# Rothamsted Experimental Station Report for 1985

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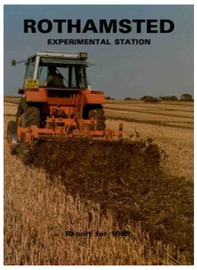


## Multidisciplinary Agronomy

### Rothamsted Research

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# MULTIDISCIPLINARY AGRONOMY

Three new series of multidisciplinary field experiments were started. One, on straw incorporation, was begun to support the AFRC Coordinated Programme on this topic (see also pp. 172–173). The second was designed to gain new information on some of the factors affecting the production and survival of winter wheat tillers; it arose from consideration of the data obtained from the completed multifactorial experiment on winter wheat (*Rothamsted Report for 1984,* 23–28). The third was a multifactorial on the factors limiting the yield of winter oilseed rape.

The multidisciplinary experiments on winter barley, winter beans and potatoes continued with little change of treatments. Comment on the potato experiment is postponed until next year which will be the first of the three test years.

## Factors limiting yield of winter barley

The second series of experiments, begun in 1984 (*Rothamsted Report for 1984,* 28–32), continued on a new site with comparisons between the three crop sequences, (1) barley–barley–barley, (2) barley–oats–barley, and (3) barley–fallow–barley. In the first sequence the seven factors shown in Table 1 were tested in factorial combinations ($2^7$) using a half replicate design. Additional plots allowed the second and third cropping sequences to be compared with the first, over a restricted set of treatments; all were sown with a two-row winter barley (Panda). Further additional plots in sequences (1) and (2) only were sown with a six-row winter barley (Pirate). These 80 plots, plus four which did not receive any nitrogen fertilizer, were arranged in two blocks of 42 plots.

**Nitrogen in the soil.** The site chosen had been long used to grow arable crops and as expected the soil after cereals contained little $NO_3$-N in autumn. On 1 October, shortly after crop emergence, there were only 42 kg $NO_3$-N ha$^{-1}$ to 90 cm and on 8 November 24 kg ha$^{-1}$, whilst amounts in the top 30 cm diminished from 23 to 7 kg ha$^{-1}$, presumably reflecting uptake by the barley. Subsequently there was little change so that on 1 February 17 kg $NO_3$-N remained to 90 cm. To test the effect of overcoming the shortage of $NO_3$-N from soil, 'winter' N was applied, as urea, at 30 kg N ha$^{-1}$ on 9 November, repeated on 4 February. Effects were monitored by measuring $NO_3$-N concentration in stem sap at fortnightly intervals. On 1 November there were only 390 ppm $NO_3$-N in the sap, and by 4 December 420 ppm $NO_3$-N where no urea had been applied, but 830 ppm where it had. Relative values then became 430 *vs* 830 on 2 January, 540 *vs* 750 on 25 February and 8 *vs* 540 on 2 April, the date when the main spring top-dressing of N was applied. A $NO_3$-N deficiency threshold of 200 ppm was reached on 21 March by the barley not given 'winter' N. (Widdowson, Bird and Darby, Soils and Plant Nutrition)

**Development, tillering and leaf areas.** The experiment was sown on 13 September. From 300 seeds sown about 260 plants were established and from 450 seeds, 320 plants. Unusually the 'Baytan' seed treatment (triadimenol+fuberidazole) increased the number of plants established, although not significantly, from 278 to 301 m$^{-2}$. The barley was sown earlier and the autumn was warmer than last year, so each development stage was reached at an earlier date. Panda reached the double ridge stage on 30 November and maximum spikelet/awn primordium stage on 1 April; neither total leaf nor maximum spikelet numbers were affected by treatments. Leaf number was greater (14·7 *vs* 13·5) but maximum spikelet number smaller (43·0 *vs* 48·2) than last year. Although the duration of spikelet production was similar in both years (900 accumulated °C days above 0°C), the rate of production was slower this year (21·0 *vs* 18·7 °C days per spikelet). Pirate reached each development stage slightly



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later than Panda (double ridges: 21 December; awn primordium: 9 April); it had similar numbers of leaves but fewer spikelets (36·1). Anthesis was on 1 June for Panda and 2 June for Pirate. Both cultivars grown after barley had lost all green leaf by 14 July and were mature (Zadoks growth stage 92) by 19 July. Both stages were delayed by two to three days where the crops had 'winter' nitrogen or were sprayed with fungicides, and by a week where they were grown after oats or fallow.

Maximum shoot number was less than last year (959 *vs* 1405 $m^{-2}$ for crops without 'winter' N) probably reflecting the smaller amount of residual nitrogen in the soil (42 *vs* 83 kg $NO_3$-N $ha^{-1}$ in the top 90 cm of soil). 'Winter' N increased maximum shoot number to 1273 $m^{-2}$, similar to the number produced in the previous year without it. Ear number was less than in 1984 (867 *vs* 1033 $m^{-2}$) but in contrast to the previous year it was increased by 'winter' nitrogen, but not by seed rate.

Leaf area indices were increased by 'winter' N and 'Baytan' during winter and spring (+77% and +28% respectively on 1 April), with an even greater response (+142%) where both were applied. At anthesis leaf area indices were less than in the previous year (7·8 *vs* 10·5) and were increased only by fungicide sprays (+18%). (Wood and Rainbow, Physiology and Environmental Physics)

**Growth and yield in the first crop sequence.** Samples were taken on three occasions for dry weight, shoot number and leaf area index. By 4 March mean plant number was 237 $m^{-2}$, where neither 'Baytan' nor 'winter' N had been given, 338 $m^{-2}$ with both. The number of shoots was increased greatly by 'winter' N (944 *vs* 1290 $m^{-2}$), less by seed rate (1063 *vs* 1171

**TABLE 1**

*The effect of seven factors on the number of ears on 3 June and on the grain yield (t $ha^{-1}$) of Panda winter barley*

| | Ears $m^{-2}$ | Grain yield |
|---|---|---|
| (1) Seeds sown $m^{-2}$ | | |
| 300 | 851 | 6·67 |
| 450 | 882 | 6·48 |
| (2) Seed treatment ('Baytan')* | | |
| Without | 825 | 6·43 |
| With | 909 | 6·72 |
| (3) Winter nitrogen (60 kg N $ha^{-1}$ as urea) | | |
| Without | 837 | 6·34 |
| With | 896 | 6·81 |
| (4) Early growth regulator (CCC)† | | |
| Without | 859 | 6·53 |
| With | 875 | 6·62 |
| (5) Fungicide sprays‡ in spring and summer | | |
| Without | 873 | 5·92 |
| With | 860 | 7·23 |
| (6) Spring nitrogen (kg N $ha^{-1}$) on 2 April | | |
| 120 | 842 | 6·44 |
| 180 | 892 | 6·71 |
| (7) Insecticide ('Ambush C')§ | | |
| Without | 839 | 6·43 |
| With | 895 | 6·72 |
| SED | 26·9 | 0·144 |

* 'Baytan' a.i. triadimenol+fuberidazole.
† Chlormequat at 0·52 kg $ha^{-1}$ a.i. on 23 October, 26 November and 10 April.
‡ 'Sportak Alpha' a.i. prochloraz+carbendazim on 10 April; 'Cosmic' a.i. maneb+tridemorph+carbendazim on 29 April; 'Bayleton CF' a.i. triadimefon+captafol on 20 May.
§ 'Ambush C' a.i. cypermethrin on 30 October.



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$m^{-2}$) and little by 'Baytan' (1109 *vs* 1125 $m^{-2}$). By contrast dry weight was significantly increased by 'winter' N and 'Baytan' and a little by seed rate.

On 1 April plant number was significantly increased only by seed rate and 'Baytan', the number of shoots only by 'winter' N (972 *vs* 1255 $m^{-2}$). Dry weight was significantly increased only by 'Baytan' and 'winter' N. On 3 June the number of ear-bearing stems was significantly increased by 'Baytan', 'winter' N and the autumn insecticide and more by N in spring than by the larger seed rate (Table 1). Dry weight was increased significantly by all the treatments except seed rate and insecticide.

At harvest on 15 August (Table 1) the fungicide sprays in spring and summer had by far the greatest effect on grain yield (+1·31 t $ha^{-1}$) largely because of an increase in 1000 grain weight (30·5 *vs* 34·8 g). 'Winter' N increased yield by 0·47 t $ha^{-1}$ and both 'Baytan' and insecticide by 0·29 t $ha^{-1}$. Neither CCC nor the larger seed rate had any appreciable effect on yield. The weight of 1000 grains was little changed by any factor other than the spring and summer fungicides.

**Growth and yield in all three crop sequences.** Plant establishment was the same after oats and barley, but less after fallow (290 *vs* 252 plants $m^{-2}$) and identical for both cultivars. By 4 March there were fewer shoots on the six-row cv. Pirate than on the two-row cv. Panda (1190 *vs* 1365 $m^{-2}$); numbers were unaffected by previous cropping. On 1 April the pattern was the same. By 3 June both dry weight and the number of ear-bearing stems were similar for both cultivars, but by then were affected by previous crop (Table 2). On this date dry weight and number of ears were greatest after fallow, least after barley. These effects were maintained through grain filling and barley after oats or fallow had grains with a greater 1000 grain weight than barley after barley. This increase occurred with both cultivars; after oats their mean grain weights were 11% larger than after barley. This effect explains about half of the mean benefit of 1·52 t $ha^{-1}$ of grain from growing oats before the barley.

**TABLE 2**

*The effect of previous cropping and cultivar on the number of ears on 3 June and on the grain yield (t $ha^{-1}$) of winter barley*

| | Ears $m^{-2}$ | Grain yield |
|---|---|---|
| Two-row barley (Panda) | | |
| Previous crop | | |
| Fallow | 965 | 8·16 |
| Barley | 868 | 7·05 |
| Oats | 898 | 8·61 |
| Six-row barley (Pirate) | | |
| Previous crop | | |
| Barley | 682 | 7·59 |
| Oats | 859 | 9·08 |
| SED | 90·9 | 0·183 |

The barley lodged extensively especially with 'winter' N and with 'Baytan'. However the severity of lodging was significantly diminished by the fungicide sprays applied in spring and summer. Pirate lodged more severely than Panda.

The mean percentage of N in grain was 1·92; it was increased from 1·89 to 1·95% by the 60 kg N $ha^{-1}$ in 'winter' N and from 1·80 to 2·04% by the extra 60 kg N $ha^{-1}$ in the larger N-rate applied in April. Fungicides in spring and summer slightly decreased percentage of N in grain, presumably by greatly increasing yield. (Widdowson and Darby, Soils and Plant Nutrition; Scott, Insecticides and Fungicides; Kerry, Nematology; Gutteridge, Jenkyn and Plumb, Plant Pathology; Wood, Physiology and Environmental Physics; Ross, Statistics)



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**Fungal diseases.** Powdery mildew (*Erysiphe graminis* f. sp. *hordei*) was common in the autumn and winter but was lessened by 'Baytan' (0·2 *vs* 0·0% area of first seedling leaves of Panda affected in late October; 2·4 *vs* 0·9% on second youngest leaves in mid-December). In December more disease was seen on Panda than Pirate but, unlike last year, it was not greater after fallow. From mid-March amounts of mildew were negligible but leaf blotch (*Rhynchosporium secalis*) became common. In March it was more severe where 'winter' N had been applied (3·1 *vs* 1·7%, on second youngest leaves) and was slightly decreased by 'Baytan' (2·6 *vs* 2·0%). In mid-May the disease was most affected by the fungicide sprays (3·9 *vs* 0·5% on fourth youngest leaves). The fungicide sprays were also effective in June (7·3 *vs* 0·1% on second youngest leaves) but applying extra nitrogen in either winter or spring increased the disease (6·0 *vs* 8·9%; 5·9 *vs* 8·9% on second youngest leaves of plots not given fungicide sprays respectively).

In February patches of rotting plants were conspicuous in some plots. Symptoms were characteristic of snow mould and apparently caused by *Fusarium* spp. Total areas affected were small and mostly restricted to tractor wheelings. They were greater with 'winter' N and were strikingly affected by previous cropping (3·4 *vs* 0·2 *vs* 0·0% of plot area affected after fallow, barley and oats respectively).

Take-all (*Gaeumannomyces graminis* var. *tritici*) was predictably more prevalent after barley than after oats or fallow (125 *vs* 73 *vs* 50, take-all ratings in mid-June). In late October about 20% of plants after barley were affected by the disease, with an average of 0·4 infected roots per plant, but without any consistent effect of 'Baytan'. However, in December and March, 'Baytan' consistently but not always significantly, decreased the proportion of plants showing symptoms and decreased the average numbers of infected roots per plant (2·6 *vs* 1·6; 3·3 *vs* 2·2 respectively in December and March). 'Baytan' only slightly decreased the take-all rating in June (134 *vs* 120) but did decrease numbers of plants with severe symptoms (7·5 *vs* 3·2%). Take-all was less severe with 'winter' N (1·5 *vs* 2·7 infected roots per plant in December, 2·1 *vs* 3·3 in March; 105 *vs* 149, take-all rating in June).

Eyespot (*Pseudocercosporella herpotrichoides*) was well controlled by the fungicide sprays (3·5 *vs* 33·5% straws with moderate or severe symptoms). The disease was decreased by applying extra nitrogen in either winter or in spring (27·6 *vs* 40.0% and 30·4 *vs* 36·8% respectively on plots not given fungicide sprays). It was more severe with 'Baytan' (36·3 *vs* 30·9% on plots not given fungicide sprays).

Sharp eyespot (*Rhizoctonia cerealis*) and brown foot rot (*Fusarium* sp.) each affected less than 1% of straw; brown foot rot was decreased by the fungicide sprays.

In late October seedlings of barley following oats were yellower than those following barley, were much smaller (49·5 *vs* 85·6 mg per plant) and had fewer shoots (1·2 *vs* 2·1 shoots per plant). By December differences in colour were no longer apparent but seedlings following oats remained smaller (174 *vs* 292 mg per plant) and had fewer shoots (3·5 *vs* 4·6 per plant). These differences appear not to have been caused by leaf or root diseases. They may result from differences in toxin production by decaying oat and barley straw. (Jenkyn, Gutteridge and Feekins, Plant Pathology)

**Aphids.** The autumn migrations of *Sitobion avenae* and *Rhopalosiphum padi* continued into early November. This probably resulted in successful crop colonization but this could not be confirmed by vacuum insect sampling beause of the wet autumn conditions. Following the cold winter very few aphids were found in February and none in March, although polyphagous predators (carabid and staphylinid beetles and spiders) were present on the latter date. Visual examination of shoots in early July, probably just after the peak aphid densities, showed aphid populations up to 2·15 per shoot, with *Metopolophium dirhodum* predominating, especially on plots given the larger amount of spring nitrogen. This amount of infestation is unlikely to have caused significant yield loss. (Carter, Entomology)



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**Barley yellow dwarf virus (BYDV).** Results from monitoring populations of potential virus vectors in autumn 1984 indicated that infection of September-sown crops was likely to be slightly greater than in autumn 1983 (*Rothamsted Report for 1984*, 129). This was supported by the presence of symptoms of BYDV infection on 21 May when plots not given cypermethrin in autumn had up to 10% (average 2%) plants with symptoms; plots given cypermethrin had less than 0·1% infection. However, this treatment increased yield by 0·29 t ha$^{-1}$ (4·5%), more than was expected from controlling virus alone.

In addition to the characteristic chrome yellow discolouration resulting from BYDV infection, some plants also showed conspicuous striping. (Plumb, Plant Pathology)

## Factors limiting yield of winter oilseed rape

A new series of experiments was begun on Bienvenu winter oilseed rape; the site this year followed winter barley and was on a deep flinty loam of the Charity complex. The seven factors shown in Table 4 were tested in factorial combinations ($2^7$) in a half replicate design of 64 plots. Thirty-two extra plots were included to test an extended range of nitrogen applications, a seedbed nematicide and for detailed physiological study, for root growth measurements and for nitrogen balance using $^{15}N$.

**Growth and development.** Despite emergence within seven days early-sown (E) plots established fewer plants than later-sown (L) plots and this difference was maintained until maturity (Table 3). E plots produced a dense leaf canopy in autumn but growth on L was much slower. Freezing conditions in January and February, when temperatures reached −18°C, halted growth and killed many plants, and much leaf tissue on surviving plants, on E plots, particularly those without insecticide. Insecticide increased all growth parameters of E plots throughout the season. On the return of warmer weather growth was rapid and L plots soon equalled E plots for growth stage and dry matter and exceeded them for leaf area.

TABLE 3

*Changes with time in total dry weight (g m$^{-2}$), number of plants m$^{-2}$ and leaf area index of Bienvenu winter oilseed rape sown early (E, 16 August) or later (L, 6 September)*

| | Dry weight | | Number of plants | | Leaf area index | |
|---|---|---|---|---|---|---|
| | E | L | E | L | E | L |
| 12 November | 246 | 53 | 82 | 123 | 2·7 | 1·1 |
| 26 February | 203 | 117 | 70 | 118 | 1·2 | 1·1 |
| 30 April | 568 | 596 | 57 | 102 | 2·8 | 3·1 |
| 11 June | 1024 | 1056 | 58 | 102 | — | — |
| 22 July | 1500 | 1660 | 45 | 87 | — | — |

Plants on E plots developed a distinctly different canopy with more secondary branches (10·0 *vs* 4·7) and a seven-fold greater weight of branch dry matter on 30 April. Branch leaves therefore provided proportionately a much greater contribution to the leaf canopy and developing flower canopy on E plots at this time. Later branching increased on L plots and these had 15% more fertile pods per unit area by 11 June and 15% greater pod weight by 22 July.

Flowering started on E plots on 19 April, all flowers were open by 14 May, about a week before L plots, this difference persisted until podset. Harvest index was 5% greater on L, 13% greater on all plots given insecticides. (Leach, Mullen and Keirle, Physiology and Environmental Physics; Yeoman, Field Experiments)



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**Yield at maturity and at combine harvest.** Strong winds and much rain between desiccation with diquat on 25 July and combine harvesting on 12 August caused much seed to be shed. Accordingly we give yields obtained from a hand harvest (0·85 $m^2$ per plot, 3·7% of the combine harvest area) on 22 July before shedding started as well as combine harvest yields (Table 4). These show a mean loss of 1·3 t $ha^{-1}$ from shedding, greatest on E plots and on those plots given treatments which hastened maturity. Consequently even the large benefit from insecticides (0·96 t $ha^{-1}$) was lost by the later harvest date. Both sets of data showed benefit from the later sowing date; this, and that from the insecticides, came from increased numbers of fertile pods per unit area. Increases in 1000 seed weights were caused by earlier sowing, growth regulator and by spring and summer fungicides. (Rawlinson, Plant Pathology; Leach, Physiology and Environmental Physics; Darby, Soils and Plant Nutrition; Evans, Nematology; Digby, Statistics; Williams, Entomology)

**TABLE 4**

*Factors tested and their effects on seed yield (t $ha^{-1}$ at 90% DM) of Bienvenu winter oilseed rape*

| | Hand harvest 22 July | Combine harvest 12 August |
|---|---|---|
| (1) Sowing date | | |
| 16 August | 4·87 | 3·63 |
| 6 September | 5·63 | 4·28 |
| (2) Spring nitrogen rate (kg N $ha^{-1}$) | | |
| 175 | 5·00 | 3·94 |
| 275 | 5·50 | 3·97 |
| (3) Spring nitrogen timing | | |
| All on 25 February | 5·27 | 3·97 |
| One-third on 25 February, two-thirds on 25 March | 5·23 | 3·94 |
| (4) Insecticide* | | |
| Without | 4·77 | 3·93 |
| With | 5·73 | 3·97 |
| (5) Autumn fungicide† | | |
| Without | 5·22 | 3·96 |
| With | 5·28 | 3·95 |
| (6) Spring and summer fungicide‡ | | |
| Without | 4·96 | 3·95 |
| With | 5·54 | 3·95 |
| (7) Growth regulator§ | | |
| Without | 5·19 | 4·03 |
| With | 5·31 | 3·88 |
| SED | 0·269 | 0·065 |

* 'Decis' a.i. deltamethrin on 4 October and 28 November + 'Hostathion' a.i. triazophos on 17 June.

† Fenpropimorph in the seed dressing + 'Sportak' a.i. prochloraz on 26 November.

‡ 'Sportak' a.i. prochloraz on 4 April + 'Rovral Flo' a.i. iprodione on 17 June.

§ 'Cerone' a.i. 2-chloroethylphosphonic acid on 23 May to early-sown, on 29 May to later-sown plots.

**Nitrogen in the soil.** On 4 September L plots (not yet sown) had more $NO_3$-N, measured to a depth of 90 cm than E plots (195 *vs* 143 kg $ha^{-1}$). By 1 October $NO_3$-N was still greater on L plots (91 *vs* 40 kg $ha^{-1}$). On 31 January amounts ranged from 13 to 19 kg $NO_3$-N $ha^{-1}$ regardless of sowing date.

**Nitrogen content in plants.** The percentage of N in dry matter in November was larger in L plants (5·28 *vs* 3·94%) but the greater growth of E plants gave much larger N uptakes (96 *vs*



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28 kg N $ha^{-1}$). Autumn fungicide and insecticide caused small decreases in percentage of N but little change in N uptake. On 26 February percentage of N remained greater in L plants (4·82 *vs* 4·40%). Dry matter accumulated through the winter on L plants, but was lost in E plants, so N uptakes increased on the former and declined on the latter (57 *vs* 89 kg N $ha^{-1}$ respectively). The larger spring N dressing increased percentage of N in dry matter on 30 April (3·80% *vs* 3·45%) but was not significantly affected by sowing date or N division. Dry matter on L plots continued to exceed that on E leading to a greater N uptake (216 *vs* 201 kg N $ha^{-1}$). Autumn insecticide prevented loss of plants in E plots and slightly increased N uptake in November (60 *vs* 65 kg N $ha^{-1}$); this effect increased in February and April (64 *vs* 81, and 187 *vs* 230 kg N $ha^{-1}$ respectively). Data from samples taken in June, July and at harvest await processing.

**Nitrogen in plant sap.** Until 18 December the concentration of $NO_3$-N in sap in the petiole of the youngest expanded leaves was greatest on L plots (800 *vs* 550 $\mu$g $NO_3$-N $ml^{-1}$). Thereafter concentrations declined to zero in mid-March on L, end of March on E. Nitrogen fertilizer applied in February caused a rapid increase to 700 $\mu$g $NO_3$-N $ml^{-1}$ in both E and L plants. (Darby, Bird and Hewitt, Soils and Plant Nutrition)

**Root growth.** Two of the extra plots, sown early, given 275 kg N $ha^{-1}$in spring as a single application and given all the insecticides and fungicides, were used for root sampling. On 15 November, when shoot dry matter was 263 g $m^{-2}$, roots were present to the sampling depth of one metre. The total root length was 15 km $m^{-2}$ of which 62% was in the 0 to 20 cm soil layer and only 1% at a depth of 80 to 100 cm. Root length increased to 21 km $m^{-2}$ by 11 March. Later samples await processing. (Barraclough, Doran, Kent, Ashton and Green, Soils and Plant Nutrition)

**Insect pests.** In autumn adult cabbage stem flea beetles (*Psylliodes chrysocephela*) caused much damage on E plots but little on L. By 26 February visible damage remained greatest on E plots (98% *vs* 37% plants, 76% *vs* 12% petioles without insecticides, 32% *vs* 3% plants, 7% *vs* 1% petioles with insecticides). On 5 March counts of larvae per plant also showed larger numbers on E plots (11·5 *vs* 0·8 without insecticides; 0·8 *vs* 0·0 with). Pollen beetles (*Meligethes aeneus*) did not exceed 0·3 per plant. Seed weevils (*Ceutorhynchus assimilis*) and pod midge (*Dasineura brassicae*) were rare. (Williams and Martin, Entomology; Stevenson and Smart, Insecticides and Fungicides)

**Nematodes.** Eight of the extra plots tested oxamyl applied to the seedbed. This decreased numbers of *Pratylenchus* (mainly *P. neglectus* with a few *P. thornei*) in May (7 *vs* 16 per g of root, 4680 *vs* 9200 per litre of soil). Total ectoparasitic nematode numbers were also decreased (11800 *vs* 22440 per litre of soil). Although these numbers were considerable no species was present in numbers likely to cause damage in such a wet year and oxamyl did not significantly affect yield. (Evans, Nematology)

**Diseases.** Fungal diseases were never severe during the season, but incidence was always greater on E than on L plots except for light leafspot (*Pyrenopeziza brassicae*) which after April was more prevalent on L. On 12 November E plots had more downy mildew (*Peronospora parasitica*) (86 *vs* 71% plants and 21 *vs* 17% leaves infected), more grey mould (*Botrytis cinerea*) (34 *vs* 24% plants and 7 *vs* 5% leaves infected) and more dark leaf spot (*Alternaria* spp.) (4 *vs* 2% plants and 0·5 *vs* 0·3% leaves infected). All diseases except downy mildew were lessened by seed treatment with fenpropimorph. On 31 January the only disease recorded was light leaf spot, more prevalent on E (7 *vs* 1% plants and 2 *vs* 0·2% leaves infected). Incidence was less on plots given autumn fungicide (6 *vs* 2% plants and 2 *vs*



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0·7% leaves infected). By 26 February the incidence of light leaf spot had changed little. Incidence of beet western yellows virus, detected by ELISA and ISEM, was four times greater on E plots than L and eight times greater on plots without insecticide than on those with (p. 123). On 22 April incidence of downy mildew, light leaf spot and the *Phoma* leaf spot stage of canker (*Leptosphaeria maculans*) was greater on E plots (26 *vs* 19, 5 *vs* 4 and 1 *vs* 0·1% leaves infected respectively). Both fungicide treatments decreased light leaf spot (4 *vs* 45% and 18 *vs* 31% plants infected after autumn and spring fungicides respectively) and *Phoma* (2 *vs* 16% and 4 *vs* 14% plants infected after autumn and spring fungicides respectively). By 11 June L plots had more light leaf spot than E plots but downy mildew, canker and grey mould remained more prevalent on E plots. Incidence and severity of light leaf spot was significantly less on plots given either autumn or spring fungicide and least on plots given fungicide on both occasions. On 17 July incidence of light leaf spot on pods was significantly less after either autumn or spring and summer fungicide and was least on plots given all three sprays. A few plants, scattered throughout the experiment, were infected with stem rot (*Sclerotinia sclerotiorum*). (Rawlinson, Church and Duckney, Plant Pathology)

**The superficial microflora of leaves and pods.** Bacteria on uppermost leaves increased from $3\times10^6$ to $10^9$ colony forming units (CFU) $g^{-1}$ of tissue from mid-April to leaf death in mid-June. On pods they increased from $10^6$ to $10^{11}$ CFU $g^{-1}$ between the start of flowering and harvest.

Yeasts were generally the commonest fungi with many more white yeasts, probably *Cryptococcus* spp., than *Sporobolomyces* spp. The only yeast-like fungus was *Aureobasidium pullulans* which reached $10^5$ CFU $g^{-1}$ on leaves at leaf death and to $10^6$ CFU $g^{-1}$ on pods at harvest. The main filamentous fungi were species of *Cladosporium, Alternaria, Phoma, Acremonium* and *Botrytis cinerea.* Numbers reached $10^4$ to $10^6$ CFU $g^{-1}$ on leaves, $3\times10^6$ on pods at harvest. Seeds were colonized by *Alternaria,* and to a lesser extent by *Cladosporium* when they were almost mature but not before. The fungicide treatment had little effect on either the superficial microflora of the pods or on seed infection. (Lacey and Nabb, Plant Pathology)

**Recovery of $^{15}$N-labelled fertilizer.** Labelled ammonium nitrate was applied at 254 kg N $ha^{-1}$ to E plots on 4 March. Below-average rainfall in March and April combined with low temperatures minimized leaching and denitrification. At maturity 82% of the labelled fertilizer could be accounted for: 63% in above-ground crop, 16% in soil (0–23 cm) and 3% in surface leaf litter. After harvest a total of 159 kg N $ha^{-1}$ remained in crop residues of which 85 kg $ha^{-1}$ came from fertilizer. Soil contained a further 42 kg N $ha^{-1}$ derived from fertilizer. (Powlson, Poulton, Rodgers, Jenkinson, Brown and McCann, Soils and Plant Nutrition)

## Field beans (*Vicia faba*): effects of pests and pathogens

The multidisciplinary experiment on winter beans completed a fifth and final year comparing the three sets of crop protection treatments: current standard practice, economically enhanced practice and full control.

Standard practice, in accordance with a year in which chocolate spot was prevalent, used three applications of a mixture of benomyl (0·50 kg $ha^{-1}$) and chlorothalonil (1·0 kg $ha^{-1}$), on 29 March, 11 June and 3 July. 'Economic' control included these sprays plus seed treatment with carbendazim and thiram (at about 1 g of each per kg of seed) and phorate (1·7 kg $ha^{-1}$) as granules on 19 April. 'Full' control included all these foliar sprays and the seed treatment plus aldicarb (10 kg $ha^{-1}$) worked into the seedbed, carbofuran (1·7 kg $ha^{-1}$)as granules on 19 April and additional foliar sprays, of fosetyl-Al (1·6 kg $ha^{-1}$) mixed with benomyl (0·56 kg $ha^{-1}$) and chlorothalonil (0·98 kg $ha^{-1}$) on 7 March, of



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deltamethrin (7·5 g ha$^{-1}$) mixed with benomyl (0·50 kg ha$^{-1}$) and chlorothalonil (1·15 kg ha$^{-1}$) on 22 May and of pirimicarb (0·14 kg ha$^{-1}$) mixed with benomyl (0·56 kg ha$^{-1}$) and propiconazole (0·12 kg ha$^{-1}$) on 23 July. The treatments were arranged in six randomized blocks of three plots.

The grain yield of 'standard' plots was 4·3 t ha$^{-1}$, the largest from this treatment in this series of experiments. Yield was increased to 4·5 t ha$^{-1}$ by 'economic' and to 5·0 t ha$^{-1}$ by 'full' control. (Bardner, Entomology; McEwen and Yeoman, Field Experiments; Griffiths, Insecticides and Fungicides; Beane and Webb, Nematology and Cockbain and Lapwood, Plant Pathology).

**Plant growth.** The experiment was sown to cv. Banner at Rothamsted on 15 October using a seed rate of 18 seeds m$^{-2}$ (140 kg ha$^{-1}$), half that used in previous years, and was harvested on 24 September. Counts on 6 February showed an average of 17 plants established and were unaffected by treatment. By maturity both 'standard' and 'economic' had nearly 30 pod-bearing stems, 'full' had 34. Total above-ground dry matter, measured on 15 August, was 19·3 t ha$^{-1}$ and was unaffected by treatments. (McEwen and Yeoman, Field Experiments)

**Weevils (*Sitona lineatus*).** Adult feeding damage was assessed on 16 May when 'standard' plots had ten notches per leaf, lessened to six by 'economic', to four by 'full'. (Griffiths, Insecticides and Fungicides)

**Viruses.** At late-flowering stage on 5 July, plants were examined for virus symptoms. 'Standard' plots had 4% bean leaf roll virus, lessened to 2% by 'economic' and 'full'. Both 'standard' and 'economic' had 0·2% pea enation mosaic virus, none on 'full'. (Cockbain, Plant Pathology)

**Foliar fungi.** Chocolate spot (*Botrytis fabae*) was favoured by the wet summer but the foliar fungicides used gave good control. On 15 May 7% of the area of the lower leaves was affected on 'standard' plots, 4% on 'economic', 3% on 'full'; all treatments had less than 1% of the upper leaves affected. On 27 June amounts on lower leaves of 'standard' and 'full' had changed little but those on 'economic' had increased to 24%, control on the upper leaves remained satisfactory at less than 3% on all treatments.

Rust (*Uromyces viciae-fabae*) was first seen in the experiment on 4 June but was slow to develop, perhaps because of low temperatures. In August development was rapid. On 29 August both 'standard' and 'enhanced' plots had about 70% of leaf area affected, lessened to 58% by 'full'. (Yeoman, Field Experiments; Lapwood, Plant Pathology)

**Root fungi.** In April about 14% of the root area in 'standard' and 'enhanced' plots was affected by root blackening, 9% in 'full'. By the end of June these had fallen to 7% in 'standard' and 'enhanced', 4% in 'full'. (Yeoman, Field Experiments; Lapwood, Plant Pathology)

**Nematodes.** Root lesion nematodes of the genus *Pratylenchus* were the most numerous plant parasitic nematodes found. They were present in moderate numbers reaching a maximum in June of 1500 l$^{-1}$ of soil, 116 g$^{-1}$ of fresh root. Most (85%) were of the less damaging species *P. neglectus* with smaller numbers of the more damaging *P. thornei* (14%) and *P. pinguicaudatus* (1%). None of the treatments gave significant control. (Beane and Webb, Nematology)

**Conclusions.** In previous years this experiment has been sown early at a relatively large seed rate and we have sometimes found that improvements in plant health have increased



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total dry matter but not grain yield. Another series of experiments started in 1984 gave results (*Rothamsted Report for 1984,* 58–59), supported by results this year (p. 60), that suggest large seed rates should be used only for late sowings. Accordingly the multidisciplinary experiment, although sown a month later than planned, was given only half the seed rate used previously. Perhaps as a result a good grain yield of 4·3 t $ha^{-1}$ from 'standard' control was obtained but was nevertheless increased by 0·7 t $ha^{-1}$ by the improved health given by 'full'. Numbers of nematodes were too few, and amounts of virus and root disease too small, to have affected yield so this increase is attributed to the control of weevils and rust and to a small improvement in chocolate spot control. 'Economic' gave similar control of weevils, judged by leaf notching, but not of rust or chocolate spot, and consequently increased yield relative to 'standard' by only 0·2 t $ha^{-1}$, this would only just have paid for the extra cost of £30 $ha^{-1}$ which this treatment cost. If 'correct' seed rates can consistently give good yields and greater responses to improved plant health the 'economic' treatment package could be upgraded to increase its profitability.

## Straw incorporation

A series of experiments on straw incorporation was started in autumn 1984 in response to the urgent need for information on this topic. These experiments form part of the AFRC's coordinated inter-institute programme on straw disposal. Two of these experiments are multidisciplinary and are reported here, others which are not are reported elsewhere (pp. 172 and 173)

**Comparison of straw incorporation methods on different soil types.** A long-term experiment was started on contrasted soil types at Rothamsted (flinty silty clay loam) and Woburn (sandy loam) to test four cultivation systems for straw incorporation: Shallow tillage, deep tillage, shallow tillage followed by ploughing, ploughing alone. These treatments are tested on plots where straw is either burnt or chopped. In the short term this should give information on the practicability of these systems and their consequences on yield. In the long term they will be used to study changes in nitrogen immobilization and release in the soil, and changes in pests, diseases and beneficial fauna.

**TABLE 5**

*Effects of cultivations and straw treatments on grain yield (t $ha^{-1}$) of Avalon winter wheat.*

| | Shallow tillage 10 cm | Deep tillage 20 cm | Shallow tillage +plough | Plough 20 cm |
|---|---|---|---|---|
| *Rothamsted* | | | | |
| Straw burnt | 9·88 | 10·01 | 10·06 | 10·01 |
| Straw chopped | 9·76 | 9·69 | 9·93 | 9·88 |
| *Woburn* | | | | |
| Straw burnt | 9·69 | 9·49 | 9·40 | 9·35 |
| Straw chopped | 9·44 | 9·66 | 9·40 | 9·53 |

***Yields.*** In this first year, yields differed little between treatments (Table 5) or between sites. (Prew, Field Experiments; Moffitt, Farm; Henderson and Powell, Entomology; Kerry, Nematology; Gutteridge and Jenkyn, Plant Pathology; Harper, Soil Microbiology; Christian, Goss and Johnston, Soils and Plant Nutrition; Todd, Statistics)

***Growth.*** Throughout the winter the crops on chopped-straw plots particularly those not ploughed, were yellower and thinner than those on the burnt plots. There were related differences in dry matter in April. At both Rothamsted (R) and Woburn (W) the ploughed



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burnt plots had the largest dry weight (140 g m$^{-2}$), compared with burnt shallow tillage plots (R 109, W 118 g m$^{-2}$), incorporated straw ploughed (R 124, W 117 g m$^{-2}$) and incorporated shallow tillage (R 94, W 65 g m$^{-2}$). The increases came from bigger plants with more tillers, but by harvest the number of ear-bearing shoots did not differ between treatments. (Prew and Yeoman, Field Experiments)

***Pests.*** Dipteran stem-boring larvae, mainly *Opomyza* spp., were prevalent on both sites. At Woburn 80% of plants had at least one stem attacked and there were no differences between treatments. At Rothamsted 40% of plants were affected, more stems were attacked on ploughed plots (51%) than on unploughed (28%). (Powell, Entomology)

**Effects of shallow straw incorporation.** The second experiment compared straw burning with baling or chopping on a site that was then shallow cultivated without inversion, either as soon after harvest as possible or two weeks later. A multifactorial arrangement of sub-plots allowed tests of autumn nitrogen, molluscicides (not applied in 1985), insecticides and fungicides.

***Yields.*** Straw treatments had no effect on yields (Table 6). The later timing of cultivations was better only on burnt plots. Fungicides and insecticides both increased yield but did not interact with either straw or cultivation treatments. Hectolitre weights were larger with than without fungicides (76·2 *vs* 72·9 kg hl$^{-1}$). (Prew, Field Experiments; Moffitt, Farm; Henderson and Powell, Entomology; Kerry, Nematology; Gutteridge and Jenkyn, Plant Pathology; Harper, Soil Microbiology; Christian and Johnston, Soils and Plant Nutrition)

**TABLE 6**

*Factors tested and their effects on grain yield (t ha$^{-1}$) of Avalon winter wheat*

| | Straw treatment | | |
|---|---|---|---|
| | Burnt | Baled | Chopped |
| Yield | 8·28 | 8·23 | 8·36 |
| Effect of: | | | |
| Early cultivation | −0·66 | −0·20 | 0·22 |
| Autumn N | 0·18 | 0·23 | 0·36 |
| Fungicides | 1·56 | 1·65 | 1·40 |
| Insecticides | 0·34 | 0·17 | 0·34 |

***Growth.*** Early growth was better on the burnt (BU) than on the chopped (C) plots and by December there were more shoots per plant (BU 2·2, C 1·8) and more of the seedling leaf remained green (BU 91%, C 65%). The burnt plots had most plants but not significantly more than chopped. However, the counts probably underestimate the effect of straw incorporation on establishment as there were more volunteers on the chopped plots. Final ear number was greater (558) with fungicide than without (472) but there were no interactions with straw or cultivation treatments and neither of these affected ear number. (Prew and Yeoman, Field Experiments; Jenkyn and Feekins, Plant Pathology)

***Fungal diseases and pests.*** *Septoria tritici* was the principal foliar pathogen throughout the year, although *S. nodorum* was also common in the summer. In December *S. tritici* was patchily distributed and only the autumn N treatment seemed to increase its severity. In March infection on the second youngest leaf was much less on the burnt (1·4%) than on the baled (BA) or chopped plots (BA 5·6, C 4·8%) with no effect of autumn N. By July, on plots without fungicide, the infection on the flag leaf was severe, and least on chopped plots (BU 27·1, BA 24·2, C 15·6%). The disease was well controlled by the fungicide on all straw

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treatments (0·7% on flag leaf) and presumably accounts for much of the yield response to this treatment. Infection by take-all (*Gaeumannomyces graminis* var. *tritici*) in March was slight (11% plants infected) with no differences between treatments. By April the burnt plots had most plants infected (BU 23, BA 15, C 10%) and there was more where cultivations had been done early (19%) rather than later (12%). In July the take-all rating showed similar effects of straw treatment (BU 123, BA 116, C 96) with plots cultivated early again having more (126) than those done later (98). Also in July, on plots without fungicides, the percentage of plants with moderate or severe eyespot (*Pseudocercosporella herpotrichoides*) infection tended to be least on chopped plots (BU 21, BA 27, C 13%) and more with early (28%) than later (13%) cultivations. The fungicide treatment decreased infection to 1%, presumably also contributing to the yield benefit from fungicide application. Sharp eyespot (*Rhizoctonia cerealis*) and brown foot rot (*Fusarium* spp.) were slight (2 and 1% straws infected respectively) and did not differ with treatments.

Damage by stem borers (*Opomyza* spp.) in April was much greater on burnt plots than on baled or chopped (BU 46, BA 24, C 17% plants infested). (Jenkyn, Gutteridge and Feekins, Plant Pathology)

### Assessment of the positions of straw in soil

A standard method to describe the positions of straw in the soil profile was not available for the first year of these experiments. A method has now been devised and, together with the method developed at the National Institute of Agricultural Engineering (NIAE) to estimate surface cover of straw (Holden & Knight, *Aspects of Applied Biology* (1985) **10,** 451–463), will be used in future work.

The method requires that soil is left to settle after straw incorporation and that assessment is done after seedbed preparation has produced a level soil surface. A pit just over one metre long is dug across the direction of cultivation to reveal the profile down to the depth of soil disturbance. A face is prepared at approximately 45° to the vertical and a grid (1 m by 30 cm), consisting of a frame supporting wires or string at 5 cm horizontal and 7 cm vertical spacing is placed against the exposed profile. The 7 cm spacing represents 5 cm of soil depth. Within each area of 5 cm by 7 cm the percentage cover of straw is recorded by comparison with a series of 'standard' photographs. The technique shows the position of straw but as yet provides only a qualitative description of distribution. The results can be presented in diagrammatic form with the aid of a computer. (Harper and Bowen, Soil Microbiology)

### Factors affecting tillering of winter wheat

The series of multifactorial experiments investigating factors limiting yield of winter wheat, which was completed last year, produced data showing that in most years applying the main spring nitrogen dressing in mid-April instead of early March increased grain yield, especially when wheat was sown in September rather than October. The data suggested that the earlier timing was preferable when supplies of nitrogen from the soil were very small and sometimes when take-all was severe. Otherwise it was unnecessary to supply nitrogen fertilizer until the warmer temperatures of April caused increased growth and nitrogen demand. Later nitrogen applications are generally to be preferred because they are at less risk from leaching or denitrification. The results did not support the view that apical development is of overriding importance as a criterion for determining nitrogen timing. September-sown wheat reached a particular development stage sooner than did wheat sown in October, but generally required nitrogen later. However, apical development is a convenient way of identifying the physiological stage when tiller production stops and tiller death starts. It can thus be used to indicate when nitrogen should be used to increase tiller number and when to increase tiller



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survival. The general conclusions from the experiments, which depended to some extent on the contrast between results obtained in 1980–81, when there were large nitrogen residues from previous potato crops, and in 1982–84, when residues from previous cereals were less, may have been affected by the change in variety in 1982 from Hustler to Avalon. A new experiment was therefore started this year to see whether the response of Avalon to the timing of spring nitrogen depended on the residues from previous crops.

The experiment, sown on 19 September, was a single replicate $2^5$ factorial. Factors tested were: (1) winter oats or spring oilseed rape as previous crop, (2) winter N: 60 kg ha$^{-1}$ applied 7 November or none, (3) early spring N applied 18 March or half on 18 March and half on 25 February, (4) late spring N applied 15 April or half on 15 April and half on 9 May, (5) summer N: 60 kg ha$^{-1}$ on 30 May at flag leaf emergence or none. Early spring N was 80 and 60 kg ha$^{-1}$ after oats and rape respectively. Late spring N was 160 and 120 kg ha$^{-1}$ after oats and rape respectively.

**Yield at maturity.** Grain yield decreased with increase in supply of nitrogen in winter, whether this was from the previous crop or fertilizer. Yields without and with winter nitrogen were: after oats 10·66, 10·42, after rape 10·34, 9·82 t ha$^{-1}$. These yields were well related to amounts of lodging, which started after heavy rain 10 days before anthesis, and increased from a mean of 10% of the plot area lodged on 10 June to 87% on 9 August. Because of severe lodging the whole plot width was harvested, so yields are not comparable with previous ones from the multifactorial experiments. Decreased yields with lodging were accounted for by fewer grains per ear. Dry weight per grain was unaffected and averaged 41·5 mg, less than in 1984 but greater than in 1982 or 1983. The spring treatments had no effect on dry grain weight or grain yield. Summer nitrogen increased yield by 0·3 t ha$^{-1}$. (Thorne and Wood, Physiology and Environmental Physics; Prew, Field Experiments; Penny and Darby, Soils and Plant Nutrition; Todd, Statistics)

**Growth and development.** Wheat after rape developed faster than that after oats. Dates of double ridges, terminal spikelet and anthesis were: after rape 4 March, 19 April, 16 June; after oats 12 March, 23 April, 17 June (p. 63). Winter nitrogen did not affect these. Wheat after rape had greater dry weight, leaf area and shoot number than wheat after oats throughout the winter and spring, but the differences were less than 5% by anthesis. Winter nitrogen had similar though initially smaller effects. By mid-March growth of wheat after oats with winter nitrogen equalled that after rape without winter nitrogen. Applying nitrogen in February and March instead of only in March initially increased dry weight of crop not given winter nitrogen, but all effects of these treatments were negligible by anthesis. The paucity of interactions during growth up to anthesis between winter nitrogen supply and later treatments make it unlikely that interactions affecting grain yield were obscured by lodging. (Thorne, Wood and Mullen, Physiology and Environmental Physics)

**Nitrate-N in the soil.** On 1 October the soil contained, to a depth of 90 cm, 82 kg $NO_3$-N ha$^{-1}$ after rape and 22 kg after oats. This 60 kg difference led to the choice of this amount for the winter N treatment. On 31 January the same plots were sampled again; amounts of $NO_3$-N had by then fallen to 25 kg ha$^{-1}$ after rape and 14 kg after oats.

**Nitrate-N in wheat shoots.** Without fertilizer N, the sap of the lower parts of the wheat shoots sampled on 20 November, 17 December, 29 January and 25 February contained, after rape and oats respectively, 920 *vs* 400, 710 *vs* 460, 540 *vs* 420 and 430 *vs* 380 ppm of $NO_3$-N. Values fell to less than 200 ppm in late March after oats and in early April after rape and to nil in late April after oats and in early May after rape. Winter N increased the concentration of nitrate-N (e.g. in November, 1000 ppm after rape *vs* 920 after oats; in January, 750 after rape



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*vs* 710 after oats) but decreased the initial large difference from previous crop. After the application of spring N the content of $NO_3$-N increased but did not differ consistently with previous crop; mean values fell from 730 ppm on 26 March to 270 ppm on 11 June when sampling stopped.

**Nitrogen contents of crops.** In March, although the crop was larger after rape than after oats, percentage of N in the dry matter was smaller (4·18 *vs* 4·38) but by anthesis (in June) percentage of N in each was the same (2·00). Uptake of N in March, however, was much larger after rape than after oats (74 *vs* 48 kg N ha$^{-1}$) but at anthesis they hardly differed (259 *vs* 262 kg).

Winter N had little effect on percentage of N in March but had nearly always increased it by anthesis. In March, the uptake without winter N was 36 kg N ha$^{-1}$ after oats and 66 kg after rape, and with winter N, 60 and 82 kg N ha$^{-1}$ respectively. The uptakes after rape without winter N and after oats with winter N were not significantly different. At anthesis, uptakes of N after rape and after oats were similar without winter N (240 *vs* 248 kg N ha$^{-1}$) and also with it (278 *vs* 275 kg).

At anthesis neither timing nor division of spring N significantly affected percentage of N and uptake after either crop. Summer N significantly increased percentage of N and uptake after oats, but only where winter N had not been given, but not after rape. (Penny, Widdowson, Bird, Darby and Hewitt, Soils and Plant Nutrition)

**Diseases.** Foliar diseases were well controlled by basal fungicide applications so that the greatest mean infection was only 1·5% of the area of leaf 2 with Septoria in mid-July. The only effect of treatments was a slight increase in Septoria with winter N application. Foot and root rots were very slight in spring (take-all 1·1% plants infected, eyespot 1·3% shoots infected, and sharp eyespot 3·0% shoots infected). Only sharp eyespot developed so that in July 30·5% of straws were infected, 13·0% severely; amounts were slightly greater when the early-spring nitrogen application was divided. (Prew and Yeoman, Field Experiments)

### 'Cereals '85' at Stoneleigh, Warwickshire

Demonstration plots were sown to Igri winter barley and to Avalon winter wheat, both given much or little nitrogen, with or without crop protection chemicals. These plots provided a backcloth to the presentation of results from the multidisciplinary experiments by members of the two teams. Once again the interest of these results to farmers was evident by the numbers gathered around the boards even in the appallingly cold and wet conditions on the second day.

## PUBLICATIONS

### Research Papers

McEwen, J., Bardner, R., Bater, J. E., Cockbain, A. J., Fletcher, K. E., Lapwood, D. H., Salt, G. A., Webb, R. M., Williams, T. D. & Yeoman, D. P. (1985) Control of pests and pathogens of spring-sown field beans (*Vicia faba* L.). *Research and Development in Agriculture* **2,** 177–185.

Prew, R. D., Church, B. M., Dewar, A. M., Lacey, J., Magan, N., Penny, A., Plumb, R. T., Thorne, G. N., Todd, A. D. & Williams, T. D. (1985) Some factors limiting the growth and yield of winter wheat and their variation in two seasons. *Journal of Agricultural Science, Cambridge* **104,** 135–162.



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