Report for 1980 - Part 1

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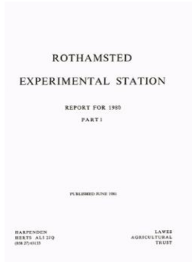
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Report on Multidisciplinary Activities

E. Lester

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MULTIDISCIPLINARY ACTIVITIES

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The chapter includes reports of experiments on winter barley, field beans, leafless peas and a new deep cultivations and manuring experiment in addition to the second of the series investigating yield variation in winter wheat. Considerable effort has been devoted to correcting a general dearth of precise measurements of soil and root conditions, compared with a wealth of above-ground measurements. This has involved the provision of substantial areas for destructive sampling that stretches our land resources to the limit. The volume of work involved in processing samples of roots taken on several occasions through the life of the winter wheat crop has meant that the data from these samples are not available for inclusion in this report. The detailed measurements on soil, water and roots have had to be shared among three Departments, Botany, Physics, and Soils and Plant Nutrition. Without a high degree of willing cooperation comprehensive data could not have been collected.

On winter wheat, seasonal effects on treatment responses are of interest. Early sowing gave a mean increase of 1·0 t ha^{-1} (1979 = +0·15), aphicide + 0·1 (1979 = +1·3) and fungicide + 0·8 (1979 = +0·97). Irrigation again slightly depressed yield but more on early-sown, late-nitrogen, no-fungicide plots (−0·6 t ha^{-1}). Mean yield of all plots was 9·6 t ha^{-1} (1979 = 9·7), one-third of the plots in both years yielded more than 10 t ha^{-1} but fewer yielded more than 11 t ha^{-1} in 1980, six compared with 16 in 1979. The winter barley experiment also produced large yields, the best being in excess of 9 t ha^{-1}. Early sowing, the later application of a single nitrogen dose and particularly the use of a growth regulator had the greatest beneficial effect, the last giving a mean increase of 0·83 t ha^{-1}.

In spring beans, the most effective pest and pathogen control increased yield by 1·7 t ha^{-1} in 1980 but at very high cost; 'economic' control (£40 ha^{-1} in this experiment) gave 0·7 t ha^{-1} more grain. Unexpectedly, irrigation caused a mean yield depression, the more so the better the control of pests and pathogens. In leafless peas soil treatment with aldicarb consistently had the greatest beneficial effect on yield but the effects were not accounted for satisfactorily by the differences in pest and disease levels recorded.

TABLE 1

Factors tested and their effects on grain yield (t ha^{-1}) of Hustler winter wheat. Means over all other factors

Level 1	Yield	Level 2	Yield
(1) Sown early (E) 20 September	10·12	Sown later (L) 19 October	9·10
(2) Nitrogen rate 1 105 kg ha^{-1}	9·43	Nitrogen rate 2 175 kg ha^{-1}	9·80
(3) Nitrogen single application	9·57	Nitrogen split application 40 kg early, 25 kg late, remainder at time of single application	9·66
(4) Timing of main nitrogen application Ear initiation early-sown (4 March)	9·38	Timing of main nitrogen application Ear initiation late-sown (15 April)	9·85
(5) Irrigation 150 mm Soil moisture deficit limited to 25 mm	9·55	None	9·68
(6) Autumn pesticide—aldicarb Applied to seedbed 5 kg ha^{-1}	9·61	None	9·62
(7) Summer aphicide—pirimicarb 0·14 kg ha^{-1} (18 June)	9·68	None	9·55
(8) Fungicide 'Cosmic'* + 'Sanspor'† 4 kg ha^{-1} + 2·0 l ha^{-1} 9 May and 18 June	10·01	None	9·22

* 'Cosmic', a.i. maneb + tridemorph + carbendazim
† 'Sanspor', a.i. captafol

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Factors limiting yield of winter wheat

The study of factors controlling the yield of winter wheat cv. Hustler started in 1978–79 (*Rothamsted Report for 1979*, Part 1, 17–22) was continued with another multifactorial experiment. Seven of the factors tested were similar to the previous experiment (Table 1). The comparison between drills was not repeated: the whole experiment was precision-sown with the Stanhay drill. An additional factor tested was nitrogen applied early or late: at ear initiation (double ridge) stage of the early- and later-sown crops respectively. Nitrogen had been applied between these stages in 1979. Also the method of estimating the rates of nitrogen required was modified, resulting in smaller dressings in 1980. This year there was no similarly-treated wheat grown on the Lower Greensand at Woburn for comparison.

Yield at maturity. Grain yields were again large. The mean of all plots was 9·6 t ha^{-1}; a third yielded more than 10 t ha^{-1} and six plots more than 11 t ha^{-1}. The largest increases were obtained by earlier sowing and applying fungicide (Table 1). The early-sown crop yielded 1·0 t ha^{-1} more than the later-sown one. It had more ears with fewer, larger, grains. Fungicide increased yield by 0·8 t ha^{-1} by increasing weight per grain. This effect increased to 1·2 t ha^{-1} on irrigated plots given the larger amount of nitrogen. Averaged over all plots, aphicide increased and irrigation decreased yield by 0·1 t ha^{-1} and aldicarb had no effect. The decrease with irrigation was greater (0·6 t ha^{-1}) with early sowing, late nitrogen and no fungicide probably because of an increase in *Septoria*. It could be accounted for by smaller grains. The test of a wider range of nitrogen rates on extra plots showed that the optimum was close to the high rate used in the main experiment (175 kg N ha^{-1}) which, with fungicide, outyielded the low rate (105 kg N ha^{-1}) by 0·6 t ha^{-1} and the two plots given no fertiliser nitrogen by 3·5 t ha^{-1}. The additional nitrogen increased the number of ears in late-sown crops, increased grain number per ear in early-sown crops and decreased grain size in both. Dividing the nitrogen application into three had a negligible affect on grain yield compared with a single application. The later time of application gave a larger yield with early but not with later sowing; the difference could be accounted for by an increase in grains per spikelet. In contrast to grain yield, straw yield was greater with early than with late nitrogen and was increased by irrigation: it was increased relatively more than was grain yield by earlier sowing and relatively less by fungicide. The results of individual sponsors' sampling are reported below. (Thorne, Botany Department, Dewar, Entomology Department, Williams, Nematology Department, Lacey, Plumb, Prew, Plant Pathology Department, Penny, Soils and Plant Nutrition Department, Church and Todd, Statistics Department)

Growth and development. The experiment was sampled seven times (Table 2). The number of plants established with early sowing was 294 m^{-2} and with later sowing 222 m^{-2} (77 and 58% of the seeds sown). The early-sown crop tillered much earlier and had a larger maximum shoot number than the later-sown crop (Table 2). For both, maximum tiller number coincided with the double ridge stage. Only 30% of the early-sown shoots and 36% of the later-sown ones survived to form mature ears. As with shoot number, dry weight and leaf area during the winter were much greater with early sowing. The difference in dry weight was 2–3 t ha^{-1} by mid-April; it changed little thereafter. Later sowing considerably decreased leaf area index at anthesis but the light intercepted by the crop was decreased only slightly—from 98 to 92% of the incident. The relative effect of sowing date on ear dry weight at anthesis, as on grain yield, was considerably less than on total dry weight.

Increasing the amount of nitrogen applied from 105 to 175 kg N ha^{-1} increased shoot

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TABLE 2

Change with time in total dry weight (g m–²), leaf area index, number of shoots m–² and Zadoks' growth stage of winter wheat sown on 20 September (E) or 19 October (L). Means over all other treatments

	Sowing date	10 December	3 March	14 April	6 May (E) 20 May (L)	12 June (E) 19 June (L)	7 August	21 August
Total	E	61	141	316	508	1147	1839	1710
Dry weight	L	5	20	93	397	871	1563	1450
Leaf Area	E	1·0	1·7	4·0	6·5	8·0	0·9	0
Index	L	0·1	0·3	1·0	4·7	5·8	1·8	0
Number of	E	1567	1871	1294	864	561	541	546
shoots	L	214	837	1338	699	473	477	473
Growth	E	14/24	16/25*	30	32	65	87	92
stage	L	12/20	15/23	26*	36	65	85	92

*'Double ridge' (ear initiation) stage

number, dry weight and leaf area at most samplings by up to 16%. In the early-sown crop, tiller death was delayed with the larger amount of nitrogen but final ear number was not affected. With early sowing, applying nitrogen when tiller number was maximal (early N) or when almost half the tillers had died (later N) resulted in the same number of ears at anthesis. With later sowing, applying nitrogen during tillering (early N) increased maximum tiller number by 645 m^{-2}. Fewer of these tillers survived than in plots given later nitrogen and final ear numbers were similar. When 40 kg N ha^{-1} (first application of divided N) was applied before maximum tiller number was reached in early- or later-sown crops, this number was increased but the number of ears was the same as with the single application of nitrogen. The response of total dry weight and leaf area to delaying or dividing the application of nitrogen was unaffected by sowing date. Total dry weight up to anthesis and stem dry weight after were less with the later than with the early nitrogen application. Delaying the application of nitrogen increased the growth of ears after anthesis with early but not with later sowing. Delaying the application of nitrogen decreased leaf area index in April and May, did not affect it at anthesis and delayed leaf senescence in August. Dividing the nitrogen application into three resulted in faster growth soon after the first application than in crops that had not yet received nitrogen. Any difference in dry weight or leaf area between crops given a divided and a single application disappeared soon after the main application when this was in March and persisted only until anthesis when the main application was delayed until April.

Aldicarb and pirimicarb had negligible effects on growth. Fungicide delayed leaf senescence, did not affect stem weight and increased dry weight of ears significantly only at maturity. Between 7 August and maturity on unsprayed plots ear dry weight decreased but on sprayed ones continued to increase.

Irrigation (150 mm) was applied between 13 May and 26 June. This decreased the death of tillers before and after anthesis so that final ear number was increased from 480 without to 539 with irrigation, but dry weight per ear decreased, so that ear dry weight m^{-2} was unaffected. Dry weight of stem plus leaf and leaf area from anthesis onwards were also increased by irrigation. The main differences in crop growth from that in 1979 were that the early-sown grew faster during the winter and at anthesis its dry weight was greater; and a greater proportion of tillers died resulting in fewer ears. (Taylor and Thorne, Botany Department)

Nitrogen contents

Early v. later sowing. On 10 December and 3 March early-sown wheat contained 4·91 and 3·87 %N respectively whereas the later-sown contained about 5% on both

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dates. Because of huge differences in growth, uptakes of N by the early-sown wheat in December (30 kg ha^{-1}) and in March (55 kg) were 12 and five times larger respectively than by the later-sown. R. J. B. Williams measured NO_3-N in the stems: on 10 December the early-sown contained 860 ppm, the later-sown 730. On 25 January values were 750 and 830 ppm respectively and by 3 March they had decreased to 250 and 230 ppm (on wheat not yet given N). On 14 April the early-sown wheat contained 3·15 %N, the later-sown 4·32% but thereafter the differences became much smaller. At anthesis, values for the early- and later-sown were 1·53 and 1·62 respectively; by 7 August they had decreased to 1·10 and 1·17 %N. Because of the large differences in dry matter, uptake of N by the early-sown on 14 April (102 kg ha^{-1}) was more than double that by the later-sown and in May (139 kg ha^{-1}) 30% more. By 7 August the early- and later-sown had taken up 203 and 183 kg ha^{-1}, about 15 and 30% more respectively than at anthesis. On 21 August the early-sown contained 189 kg N ha^{-1} in grain plus straw, 19 kg more than in the later-sown and on 24 August 157 kg ha^{-1} in the combine-harvested grain, 11 kg more than in the later-sown.

Split v. single and early v. late nitrogen. Forty kg N ha^{-1} applied on 30 January significantly increased %N in both early-and later-sown wheat on 3 March, but uptake of N only by the early-sown (from 48 to 75 kg ha^{-1}), and increased stem NO_3-N contents from 250 and 230 ppm in the early- and later-sown crops to 710 and 830 ppm respectively. Forty kg N ha^{-1} applied on 4 March approximately doubled N uptake by 14 April, to 95 kg ha^{-1} by the early-sown and 40 kg by the later-sown. Without N, stems of the early-sown contained only 20 ppm of NO_3-N, those of the later-sown none; 40 kg N in March did not alter NO_3-N content of the early-sown but increased that of the later-sown to 130 ppm. Although, at this sampling, %N in wheat given all its N on 4 March was larger than in that given only two (30 January and 4 March) of the three split dressings, N uptakes differed little because yields were larger with the latter treatment. Mean NO_3-N content of the early-sown was larger with the single N dressing (460 ppm) than with only two parts of the divided (420 ppm); values in the later-sown did not differ (mean 520 ppm). By May, %N tended to be larger where N had been applied late rather than early; by contrast N uptakes were larger with N applied early, because yields were larger. On 20 May stems of both early- and later-sown wheat not given N contained only 10 ppm of NO_3-N; mean values with early and late N were 40 and 80 in the early-sown, 80 and 90 in the later-sown. From anthesis (Table 3) both %N and N uptake were nearly always larger with single than with split N dressings, and always larger with late than with early N, for both sowings.

TABLE 3

Effects of timing and splitting nitrogen application on N content and uptake by winter wheat

	%N in dry matter				N uptake (kg ha^{-1})			
	Split N		Single N		Split N		Single N	
Applied	Early	Late	Early	Late	Early	Late	Early	Late
Whole crop								
Anthesis	1·49	1·59	1·50	1·70	153	160	159	160
7 August	1·08	1·11	1·13	1·22	185	189	192	207
Grain								
24 August	1·81	1·87	1·80	1·93	146	156	142	162

Nitrogen rates. N rates could not be compared strictly until anthesis; then and afterwards 175 instead of 105 kg ha^{-1} always significantly increased %N and N uptake. By 7 August (when N uptakes were largest) early-sown wheat had taken up 183 and 223

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kg ha^{-1} respectively with the two amounts of N, and the later-sown 164 and 202 kg. Corresponding uptakes by the mature grain were about 30% smaller and there was a significant positive rate of N × fungicide interaction on them, reflecting a similar interaction on grain yield. (Darby, Hewitt, Penny and Widdowson, Soils and Plant Nutrition Department)

Nematodes. The site was sampled three times (Table 4). Aldicarb was the only main factor to affect nematode numbers consistently although, in May soil samples, *Tylenchus* and total nematode counts were highest on early-sown, while in August larger numbers of *Pratylenchus* were associated with the later-sown plots. Nematode numbers were

TABLE 4

The effects of aldicarb (A with, — without) on plant parasitic nematodes (nematodes per litre of soil). Means over all other treatments

	Pratylenchus spp.		*Tylenchus* spp.		*Tylencho-rhynchus* spp.		*Helico-tylenchus* spp.		Total spear-bearing nematodes	
Pre-crop 1979	375		400		275		0		1325	
	A	—	A	—	A	—	A	—	A	—
May 1980	94	281	359	625	44	209	19	116	575	1406
August 1980	325	734	375	578	272	803	69	366	1159	2722

negligible in the May root samples—probably due to the spring drought (only 11 mm rain fell between 6 April and 17 May, the potential soil moisture deficit reaching 98 mm by the latter date). All counts showed significant decreases with aldicarb but numbers generally were below those usually expected to affect yield. Except for *Tylenchus*, numbers increased between May and August with and without aldicarb but less so with treatment. The results were generally similar to those for 1979. (Bean and Williams, Nematology Department)

Aphids. Vacuum samples were taken throughout the winter. Aphids were present only on the early-sown plots; total numbers were about half those in 1979 (2 m^{-2} in October; 3 m^{-2} in November) with over twice as many *Rhopalosiphum padi*. Aldicarb greatly decreased the numbers. In later samplings aphids were present only in the absence of aldicarb, numbers of *Sitobion avenae* remaining fairly constant while *R. padi* increased to 10 m^{-2} in January and early February decreasing to 1 m^{-2} later in February. A new species of *Metopolophium*, as yet unnamed, was present in small numbers at each sampling.

In the summer *S. avenae* was the most prevalent species with a substantial number of *Metopolophium* sp. present in May. *S. avenae* reached a maximum about a week earlier on the early-sown than the later-sown but persisted longer on the latter and in all crops were greatly decreased by primicarb (Table 5). However, predator populations (ladybirds, syrphids and lacewings) built up fast, especially on the crops with most

TABLE 5

Effects of nitrogen, sowing date and pirimicarb (P with, — without) on numbers of Sitobion *on winter wheat. Means over all other treatments*

		Aphids m^{-2}		Aphids per 100 shoots				
	kg N ha^{-1}	7 May	28 May	10 June	25 June		2 July	
					P	—	P	—
Sown early	105	8·5	21·0	181	21	198	8	15
	175	30·5	49·0	200	22	220	3	14
Sown later	105	0·5	13·6	100	26	310	4	133
	175	9·0	15·0	105	17	229	9	54

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aphids, decreasing the potential benefit of the pirimicarb. (Dewar, Entomology Department)

Barley yellow dwarf virus (BYDV). The incidence of BYDV was assessed on 30 June and 21 July. There was more infection than in 1979 and several foci of infection up to 1 m diameter were seen. Infection was four times as common on early- as on later-sown plots but the mean percentage infection even on early-sown plots was less than 1% though some showed 2–3% infection. Aldicarb decreased virus incidence on early-sown plots by 92% but had very little effect on those sown later. (Plumb, Plant Pathology Department)

Fungal diseases. Mildew was present from early in the season but never became severe. *Septoria* infection did not develop on the upper leaves until early July but thereafter became progressively more severe especially on early-sown irrigated plots without fungicide. Foot rots, although less than 5% straws were infected in early spring, were prevalent by July. Eyespot was worst with early sowing and without fungicide. Sharp eyespot was unaffected by fungicide but greatly decreased by irrigation (Table 6). (Prew, Plant Pathology Department)

TABLE 6

Effects of fungicide on diseases of winter wheat. Means over all other treatments

		Foliar diseases (% leaf area infected)				Foot rots (% straws infected)	
		11 June leaf 3	21 July leaf 1		6 Aug. leaf 1	4 July	
		Mildew	Mildew	Septoria	Septoria	Eyespot	Sharp eyespot
Fungicide	full	0·49	0·03	0·03	1·11	4	14
	none	0·66	0·06	0·53	5·47	40	12
Irrigation	full	0·66	0·04	0·33	4·27	24	7
	none	0·48	0·05	0·23	2·32	19	19
Sown	early	0·43	0·03	0·46	3·76	28	11
	later	0·72	0·07	0·11	2·83	16	15
Nitrogen	early	0·73	0·05	0·34	3·45	26	16
	later	0·42	0·05	0·23	3·14	17	10

Microflora of developing ears. Bacteria again dominated the microflora of developing ears but the numbers grown in dilution plates were about ten times greater than in 1979. Numbers increased steadily throughout the ripening period reaching a maximum of about $9{\cdot}5 \times 10^8$ g^{-1} fresh weight at harvest (Table 7). The fungal flora was at first dominated by pink and white yeasts with smaller numbers of the yeast-like fungi *Aureobasidium pullulans* and *Hyalodendron* sp. Between growth stages 75 and 78, the yeasts declined in number

TABLE 7

The effects of fungicide (F with, — without) on the microflora of developing ears of winter wheat assessed by dilution plating. Means over all other treatments

Date	19/6		3/7		21/7		18/8	
Growth stage	60		73–75		78–79		91–92	
	(No. colonies g^{-1} fresh wt $\times 10^{-5}$)							
	—	F	—	F	—	F	—	F
Yeasts	21·3	9·5	29·5	20·6	8·5	9·4	12·8	17·6
Yeast-like fungi	3·1	1·9	6·7	4·4	9·6	10·2	24·2	37·4
Filamentous fungi	1·4	1·2	9·1	6·8	13·5	12·5	44·6	55·9
Bacteria	872	375	2120	1750	1970	2140	9460	9510

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but yeast-like and filamentous fungi continued to increase with *Cladosporium herbarum*, *C. cladosporioides*, *Verticillium lecanii*, *Alternaria tenuis* and *Epicoccum purpurascens* predominant. At harvest up to 70% of the grain carried *Alternaria*, 75% *Cladosporium*, 35% *Epicoccum* and 20% *Fusarium culmorum* but storage fungi were few with *Penicillium* spp. on only 5–15% of grains and *Aspergillus* spp. on less than 1%.

The fungicide treatment resulted in an immediate significant decrease in the population of fungi on the ears but this persisted for only 2 weeks. Numbers then recovered to a level similar to that on untreated plots. This decrease was largely due to a significant decrease in numbers of pink yeasts and *Aureobasidium*. Populations of *Cladosporium*, *Alternaria*, *Verticillium* and bacteria were little affected by fungicide treatment. (Lacey and Magan, Plant Pathology Department)

Winter barley: effects of sowing date, timing of nitrogen and a growth regulator

Sonja winter barley (dressed 'Muridal') followed early potatoes and was sown on 18 September or 16 October. Fungicides were given basally, tridemorph on 15 November and 5 April and tridemorph+benodanil on 14 May; 35 kg N ha^{-1} (as 'Nitro-Chalk') was given on 25 January in combination with either 75 or 110 kg N ha^{-1} applied either on 7 March or on 8 April or half on each date. Table 8 gives the apical development stage, classified according to a scheme devised by Dr E. J. M. Kirby at the Plant Breeding Institute, that the crops had reached on these dates.

TABLE 8

The developmental stage of the apex at the date that nitrogen fertiliser was applied to Sonja winter barley sown on 18 September (E) or 16 October (L)

Application date		25 January	7 March	8 April
Stage	E	Triple mound	Lemma primordia	Awn primordia
	L	Early double ridges	Glume primordia	Anther primordia

Mepiquat chloride+ethephon was applied at the two-node stage on 22 April to the September-sown and on 7 May to the October-sown crop. These five factors, 4 at 2 levels and 1 at 3 were evaluated as a single replicate of 48 plots and together with two plots not given nitrogen, were arranged in two blocks of 25 plots. Five plots from each sowing date which were not treated with the growth regulator were used to study plant establishment, tillering and apical development. About 250 plants m^{-2} were established for both sowings. There was no detectable decline in plant population during the mild winter. On average, each plant of the early sowing produced 9·5 tillers, 31% of which survived to give 3·9 ears per plant (including the mainstem ear). Comparable figures for the later sowing were 7·9, 17% and 2·4 respectively. Ear counts on all plots in June confirmed that the September sowing gave more ears than the October sowing (993*v*. 648 ± 20·0) but that neither amount of nitrogen nor its timing had any significant effect, though April N gave most ears.

Mainstems of the early-sown crop produced 14·5 leaves on average and those of the late-sown about 12. Maximum spikelet numbers on the mainstems were 43 and 42 respectively. The fraction of spikelets that produced grain was greater for the late (0·57) than for the early sowing (0·44). This was associated with faster growth per culm during the phase of spikelet death for the late-sown crop.

Straw length was measured on 13 June. It was decreased by early sowing (92·0 *v*. 95·9 cm), increased by January N (+5·2 cm), unaffected by N given in March or April

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and greatly decreased by the growth regulator (100·6 to 87·4 cm $\pm$ 1·25). The regulator had more effect on the straw length of the late- than of the early-sown crop. So each then was of a similar length (86·6 *v.* 88·2 cm $\pm$ 1·77) to the base of the ear. The regulator greatly reduced lodging, which was more widespread on the October- than the September-sown plots.

Grain yields were enhanced by early sowing (8·35 *v.* 8·12 t ha^{-1} $\pm$ 0·142) but little by giving N in January. The main dose of N was best applied to both the early and the late sowings as a single dressing; and in April (8·45 t ha^{-1}) rather than in March (8·01 t ha^{-1}); a split application gave a smaller yield than a single application in April.

The growth regulator increased yields of the first sowing by 0·78 t ha^{-1}, and of the second sowing by 0·88 t ha^{-1}. It had no significant influence on the dry mass per grain of either the September- (41·0 mg) or the October-sown (46·0 mg) crops; its effect was due to an increase in the number of grains m^{-2}. This was caused by slight increases in ears m^{-2} and grains per ear but this last response was associated with a lesser degree of bird damage. Mean yield without nitrogen was 6·35 t ha^{-1}. Best yields were in excess of 9 t ha^{-1} and were obtained with treatments involving September sowing, 35 kg N ha^{-1} in January, 110 kg N ha^{-1} in April and the growth regulator. In all the combinations possible with three of the five treatments, this combination of nitrogen treatment and growth regulator gave the largest mean yield (9·30 t ha^{-1}). The growth regulator increased grain yields significantly in 20 of 30 comparisons made in these 3-factor tables. (Gallagher, Botany Department, and Widdowson, Soils and Plant Nutrition Department)

Spring barley: effects of subsoiling and deep incorporation of P and K

We have previously reported benefits, at Rothamsted and Woburn, from both subsoiling and deep incorporation of P and K using the Wye double-digger (*Rothamsted Report for 1978*, Part 1, 123–124). This machine rotary cultivates the subsoil at the base of one furrow while mouldboard ploughing the adjacent furrow and can be adapted to mix fertiliser into the subsoil. The previous experiments were too small to permit detailed sampling to determine the causes of the effects.

This year a new experiment was started at Rothamsted, using the Wye double-digger with plots large enough to study the effects on both yield and other variables. Soil treatments tested were subsoiling alone with a plough depth of about 23 cm and the subsoil rotary cultivator working a further 15 cm deep, subsoiling with deep incorporation of a large dressing of phosphate (1000 kg P_2O_5 ha^{-1}) and of potash (500 kg K_2O ha^{-1}) either singly or together, mouldboard ploughing alone to 23 cm depth (duplicated) and the same rates of phosphate and potash applied together to the topsoil, half before mouldboard ploughing, half after. Soil treatments were applied in autumn and were tested in two replicates of all combinations with N fertiliser applied in the spring to the seedbed at 0, 40, 80 and 120 kg N ha^{-1}. All plots were given a basal compound fertiliser, combine drilled with seed, to supply 60 kg P_2O_5 and 60 kg K_2O ha^{-1}. The experiment was sown with cv. Georgie on 5 March and harvested on 19 August. Nearly 100 mm of rain fell in the 5 weeks after sowing but it was then generally dry until early June; thereafter there was above-average rainfall until maturity.

Grain yields (Table 9) showed benefits, relative to mouldboard ploughing, at all rates of N, from both subsoiling (mean + 0·5 t ha^{-1}) and subsoiling plus deep PK (mean + 1·1 t ha^{-1}) but there was much variability between the replicates and consequently large standard errors, a problem also encountered in other measurements. (Taylor and Welbank, Botany Department, McEwen and Yeoman, Field Experiments Section, W. Day, French and Leach, Physics Department, Barraclough, Johnston, Leigh and Poulton, Soils and Plant Nutrition Department)

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TABLE 9

Effects of subsoiling and deep PK on grain yield of spring barley, t ha⁻¹ at 85% dry matter

	N (kg ha^{-1}) 0	40	80 ($\pm 0 \cdot 88$)*	120	Mean ($\pm 0 \cdot 44$)*
Soil treatment					
Ploughed only	3·2	4·2	5·9	6·4	4·9
Subsoiled only	3·4	5·3	6·2	6·7	5·4
Subsoiled + deep P	3·9	4·2	6·3	6·0	5·1
Subsoiled + deep K	2·8	4·6	6·6	6·5	5·1
Subsoiled + deep PK	4·7	6·0	6·5	6·9	6·0
Ploughed + topsoil PK	3·7	5·5	5·8	6·9	5·5
Mean (SED $\pm 0 \cdot 33$)	3·5	4·8	6·2	6·5	5·3

*SEDs for comparisons between 'Ploughed only' and other soil treatments are $\pm 0 \cdot 76$ and $\pm 0 \cdot 38$ for body of the table and means respectively

All subsoil treatments were also ploughed

Results from sponsors' sampling are reported briefly below.

Above-ground crop measurements. Establishment counts in mid-April showed a satisfactory mean population of 245 plants m^{-2}, with no significant effects of treatments but with considerable within-plot variation from wheeling damage at sowing. Some plots given the greatest N rate lodged, particularly those also subsoiled + PK, but it was considered that yield was not lost as a result. (McEwen and Yeoman, Field Experiments Section)

Total above-ground dry matter was measured on all plots at the end of June. Quantities ranged from 3·3 t DM ha^{-1} from untreated plots without N to 9·7 t DM ha^{-1} from plots subsoiled + PK and 120 kg N ha^{-1}. The ranking of treatment effects was similar to that of grain yields. (Johnston and Poulton, Soils and Plant Nutrition Department)

Stomatal resistance was measured for selected treatments on the youngest fully expanded leaf from mid-May to late June. Typical mean values were 1·8 s cm^{-1} for the adaxial leaf surface and 3·3 s cm^{-1} for the abaxial surface with no significant differences between treatments. Leaf water potential was measured on the same plots from mid-May to early July. Mean values for the period 1300 GMT to 1600 GMT were $-1 \cdot 6$ MPa in May and $-1 \cdot 8$ MPa in June with no significant treatment effects.

Visible light transmission to the bottom of the canopy was measured in the same plots in mid- and late May and early June. Mean values were consistently less for plots subsoiled + PK. At the July sampling the value for this treatment was 10% compared to about 16% for subsoiled alone, mouldboard ploughed alone and mouldboard ploughed + topsoil PK.

Leaf areas were measured for the same plots from mid-May to mid-July. Although on each of the five sampling occasions values for subsoiling + PK were greater than for subsoiling alone or for mouldboard ploughing, variability was large and effects were not significant. (W. Day, French and Leach, Physics Department)

Root measurements. Roots from selected treatments were sampled at intervals during the season to a depth of 1 m. The aim was to assess root development and obtain estimates of nutrient inflows throughout the growing season. Sample sorting has proved to be very time consuming and samples from May, June and August still await processing. On 21 April the total length of roots was greatest (2·0 km m^{-2}) with mouldboard ploughing and subsoiling + PK, and least with mouldboard ploughing + topsoil PK (1·3 km m^{-2}), with an indication that both amounts and proportions of roots at 40–80 cm depth were greatest with subsoiling + PK, but there was much variability between individual samples

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of the same treatment. These measurements were all made on plots given 80 kg N ha^{-1}. (Barraclough and Leigh, Soils and Plant Nutrition Department)

In addition to the above work a single, detailed sampling was made at anthesis on selected plots given 120 kg N ha^{-1}. At this time the total root length in the top metre of soil ranged from 11 to 15 km m^{-2} but with no significant effect of treatments. However there was an indication that the proportion of roots between 20 and 60 cm deep was enhanced by subsoiling. As with the earlier measurements variability was great. (Taylor and Welbank, Botany Department)

Soil and water measurements. Bulk density and related measurements were made on selected plots in May. There was little difference between subsoiled and mouldboard ploughed plots for bulk density, air-filled pore space or interclod air space. Soil water content in the 20–40 cm depth was consistently greater in the subsoiled plots. In the course of these measurements it was noted that on subsoiled plots the 20–40 cm zone was more easily penetrated by auger or spade but no penetrometer or shear vane measurements were made. (Newman, Soils and Plant Nutrition Department)

Soil water content was measured on selected treatments with a Wallingford neutron moderation meter to a depth of 120 cm at approximately weekly intervals from 23 April to 11 August. The changes in soil water content, together with rainfall totals, can be interpreted as crop water use, after making allowance for any possible drainage. Early in the season, water use with subsoiling +PK was greater than with subsoiling alone or with mouldboard ploughing, probably because of the greater ground cover with subsoiling +PK. This difference in water use continued through June and July, with water use for subsoiling alone also greater than that for mouldboard ploughing in this period. However, at the end of the season the differences between treatments were not large, subsoiling +PK plots having used about 206 mm compared to 196 mm for subsoiling alone and 193 mm for mouldboard ploughing.

Soil water potential was measured regularly in May, on selected treatments, using tensiometers at depths of 15, 30 and 45 cm. Active extraction of water by roots reached 15 cm before the end of April, 30 cm near the beginning of May and 45 cm by 10 May, in agreement with neutron probe water measurements. No significant effects of treatments were found. (W. Day, French and Leach, Physics Department, and Welbank, Botany Department)

Spring beans (*Vicia faba* L.): effects of pest and pathogens

Results from multifactorial, muldisciplinary experiments done from 1976 to 1978 were published during the year (McEwen *et al*, *Journal of Agricultural Science*, *Cambridge* (1981) **96**, 129–150). The results showed losses of grain yield of at least 0·7 t ha^{-1} in each year attributable to pests and pathogens. It was not possible to apportion losses unequivocally to particular organisms.

The experiments did not take account of the economics of pest and pathogen control and covered only three seasons, of which 1976 was exceptionally hot and dry. To gain information over a wider range of seasons on the contribution of pests and pathogens to seasonal variation of yields and to assess economic methods of control a series of simple experiments was started comparing standard practice with sets of treatments likely to give economic responses and with sets of treatments expected to give the best available control. It is intended to vary treatments in relation to anticipated pest and pathogen attack each season and to use improved materials and methods as they become available. Because of the importance of water in relation to seasonal variation of yield

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we have included a test of irrigation applied to lessen a soil moisture deficit of 50 to 25 mm before pod set, 80 to 55 mm thereafter.

Because black aphids (*Aphis fabae*) were few in 1980 the planned control treatment was omitted, hence standard practice became no pest and pathogen control. 'Economic' control used foliar sprays of permethrin (0·10 kg ha^{-1}) on 23 April (primarily to control bean weevil, *Sitona lineatus*), pirimicarb (0·14 kg ha^{-1}) on 2 June (primarily to control the pea aphid, *Acyrthosiphon pisum*, the vector of bean leaf roll virus) and benomyl (0·50 kg ha^{-1}) on 16 July (primarily to control foliar diseases and delay senescence). 'Full' control included these treatments plus aldicarb (10 kg ha^{-1}) worked into the seedbed (primarily to control soil-borne nematodes and early insect attack), a foliar spray of fosetyl-Al (aluminium tris-ethyl phosphonate) (2·0 kg ha^{-1}) on 23 April (against soil-borne fungi) and an additional benomyl spray (0·50 kg ha^{-1}) on 18 August. The treatments were arranged in four blocks of two plots, for irrigation, split into three subplots, for chemical control treatments.

TABLE 10

Effects of irrigation and control of pests and pathogens on grain yield of spring beans, t ha^{-1}

	Pest and pathogen control		
Irrigation	'None'	'Economic'	'Full'
None	3·9	4·6	5·6
Irrigated	3·6	4·2	4·9

SED ± 0·32 (± 0·26 within same level of irrigation)

Grain yields (Table 10) were lessened by irrigation but substantially increased by pest and pathogen control. On unirrigated plots 'economic' control increased yield by 0·7 t ha^{-1} and 'full' control by 1·7 t ha^{-1}. (Bardner and Fletcher, Entomology Department, McEwen and Yeoman, Field Experiments Section, Webb, Nematology Department, W. Day, Physics Department, Cockbain and Salt, Plant Pathology Department)

Results from sponsors' sampling are reported briefly below.

The season and plant growth. The experiment was sown at Rothamsted with cv. Minden on 4 March and harvested on 18 September. The season was unusually dry after sowing and very cold in late March—establishment was poor with a mean population of only 230 000 plants ha^{-1} from 500 000 seeds sown—and dry weather continued until early June. Thereafter rainfall was greater than average in June and July, average in August and below average in September. Irrigation was required only in late May/early June when a total of 125 mm was applied.

Total above-ground matter was measured on 28 August. Without treatment the total dry matter yield was 8·4 t ha^{-1}. The mean effect of irrigation was to increase total dry matter by 0·5 t ha^{-1} and the mean effects of 'economic' and 'full' control were increases of 4·6 and 6·7 t ha^{-1} respectively. (McEwen and Yeoman, Field Experiments Section)

Weevils (*Sitona lineatus*). The experiment was invaded by weevils at emergence and quite large populations of larvae averaging about eight per plant were recorded on untreated plots in June.

Leaf notching (adult feeding damage) was greatly lessened by aldicarb when assessed on 6 and 22 May. Permethrin was moderately effective on the earlier date but not later (Table 11).

Numbers of weevil larvae on the roots were estimated on 26 June (Table 11). Aldicarb

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TABLE 11

Effects of irrigation (I with, — without) and control treatments for pests and pathogens on Sitona *on spring beans*

	Pest and pathogen control					
	'None'		'Economic'		'Full'	
Notches per leaflet 6 May (SED $\pm$ 0·35)	4·2		0·9		0·2	
Notches per leaflet 22 May (SED $\pm$ 1·32)	12·5		8·9		0·8	
Sitona larvae per root $\log_e$ (n+0·5) 26 June	—	I	—	I	—	I
(SED $\pm$ 0·491)	2·16	1·81	2·21	0·83	0·17	0·05

gave excellent control while permethrin had no effect on unirrigated plots but more than halved larval numbers on irrigated plots, an interaction we are unable to explain. (Bardner and Fletcher, Entomology Department)

Viruses and vectors. Alatae of *Acyrthosiphon pisum* were common towards the end of May but population build-up was checked by the insecticide treatments. Thus early in June the numbers of adult *A. pisum* (alatae and apterae) ranged from 2·2 to 4·9 m^{-1} row in untreated plots, 0–0·8 in 'economic' control plots and 0–0·3 in 'full' control plots. Consequently, at the end of flowering the incidence of bean leaf roll virus ranged from 13 to 38% for 'none', 7–24% for 'economic' and 0–4% for 'full'; corresponding results for pea enation mosaic virus were 0–7, 0–11 and 0–1%, respectively. The incidence of bean leaf roll virus was affected by irrigation but only in plots without insecticide: at the end of flowering the mean incidences in irrigated and unirrigated plots without insecticide were, respectively, 31 and 18%.

The weevil *Apion vorax* was common on the beans in May and June but the seed- and weevil-borne viruses broad bean stain and Echtes Ackerbohnenmosaik were not detected. (Cockbain, Plant Pathology Department)

Fungal diseases. Root-rots were not serious and did not adversely affect yield. The disease rating of roots in mid-June (Table 12) was decreased more by irrigation alone

TABLE 12

Effects of irrigation and control of pests and pathogens of spring bean on disease rating (%) of roots on 11 June

	Tap roots Pest and pathogen control			Lateral roots Pest and pathogen control		
Irrigation	'None'	'Economic'	'Full'	'None'	'Economic'	'Full'
None	44	31	22	48	46	42
Irrigated	14	18	8	26	35	23
	SED $\pm$ 8·9 ($\pm$ 6·4 within same level of irrigation)			$\pm$ 8·0 ($\pm$ 4·3 within same level of irrigation)		

than by 'full' chemical control, 'economic' control having little or no effect. Consequently plots that yielded least had plants with healthier roots than those that yielded most. The most prevalent fungi were species of *Fusarium* (mostly *F. oxysporum*) found on 37% of blackened roots. *Pythium* spp. were found on 15% from irrigated plots and less than 1% from unirrigated.

Chocolate spot (*Botrytis fabae*) was present from July onwards. It became aggressive

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only on plants with bean leaf roll virus and was partially controlled by benomyl. Rust (*Uromyces fabae*) became very prevalent late in August. By mid-September all plants were defoliated and pods black but there was evidence of delayed senescence in that stems in 'full' control plots were mostly green, in 'economic' control only a few were green and with 'none', all were black. (Salt, Plant Pathology Department)

Nematodes. As in previous experiments, the most numerous plant-parasitic nematodes were members of the genus *Pratylenchus*: numbers occurring in roots were greater than any detected in previous years, reaching a mean of 227 g^{-1} of fresh root weight in June in plots not given aldicarb. Only two species, *P. neglectus* and *P. thornei*, were present, the latter comprising 86% of the total. The potentially very damaging *P. pinguicaudatus*, found in 1976, 1977 and 1979, was not found this year. *P. thornei* is moderately pathogenic to field beans and the 1980 populations were the most potentially damaging recorded in these experiments.

Aldicarb effectively decreased numbers of *Pratylenchus* spp. as well as all other nematodes. There was no significant difference in numbers of nematodes present in plots given 'none' or 'economic' treatments except that the fungal-feeding Aphelenchs were fewer in 'economic' than 'none'.

Irrigation had no effect on nematode numbers probably because of above-average June to July rainfall which may also have lessened the effects of the damage which such a large *Pratylenchus* population might be expected to cause. (Webb, Nematology Department)

Our previous contention that with good agronomy and control of pests and diseases yields of 5–6 t ha^{-1} should be obtained was supported despite a small plant population. In considering the causes of yield increases from pest and pathogen control on unirrigated plots the evidence suggests that fungal root rots were not important. The 'economic' treatment did not control *Sitona* or *Pratylenchus* and we attribute the yield increase of 0·7 t ha^{-1} to the partial control of bean leaf roll virus and chocolate spot. The much larger increase of 1·7 t ha^{-1} obtained with 'full' control is attributed to good control of *Sitona*, *Pratylenchus*, bean leaf roll virus and chocolate spot but we are unable to apportion the benefit among them. The increase was larger than found in earlier experiments, reflecting the greater than average incidence of these problems in 1980. The cost of materials used in the 'economic' treatment was about £40 ha^{-1}, that for 'full' about £650 ha^{-1} of which aldicarb was the major cost. Work done in ancillary experiments by Bardner and Fletcher shows promise for cheaper effective chemicals to replace aldicarb.

Loss of grain yield from irrigation was somewhat unexpected and contrasts with beneficial effects on total dry matter in August and on crop appearance and with expectations from past irrigation experiments. Problems in calculating true soil water deficits may have led to over-estimation of irrigation requirement in late May and much rain immediately after the last irrigation may also have had a deleterious effect.

Leafless peas: effects of pests and pathogens

Previously reported experiments done at Rothamsted and Woburn in 1977 and 1978 (McEwen *et al.*, *Journal of Agricultural Science, Cambridge* (1979) **93**, 687–692) showed that leafless peas are susceptible to a wide range of pests and pathogens. The most damaging in these trials were the pea and bean weevil *Sitona lineatus* and the powdery mildew fungus *Erysiphe polygoni* at both Rothamsted and Woburn and perhaps also migratory

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nematodes, particularly *Tylenchorhynchus*, at Woburn. Yields ranged from 2·8 to 5·3 t ha^{-1} grain, depending on year, site and treatment. The most effective pesticide used was aldicarb worked in to the seedbed at 10 kg ha^{-1}, which increased mean grain yield by 0·3 t ha^{-1} at Rothamsted and 0·8 t ha^{-1} at Woburn but its use at this rate was not economic. Lodging was a serious problem in all the experiments.

Further experiments were done at Rothamsted and Woburn in 1979 and 1980 for new tests of permethrin sprays applied early or later to attempt economic control of *S. lineatus*, aphids and pea moth; alternative fungicides for control of *E. polygoni;* and in 1980 only, a test of twice-normal seed rate to control lodging. A test of aldicarb was retained for continuity with previous work. Two randomised blocks of 16 plots were used in each year, testing four two-level factors in all combinations in 1979 and five two-level factors, with the seed rate factor tested on blocks, in 1980.

As hitherto responses to aldicarb were large (Table 13), averaging 0·8 t ha^{-1} over years, sites and other treatments. There was little if any response to permethrin sprays even when aldicarb was not applied. The fungicide fluotrimazole used in 1979 was slightly phytotoxic and gave no yield response; carbendazim used in 1980 was effective and in-

TABLE 13

Factors tested and effects on grain yield of peas (t ha^{-1}). Means over all other factors

	1979		1980	
	Rothamsted	Woburn	Rothamsted	Woburn
None	4·2	3·6	3·9	4·1
Aldicarb to seedbed at 10 kg ha^{-1}	5·4	4·2	4·2	5·0
None	4·8	3·9	4·0	4·5
Early permethrin	4·7	3·9	4·1	4·6
None	4·8	3·8	4·0	4·5
Late permethrin	4·8	4·0	4·1	4·6
None	4·8	4·0	3·9	4·3
Fungicide	4·8	3·9	4·2	4·8
Seed rate 200 kg ha^{-1}	—	—	4·1	4·8
Seed rate 400 kg ha^{-1}	—	—	4·0	4·3
SED	±0·17	±0·12	±0·14	±0·11

Notes: (1) Permethrin was applied at 0·15 kg ha^{-1} on each occasion. Early permethrin was applied on 7 June 1979; 8 May 1980. Late permethrin was applied on 10 July 1979; 18 June 1980
(2) Fungicide was fluotrimazole in 1979 (as 'Persulon' at 1·5 kg ha^{-1}) applied on 24 July, and carbendazim in 1980 applied at 0·57 kg ha^{-1} on 23 July, repeated on 14 August
(3) SEDs do not apply to seed rate test

creased yields at both Rothamsted and Woburn, by 0·3 and 0·5 t ha^{-1} respectively. Doubling the seed rate from 200 to 400 kg ha^{-1} slightly improved standing ability, did not improve yield at Rothamsted and decreased yield at Woburn. (Fletcher, Entomology Department, McEwen and Yeoman, Field Experiments Section, Whitehead, Nematology Department, Cockbain and Salt, Plant Pathology Department)

Results from sponsors' sampling are reported briefly below.

The seasons and plant growth. The experiments were sown to cv. Filby on 8 May and 15 May 1979; 7 April and 11 April 1980 at Rothamsted and Woburn respectively. They were harvested on 4 September 1979 (Rothamsted and Woburn); 27 August (Woburn) and 1 September 1980 (Rothamsted). In each year establishment was rapid and good. In 1979 when the crop was sown at a seed rate of 220 kg ha^{-1} establishment

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counts were 90 m^{-2} at Rothamsted, 73 m^{-2} at Woburn. In 1980 the two seed rates achieved establishment counts of 77 and 156 m^{-2} at Rothamsted, 85 and 172 m^{-2} at Woburn.

Although in both years late summer rainfall was about average the seasons were otherwise greatly contrasted. In 1979 a very wet spring, which caused late sowing, was followed by a dry June and July. In 1980 a dry spring was followed by greater than average rainfall from mid-June until August. In both years growth was not obviously restricted by the dry periods and the only noticeable effect of treatments was a prolongation of the flowering and pod-setting period by aldicarb. Lodging of all crops started in August and by maturity many pods were in contact with the soil surface. Consequently all were harvested by hand and threshed by a stationary combine harvester.

Nitrogen offtake in the grain was determined. In 1979 the only treatment to have a significant effect was aldicarb which increased offtake from 120 to 152 kg N ha^{-1} at Rothamsted and from 104 to 118 kg N ha^{-1} at Woburn. Data from 1980 are not yet fully processed. (McEwen and Yeoman, Field Experiments Section)

Insect pests other than aphids. Because sowing was very late in 1979 most weevils had migrated to other leguminous crops by the time the peas emerged. Consequently the incidence of both adults and larvae feeding on root nodules was relatively small. Those present were well controlled by aldicarb (Table 14). In 1980 much larger numbers were found, particularly at Rothamsted where even the substantial control afforded by aldicarb

TABLE 14

Effects of aldicarb on Sitona lineatus *on peas*

Incidence of adults
Feeding notches on stipules; numbers per plant

	1979		1980	
Treatment	Rothamsted 29 June	Woburn 2 July	Rothamsted 19 May	Woburn 19 May
None	0·35	0·66	7·89	3·81
Aldicarb	0·03	0·18	2·02	0·76
SED	±0·028	±0·112	±0·434	±0·679

Incidence of larvae, Nos per plant

	1979		1980	
	Rothamsted 30 July	Woburn 8 August	Rothamsted 17 June	Woburn 16 June
None	0·66	0·52	5·16	3·00
Aldicarb	0·05	0·02	1·09	0·34
SED	±0·139	±0·140	±1·086	±0·504

left more larvae per plant than were found on untreated plots in 1979. Early permethrin sprays decreased the number of feeding notches on the stipules for a short period only after application and did not affect the numbers of larvae on roots.

Pheromone traps were used at nearby sites to determine the timing of the late permethrin sprays against pea moth (*Cydia nigricana*). Very few adults were found and no damage was recorded even on plots not given insecticides. (Fletcher, Entomology Department)

Migratory nematodes. Migratory nematodes were counted in 1979 only. Numbers of *Pratylenchus* spp. were somewhat greater at Rothamsted, of *Tylenchorhynchus* spp. substantially greater at Woburn. Both genera were well controlled by aldicarb (Table

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15). Numbers of other migratory nematodes were very few. (Whitehead, Nematology Department)

TABLE 15

Effects of aldicarb on migratory nematodes. Numbers per litre of soil on 2 August 1979

	Rothamsted		Woburn	
	Pratylenchus spp.	*Tylenchorhynchus* spp.	*Pratylenchus* spp.	*Tylenchorhynchus* spp.
None	700	550	400	3125
Aldicarb	100	150	150	150

Aphids and viruses. Aphids (mainly the pea aphid, *Acyrthosiphon pisum*) were common each year but populations were estimated in 1979 only. Aldicarb was very effective in controlling aphids throughout the season whereas permethrin applied early had little effect on numbers present in mid-July (Table 16). Permethrin applied late (8 days before aphid populations were estimated) was moderately effective in decreasing numbers, particularly in plots without aldicarb.

TABLE 16

The effects of aldicarb (A), early permethrin (EP) and late permethrin (LP) on the incidence of aphids on peas in mid-July 1979 (log (total number of aphids m^{-1} row + 1))

Treatment combinations	Rothamsted	Woburn
— — —	2·6	2·3
— EP —	2·3	2·1
— — LP	1·5	1·1
— EP LP	1·6	1·1
A — —	1·2	1·0
A EP —	1·2	1·0
A — LP	0·6	0·5
A EP LP	0·7	0·6
SED	±0·15	±0·23

Viruses, all aphid-borne, were more common in 1980 than in 1979 but each year infection was assessed only in plots without insecticide. In 1979, 2% infection with pea enation mosaic was detected in shoot samples taken 25 July at Rothamsted and 1–2% infection with bean leaf roll and red clover vein mosaic viruses was detected in samples taken 2 August at Woburn. In 1980, 16% of shoots taken 30 July at Rothamsted and 21% taken 18 July at Woburn were infected with pea enation mosaic virus. About 4% of *A. pisum* collected from untreated plots at Rothamsted in mid-July were infective with bean roll virus and 8% with pea enation mosaic virus; corresponding results for Woburn were 1 and 31%, respectively. The nematode-borne pea early-browning virus was detected in field beans adjacent to the leafless peas at Woburn in 1980 but was not detected in the peas. (Cockbain, Plant Pathology Department)

Fungal diseases. Root rots were not important in either year but some cortical browning developed late in July more at Rothamsted than at Woburn. It was not affected by any treatment in 1979 but in 1980 at both sites roots from aldicarb-treated plots were healthier and carried many more undamaged nodules than those that had received either early permethrin or no treatment.

Powdery mildew (*Erysiphe polygoni*) was the only serious above-ground disease and although it did not appear until early August in 1979 and late July in 1980 it spread rapidly in the few weeks remaining before harvest. In 1979 it was not well controlled by

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fluotrimazole but in 1980 it was more severe and was well controlled by carbendazim. In the glasshouse mildew causes pea tendrils to dry and become brittle but it was not noticeable in the field that plots sprayed with carbendazim lodged less than those not sprayed. (Salt, Plant Pathology Department)

As with earlier work these experiments showed leafless peas were susceptible to a wide range of pests and diseases and that treatment with aldicarb, which controlled many of them, gave substantial yield increases. The pattern of yield responses to aldicarb from the four experiments, greater at Rothamsted in 1979 than 1980 but the reverse at Woburn is not readily relatable to the recorded incidence of pests and diseases unless the small numbers of *Sitona* larvae present on untreated plots in 1979 and remaining on aldicarb-treated plots at Rothamsted in 1980 were particularly damaging.

Permethrin, although an effective killer of weevils, did not give control of *Sitona* larvae perhaps because its persistence is inadequate to cater for our inability, as yet, to time a single spray in relation to egg laying. Carbendazim gave satisfactory control of powdery mildew.

Under the conditions of our experiments lodging remained a serious problem for which doubling the seed rate did not provide a remedy.

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