenchus* spp. | | *Tylenchus* spp. | | *Tylenchorhynchus* spp. | | *Helicotylenchus* spp. | | Total spear-bearing nematodes | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sampling | A | — | A | — | A | — | A | — | A | — |
| May | 184 | 331 | 197 | 241 | 100 | 203 | 9 | 31 | 603 | 1019 |
| September | 419 | 700 | 188 | 200 | 375 | 575 | 147 | 269 | 1256 | 1879 |

(aldicarb). The total number of nematodes was never large enough to cause significant plant damage. Nematode numbers in roots in May were negligible and the small but significant increase in yield with the application of aldicarb seems most unlikely to have been through its effects on nematodes. (Williams, Nematology Department)

***Barley yellow dwarf virus (BYDV).*** Aphids were numerous in September and October 1978 but only 1·2% transmitted BYDV. As a result there was little infection in the autumn, even on early-sown plots. In June the level of infection was low, reaching only 2·6% in a plot sown early and not treated with aldicarb. In the spring and summer no infective aphids were caught until mid-July, too late to cause damage and, despite their enormous numbers) *Metopolophium dirhodum* transmitted little virus. (Plumb, Plant Pathology Department)

***Aphids.*** Vacuum samples were taken on 30 October, 1 December, 9 January and 26 February. Aphid numbers were large on the early-sown plots given no aldicarb: 13·1, 46·2, 20·9, 11·3 $m^{-2}$ for the four dates respectively. Numbers were much smaller on the corresponding later-sown plots, sampled on only the three last dates: 6·7, 2·2, 0·8 $m^{-2}$. With aldicarb numbers never exceeded 1·4 $m^{-2}$ and 0·3 $m^{-2}$ on early- and later-sown respectively. *Rhopalosiphum padi* was predominant in all except the October sampling, when *Sitobion avenae* was commonest, perhaps because most alighting *S. avenae* remained in the crop while many alate *R. padi* would be migrating to the primary host (*Prunus*



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*padus*) and were thus only in transit. No aphids survived in the crop to March, a result of the coldest winter in 30 years.

In the summer only *Metopolophium dirhodum*, which migrated into the crop in late May, was present in significant numbers. Initial populations were small but increased so that by 25 June the population was 0·26 per shoot. Plants receiving the higher rate of nitrogen had 48% more aphids at that time (high 0·31, low 0·21 per shoot). This effect continued as aphid numbers increased so, by 10 July, plots receiving high and low N had 6·2 and 3·6 aphids per shoot respectively. Autumn pesticide unexpectedly decreased aphid numbers by 41% on 10 July (aldicarb 3·6 none 6·2 per shoot), presumably as a result of uptake of aldicarb from deep in the soil, which might reasonably explain the beneficial effect of aldicarb on yield (Table 1). Pirimicarb had a large effect on aphids; the first spray on 26 June decreased numbers on 10 July by 63% (from 7·8 to 2·8 per shoot). Thereafter, numbers increased rapidly on all plots so that 5 days later the corresponding numbers were 75 and 25 per shoot, necessitating a second spray which was applied on 16 July. The two sprays effectively controlled aphids during milky and mealy ripe stages and increased yields by 14·6%. In an adjacent experiment aphid numbers on plots sprayed once on June 26 became the same as on unsprayed plots by the end of July and no yield benefit accrued, suggesting that the late spray was responsible for the yield benefit in the multifactorial experiment. (Dewar, Entomology Department)

***Fungal diseases.*** *Septoria* was the only pathogen present in greater than trace amounts and its incidence was increased by early sowing and the higher rate of N (Table 4). Two

TABLE 4

*Incidence of* Septoria (*% leaf area infected*). *Means of all other treatments*

| | 22 June Leaf 3 | 16 July Leaf 2 | 2 August Leaf 1 |
|---|---|---|---|
| Sown Early | 7·5 | 16·9 | 13·6 |
| Later | 3·4 | 6·6 | 6·3 |
| Nitrogen 160 kg ha$^{-1}$ | 5·0 | 8·9 | 9·1 |
| 250 kg ha$^{-1}$ | 5·9 | 14·7 | 10·7 |
| Fungicide full | 4·9 | 6·9 | 6·6 |
| none | 6·0 | 14·7 | 13·3 |

applications of fungicide ('Cosmic', a formulation of carbendazim, tridemorph and maneb) only partially controlled the disease but gave a considerable yield increase (Table 1). (Prew, Plant Pathology Department)

TABLE 5

*Microflora of developing ears assessed by dilution plating*

| Date | 21/6 | 27/6 | 4/7 | 11/7 | 25/7 | 8/8 | 22/8 |
|---|---|---|---|---|---|---|---|
| Growth Stage | 58 | 64 | 68 | 73 | 77 | 87 | 91 |
| | (No colonies per g fresh wt. ($10^{-5}$)) | | | | | | |
| No fungicide | | | | | | | |
| Yeasts | 0·19 | 1·33 | 8·05 | 8·67 | 7·06 | 37·20 | 27·50 |
| Yeast-like fungi | 0·44 | 1·09 | 3·81 | 9·04 | 7·74 | 18·33 | 30·00 |
| Filamentous fungi | 0·07 | 0·05 | 0·21 | 0·58 | 1·29 | 4·67 | 20·25 |
| Bacteria | n.d. | n.d. | n.d. | 78·76 | 149·6 | 266·3 | 375·8 |
| Fungicide treated | | | | | | | |
| Yeasts | 0·03 | 0·57 | 1·94 | 1·48 | 4·79 | 12·00 | 16·26 |
| Yeast-like fungi | 0·11 | 1·13 | 1·53 | 2·04 | 9·51 | 18·42 | 19·17 |
| Filamentous fungi | 0·01 | 0·04 | 0·06 | 0·28 | 0·81 | 5·05 | 24·08 |
| Bacteria | n.d. | n.d. | n.d. | 175·0 | 239·6 | 176·7 | 176·3 |



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***Microflora of developing ears.*** The microflora of the developing grain was always dominated by bacteria, yeasts and yeast-like fungi whether or not plots had received fungicide (Table 5). Numbers increased steadily from anthesis to harvest, although there was a particularly large increase between growth stages 77 and 87 which coincided with the ending of a period of dry weather. *Verticillium lecanii* was the predominant filamentous fungus isolated but this showed only slight response to fungicide when total populations were small immediately after treatment. *Alternaria* and *Cladosporium* spp. were both present before harvest but showed no detectable response to fungicide treatment and by harvest populations of all filamentous fungi were similar in treated and untreated plots. (Lacey, Plant Pathology Department)

**Growth and yield of winter wheat on contrasting soils, Rothamsted and Woburn.** Land of different types on farms managed by Rothamsted commonly gives different yields in the same season. The causes of the differences are often incompletely understood. Experiments on cereals were done at Rothamsted and Broom's Barn in 1971–73 and at Rothamsted and at Woburn in 1976 to study and explain the crop yield differences (*Rothamsted Report for 1971*, Part 1, 60–61 and 106–107; and *for 1972*, Part 1, 48 and 90–92; and *for 1973*, Part 1, 49–50 and 94–96; and *for 1976*, Part 1, 32–33). The comparison between Rothamsted clay-with-flints soil and the light sandy loam at Woburn was repeated in 1979. The 32 plots that were treated with both fungicide and aphicide in summer in the experiment to study Factors Limiting Yield of Winter Wheat at Rothamsted (pp. 17–22) were compared with 32 plots given similar treatment combinations on sandy loam in Butt Close at Woburn, in a half replicate of a $2^6$ design. There were also four extra plots given different rates of N from 0 to 340 kg ha$^{-1}$. Fungicide and aphicide were applied as basals at Woburn as their effects were not expected to be related to soil differences. At Woburn the two fertiliser N rates were 205 and 296 kg ha$^{-1}$ instead of 160 and 250 kg at Rothamsted, in consideration of the smaller amount of N expected from the Woburn soil; and the amount of irrigation water was based on long term average rates of water loss instead of weekly meteorological records. Other differences, which included a different herbicide and dates of its application; a single instead of two applications of aphicide; and a different combine, may have had effects on relative yields. The observations made on the crop and soil closely paralleled those at Rothamsted and the sampling dates were also almost the same except that samples at anthesis and later were taken when each sowing reached the required stage of growth, which was a few days earlier than at Rothamsted.

***Yields at maturity.*** The range of N rates tested at Woburn indicated that 205 kg ha$^{-1}$ was near optimal for yield; 295 kg ha$^{-1}$ did not give significantly more. The mean grain yield was 7·8 t ha$^{-1}$ (85% DM), compared with 10·9 t for equivalent plots at Rothamsted. The largest yields were from early-sown plots irrigated and treated with aldicarb (mean 8·7 t ha$^{-1}$). On average, late sowing depressed yield by 0·5 t, lack of aldicarb by 0·7 t and lack of irrigation by 1·2 t ha$^{-1}$; other treatments did not significantly affect yield. At Rothamsted comparable plots averaged 11·1 t ha$^{-1}$ from early sowing, with 0·4 t ha$^{-1}$ less from October sowing, but no other treatment had a significant effect. Thus, even with the best treatment tested Woburn yielded 2·4 t ha$^{-1}$ less than Rothamsted, a difference greater than the combined effect of the two soil treatments that improved yield at Woburn.

The smaller grain yields at Woburn than at Rothamsted were accounted for by fewer ears and by the smaller weight of grain per ear on unirrigated plots. Measurement of soil water with a neutron moisture meter showed that the amounts of irrigation water supplied were not sufficient to replace evapotranspiration during July and by 3 August



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a deficit approaching 74 mm developed, which on the Woburn soil would probably have begun to affect growth. However, with irrigation, grain weights per ear were not less than any at Rothamsted, and were possibly greater, so there is doubt whether ear growth was affected by the measured water deficit on irrigated plots, although we do not know whether grain weights per ear would have been less had there been as many ears as at Rothamsted.

The yield increase due to aldicarb at Woburn was associated with slight increases in spikelets per ear and grains set per spikelet, but not in 1000 grain weight. It did not affect ear numbers. The explanation may well be an effect on aphid numbers, as observed at Rothamsted (p. 20). The yield decrease due to later sowing was associated with smaller 1000 grain weights, probably because of a shorter grain-filling period. (Widdowson, Penny, Hodgkinson, Hewitt and Williams, Soils and Plant Nutrition Department; and Welbank and Taylor, Botany Department)

***Growth of the crop.*** The Woburn wheat initially grew faster than that at Rothamsted and by 29 March the dry weights of shoots from the early and late sowings were 78 and 31 g, compared with 65 and 25 g $m^{-2}$. However, at this stage it had no advantage in shoot number or leaf area index (LAI) compared with Rothamsted. Whereas at Rothamsted there was no response to the first part of the divided N dressing (given mid-March), at Woburn LAI was increased by this N, consistent with the evidence from tissue nitrate measurements suggesting that the soil failed to supply enough mineralised N at the end of winter (p. 24).

At sampling on 15 May there were no differences in total shoot dry matter between sites, nor in LAI, but fewer shoots had survived at Woburn; 1093 compared with 1524 $m^{-2}$ at Rothamsted. Plots were sampled at anthesis on 20 and 27 June, 5 days earlier than at Rothamsted. Total dry matter then was 967 and 996 g from early and later sowings compared with 1097 and 1127 g $m^{-2}$ at Rothamsted but the difference can be accounted for by the shorter interval that had elapsed since the previous sampling in May. More significantly, fewer shoots survived at Woburn, 521 compared with 624 $m^{-2}$ at Rothamsted, and LAI was less, 7·6 compared with 9·9.

By anthesis the shoot numbers at Woburn on plots given a single dressing of N in April and which also had received aldicarb in autumn were just significantly greater than for those not given aldicarb. Consequently, these aldicarb-treated plots had greater dry matter yields and substantially greater LAI (8·9 cf. 6·4). Although time of sowing did not significantly affect shoot number or dry matter at sampling (which was of course later for October-sown plots), it interacted with time of N effect on LAI so that spreading the N applications over 3 months slightly increased LAI of early-sown crop, as at Rothamsted, but depressed LAI of the October sowing. The mean dry weight per ear at anthesis was greater for crop sown in October than in September, perhaps a result of the later sampling date. The same occurred at Rothamsted. Neither additional N nor the drills, which affected growth at Rothamsted, had any detectable effect at Woburn. Irrigation was first applied on 21 June and so was not expected to affect dry matter or leaf area significantly at anthesis.

At Woburn the mean yield of dry matter on 26 July was 1518 g, as compared with 1796 g $m^{-2}$ at Rothamsted on 5 August. The greater part of this difference was due to ear dry matter yields of 799 cf. 1065 g $m^{-2}$, occasioned by both more and heavier ears at Rothamsted. Shoot numbers had not changed since anthesis. Although sampling at each site had been timed approximately when only the laminae of the flag leaves remained green, Woburn wheat had a slightly smaller residual LAI (mean 2·9 cf. 3·3 at Rothamsted), mainly due to a smaller green area of stem-plus-leaf-sheath because of the fewer shoots.



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At this sampling irrigation greatly enhanced leaf survival, from a LAI of 2·1 to 3·8. However, its effects at Rothamsted were comparable. The higher N rate also enhanced LAI, from 2·2 to 3·7, but only slightly more than at Rothamsted. However, neither irrigation nor additional N had any detectable effect at this stage on ear dry weight, although both increased leaves-plus-stems dry weight.

It therefore appears that the effect of irrigation on grain yield must have come from more assimilation by the larger residual LAI during the final stages of grain growth, or from retranslocation of assimilates from the stems, or both. At final harvest there was no significant effect of irrigation on straw dry matter, the leaves plus stems having lost 332 g $m^{-2}$ dry matter in the final stages of ripening on irrigated plots compared with 245 g $m^{-2}$ on unirrigated, although the amount of this finding its way into grain cannot be determined. The effect of irrigation on grain yield was entirely on 1000 grain weight. (Welbank and Taylor, Botany Department)

***Nutrient uptake.*** The samples for growth analysis were also used to measure N and K concentrations in the crops and to calculate N and K uptakes. At Woburn wheat sampled in mid-December contained 27 kg N $ha^{-1}$ when September sown, but only 8 kg N $ha^{-1}$ when sown in October. After the winter (late March) comparable values were 32 and 15 kg N $ha^{-1}$ respectively. The advantage of the earlier sowing, in terms of N uptake, persisted until harvest when relative values were 130 and 120 kg N $ha^{-1}$ in the grain.

Fertiliser N was given in spring either as a single or as divided dressings. At Woburn dividing the N had little effect on the final amount of N taken up by the grain at harvest (128 *v.* 123 kg N $ha^{-1}$) whereas it greatly enhanced the $NO_3$-N content of the young plants in spring. Mean values for $NO_3$-N declined from 460 ppm on 18 December, to 184 ppm on 29 March and to 140 ppm on 6 April. At Rothamsted comparable mean values were 416, 782 and 288 ppm respectively. Hence whilst the wheat on both farms contained similar amounts of $NO_3$ in December, afterwards the Woburn wheat always contained less, partly because the soil contained less N and partly because $NO_3$-N was more readily leached. However, these means disguise the fact that at Woburn on 6 April, i.e. before the single dressings of N were given, wheat stems from plots given 40 kg N $ha^{-1}$ on 12 March contained 276 ppm $NO_3$-N compared with only 3 ppm in those from plots not yet given N. On 6 April comparable Rothamsted wheat not yet given N contained 150 ppm $NO_3$-N. Samples taken to a 90 cm depth showed that the Woburn soil contained 70 kg $ha^{-1}$ of mineral N on 27 February but only 20 kg on 5 April. Comparable values at Rothamsted were 120 kg on 2 March and 60 kg on 5 April. These soil differences help to explain differences in $NO_3$ content and tiller number of the wheat, and therefore may have been a main contributory cause of the residual yield difference between sites.

After fertiliser N had been given to all plots on 5–6 April differences in tissue $NO_3$-N contents between sites largely disappeared i.e. 277 *v.* 243 ppm at Woburn and at Rothamsted respectively with divided N and 592 at each site with a single dressing of N, though the Woburn wheat was given 45 kg more N $ha^{-1}$ than the Rothamsted wheat.

Judged against time, N uptake by wheat at the two farms was identical on 15 December (18 kg N $ha^{-1}$) and again after winter on 30 March (22 kg N $ha^{-1}$). Afterwards N uptake increased steeply to peak at 220 kg N $ha^{-1}$ in July on both soils. However, N in grain reached 160 kg N $ha^{-1}$ at Rothamsted but only 136 at Woburn.

Potassium uptakes followed the same pattern as N uptakes with larger values where most N was given and with maximum uptakes of 288 kg K $ha^{-1}$ at Woburn on 26 July and of 256 kg K $ha^{-1}$ at Rothamsted at anthesis (25 June to 2 July). There was no evidence that soil K contributed to the differences between sites. (Widdowson, Penny, Hodgkinson, Hewitt and Williams, Soils and Plant Nutrition Department)



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***Conclusions.*** Drought was clearly a major cause of smaller yields on the light soil and the effect of aldicarb suggests a connection with pests. The lack of response to spreading the N supply over 3 months suggests that inadequate rate of mineralisation of soil N at Woburn was not an important factor once fertiliser N had been supplied in spring. However, the large contribution of ear numbers to the yield differences between sites when irrigation was supplied suggests that differences in potential were established early in crop development and crop N and $NO_3$-N measurements in March indicate that the supply of soil N during the winter was at least a contributory factor. Other explanations for site differences can be suggested but need testing. The incidence of mildew at Woburn was greater than at Rothamsted in spite of fungicides, presumably because of local differences in weather or infection sources. The single application of pirimicarb may have been insufficient to control aphids, especially during the late stage of ear filling (p. 21). There is often appreciable atmospheric pollution with sulphur dioxide and fluorides at Woburn, which is believed to be worse than at Rothamsted, but its potential effects on winter wheat are uncertain.



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