ROTHAMSTED RESEARCH

Report for 1982 - Part 1

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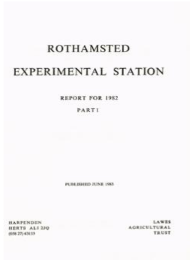
ROTHAMSTED
EXPERIMENTAL STATION
REPORT FOR 1982
PART 1

Report on Multidisciplinary Activities

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E. Lester (1983) *Report on Multidisciplinary Activities ;* Report For 1982 - Part 1, pp 19 - 41 **- DOI: https://doi.org/10.23637/ERADOC-1-129**

MULTIDISCIPLINARY ACTIVITIES

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Factors limiting yield of winter wheat

The large multifactorial experiment at Rothamsted has been modified, in the light of the past 3 years results, to include a rotational comparison. Wheat was grown on Great Knott I as a third cereal crop following either barley or oats in the year preceding the experimental year to test high *v.* low risk of take-all. Different factors have been tested and a full list of treatments is given in Table 1. The work on contrasting sites has expanded to include experiments on a heavy and a light soil at Woburn as well as on a site at Rothamsted, all following early potatoes.

Yield at maturity. Grain yields were less than in the three previous years. The best eight-plot mean was 8·8 t ha^{-1}. The mean of all factorially-treated plots was only 6·6 t ha^{-1}, largely because of the very poor yield of the crop grown after barley that was severely infected with take-all (Table 1, and p. 23). This smaller yield was accounted for by both fewer and smaller ears than in the wheat after oats. Grain size also, but not number of grains per ear, was decreased.

The yield of wheat grown after oats was increased by about 6% by more and also by earlier nitrogen (Table 1). The benefit from early nitrogen was greater with early than with later sowing. Ear number was increased by more nitrogen and by earlier application. The number of grains per spikelet was also increased by more nitrogen. Dry weight per grain was decreased by more and by earlier nitrogen. Summer fungicide increased grain yield slightly by increasing grain size.

TABLE 1

Factors tested and their effects on grain yield (t ha^{-1}) of Avalon winter wheat grown after oats (O) or after barley (B). Means over all other factors

	Level 1		Yield	Level 2		Yield
(1)	Sown early (E) 22 September	O B	8·09 4·89	Sown later (L) 22 October	O B	8·26 5·15
(2)	Nitrogen rate 1, 150 kg ha^{-1}	O B	7·89 4·74	Nitrogen rate 2, 220 kg ha^{-1}	O B	8·46 5·30
(3)	Timing of main nitrogen application Ear initiation of early-sown (9 March)	O B	8·40 5·59	Timing of main nitrogen application Ear initiation of later-sown (13 April)	O B	7·95 4·45
(4)	Growth regulator—chlormequat New '5C Cycocel' 1·75 l ha^{-1} (E 23 March, L 16 April)	O B	8·15 5·07	None	O B	8·19 4·96
(5)	Spring fungicide—benomyl 'Benlate', 0·5 kg ha^{-1} (24 March)	O B	8·23 5·10	None	O B	8·12 4·94
(6)	Summer fungicide—propiconazole 'Tilt', 0·5 l ha^{-1} (26 May, 24 June)	O B	8·29 5·15	None	O B	8·05 4·89
(7)	Pesticide (aldicarb+pirimicarb) (5 kg ha^{-1} applied to seedbed) +0·14 kg ha^{-1} (14 June)	O B	8·19 4·79	None	O B	8·16 5·24

The yield of wheat grown after barley responded relatively more to the nitrogen treatment than did the yield of wheat after oats. After barley, more nitrogen increased yield by 12% and earlier nitrogen by 26%. The number of ears and number of grains per ear responded as in wheat after oats. Dry weight per grain was scarcely affected by either nitrogen treatment. Grain yield was unaffected by sowing date and increased again by summer fungicide, but decreased by pesticide.

https://doi.org/10.23637/ERADOC-1-129

Spring fungicide and growth regulator had no consistent effects on yield irrespective of previous crop. (Thorne, Physiology and Environmental Physics; Dewar, Entomology; Prew, Field Experiments; Williams, Nematology; Lacey and Plumb, Plant Pathology; Penny, Soils and Plant Nutrition; Church and Todd, Statistics)

Growth and development. The experiment was sampled seven times (Table 2). The The number of plants established was 270 m^{-2} from early sowing and 243 m^{-2} from the later. As in previous years, during the winter and spring the wheat sown early (E) grew and developed much faster than did that sown later (L). But from June onwards the benefits of early sowing almost disappeared. The two crops reached comparable stages of development on the following dates: double ridges E 23 February, L 1 April; terminal spikelet E 5 April, L 22 April; 50% anthesis E 4 June, L 7 June. The dates of zero leaf area and ripeness differed by less than 3 days between sowing dates. Maximum tiller number for both sowings was attained between the appearance of double ridges and the formation of the terminal spikelet on the apex of the main shoot; it was well estimated by the number recorded at the sampling on 5 April. In wheat after barley growth from mid-May onwards was slower and tiller survival was less than in wheat after oats. Maximum leaf area was less and the duration of grain growth was shorter: wheat after barley lost all green area by 13 July, but that after oats not until 20 July. As a consequence, straw dry weight as well as grain yield was much smaller in wheat after barley than in wheat after oats.

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 grown after oats (O) or after barley (B) and sown on 22 September (E) or 22 October (L). Means over all other treatments

	Previous crop and sowing date		7 December	4 March	5 April	10 May (E) 24 May (L)	8 June (E) 14 June (L)	6 July (B) 20 July (O)	28 July (B) 4 August (O)
Total dry weight	O	E	29	58	161	548	1132	1699	1540
		L	6	18	70	636	1043	1627	1450
	B	E	27	54	140	464	824	993	950
		L	6	18	78	543	873	1061	1020
Leaf area index	O	E	0·5	0·9	2·1	5·9	7·8	0·4	0
		L	0·1	0·3	0·8	7·5	7·0	0·9	0
	B	E	0·5	0·8	1·6	4·3	4·4	0·4	0
		L	0·1	0·3	1·0	5·4	4·5	1·2	0
Number of shoots	O	E	948	958	1133	724	508	469	493
		L	254	637	1258	668	455	447	467
	B	E	829	893	918	691	413	341	345
		L	253	639	1369	515	389	371	377
Growth stage (GS)	O	E	14/22	17/22	18/24	33	65	85	92
		L	11	14/22	16/26	39/43	69	85	92
	B	E	14/22	17/22	18/23	33	65	85	92
		L	11	14/22	16/25	39/43	69	85	92

Applying nitrogen early rather than late resulted in more shoots and greater dry weight and leaf area at all samplings, and especially in mid-May when increases reached 50%. The benefits of early application were usually greater with early than with later sowing and in wheat after barley than after oats. Increasing the amount of nitrogen applied from 150 to 220 kg ha^{-1} always increased growth. The maximum response was a 30% increase in leaf area index in mid-May. Eight extra plots given their first 40 kg N at sowing instead of in early February or March grew better during the autumn but this advantage was soon lost.

https://doi.org/10.23637/ERADOC-1-129

The growth regulator decreased final stem height by 2 cm. The only other significant effect was a transitory diversion of dry matter from the stem to the ear shortly before anthesis. (Thorne and Wood, Physiology and Environmental Physics)

Nitrogen contents. N contents are so far available only for the first four samplings. December wheat grown after oats contained 4·71% N, after barley 4·50%; by May previous crop had no effect on %N (mean value 1·83). N uptakes differed little with previous crop until May when the larger crop after oats had taken up 109 kg N ha^{-1}, that after barley 91 kg.

In December %N in the earlier-sown wheat (4·72%) was significantly larger than in the later-sown (4·49%) but in March and April it was smaller and by May they differed little. Because yields of the early-sown wheat were much larger than those of the later-sown at the first three samplings, so also were N uptakes (13 *v.* 3 kg ha^{-1} in December, 65 *v.* 39 kg ha^{-1} in April). By May, however, N uptake was slightly larger with the later sowing.

Applying 40 kg N ha^{-1} (first part of early N) on 2 February significantly increased %N in both early- and later-sown wheat on 4 March but increased N uptake only by the early-sown (from 20 to 34 kg ha^{-1}). In April and in May N uptakes by both sowings were significantly larger with N applied early rather than late, more of the early N having been applied (amounts were not comparable until the June sampling). As expected %N and N uptake were significantly larger with the larger amounts of N.

On 2 February (before any fertilizer N had been applied) the sap of the lower parts of the wheat stems contained 810 ppm of NO_3-N. On 8 March they contained 280 ppm on plots not given any fertilizer N and 710 ppm on plots given 40 kg N ha^{-1} on 2 February. On 13 April they contained only 5 ppm of NO_3-N where no fertilizer N had been given and 35 ppm where 40 kg N had been applied on 9 March. These values increased to 520 ppm where an additional 140 kg N ha^{-1} had been applied. (Penny, Widdowson, Darby and Hewitt, Soils and Plant Nutrition)

Nematodes. Numbers of stylet-bearing nematodes present in the soil prior to sowing are given in Table 3; no cereal cyst nematodes (*Heterodera avenae*) were found. In mid-season only a small number of *Pratylenchus* spp. (12 g^{-1} root) were present in the roots, fewer (3 g^{-1}) in the presence of pesticide which also decreased numbers of nematodes present in soil. Post-harvest soil samples also showed a decrease of most species where pesticide was applied. Without pesticide, numbers were similar to those at the start of the experiment except for *Tylenchus* spp. which had decreased considerably. (Williams and Beane, Nematology)

TABLE 3

Effects of crop rotation and pesticide on plant parasitic nematodes (numbers per litre of soil). Means over all other treatments

	Pratylenchus	*Tylenchus*	*Tylenchorhynchus*	*Helicotylenchus/Rotylenchus*	Totals
8 September 1981					
After oats	450	1525	1550	750	4275
After barley	675	900	1000	800	3375
1 June 1982					
With pesticide	153	263	244	72	732
Without pesticide	309	438	1106	231	2084
11 August 1982					
After oats	519	388	1600	706	3213
After barley	153	528	869	281	1831
With pesticide	184	419	578	222	1403
Without pesticide	488	497	1891	766	3642

https://doi.org/10.23637/ERADOC-1-129

Aphids. Autumn migrations of *Rhopalosiphum padi* and *Sitobion avenae* were much smaller than usual in October and ceased before the late-sown plots emerged. Consequently aphids colonized only the early-sown plots without aldicarb. Aphid numbers were 3·6 m^{-2} on 2 November, 6·7 m^{-2} on 6 January and 0·4 m^{-2} on 2 March. *R. padi* was more numerous than *S. avenae* through the winter until killed by the hard frosts, which the more hardy *S. avenae* survived. *Metopolophium festucae* was first recorded at the beginning of March and increased gradually through April and May to reach a peak of 33 m^{-2} in late May before declining sharply and disappearing by 8 June.

The first alate cereal aphid, *M. festucae*, was caught in the suction trap at Rothamsted on 14 May, at the same time as the first aphids were recorded in the pesticide-treated plots. Aldicarb had a residual effect on aphid numbers until the beginning of June. *S. avenae* and *M. dirhodum* increased dramatically in early June when temperatures were fairly high. Pirimicarb, when applied on 14 June, significantly reduced their numbers for about a week. However, a period of wet, cold weather in mid-June combined with severe predation from coccinellid, lacewing and syrphid larvae caused the populations on unsprayed plots to decline from a peak of about one aphid per shoot to one per 10 shoots.

Populations of both *S. avenae* and *M. dirhodum* continued to decline on the rapidly maturing wheat after barley, but increased again on plots after oats, reaching a peak of over two per shoot on 23 June. These aphid populations would not be expected to affect yield. (Dewar, Entomology)

Barley yellow dwarf virus (BYDV). Relatively few aphids were caught and fewer (6·0%) were infective in autumn 1981 than in autumn 1980. Our prediction, based upon the Infectivity Index (*Rothamsted Report for 1981*, Part 1, 195–7), was that there would be little infection of any crops by BYDV. A few plants with symptoms were seen in mid-May 1982 on plots after barley not treated with aldicarb, and infection by a severe *R. padi*-transmitted isolate of BYDV was confirmed. Detailed visual assessment was hampered on plots following barley by the extensive symptoms of take-all but there was no more than an occasional infected plant on any plot except those scored in mid-May, on one of which (Plot 132, sown early, after barley, no pesticides) a small patch of infection 50 cm in diameter developed. It was not therefore expected that BYDV infection would affect yield. (Plumb and Lennon, Plant Pathology)

Fungal diseases. Little foliar disease was present throughout the season; on the top three leaves mildew was only present in trace amounts and *Septoria* never exceeded 1%

TABLE 4

The effects of rotation, sowing dates, timing of nitrogen and fungicide on the incidence of foot and root rots in Avalon winter wheat. Means over all other treatments

	Eyespot		Sharp eyespot		Take-all		
	% shoot infected				% plants infected		Take-all rating*
	5 April	24 June	5 April	24 June	7 December	5 April	24 June
After oats	2	27	4	33	6	3	8
After barley	9	41	4	44	53	65	241
Sown early	8	32	6	46	53	49	139
Sown later	4	35	2	31	7	20	110
N early	5	35	5	39	—	32	117
N later	7	32	3	38	—	36	132
Benomyl	—	14	—	49	—	—	125
None	—	54	—	28	—	—	124

* % slight + (2 × % moderate) + (3 × % severe) plants with take-all

https://doi.org/10.23637/ERADOC-1-129

of the leaf area. *Fusarium* was present on the ears, more so on the early- than the later-sown crop (11 and 4% of ears infected; 2·1 and 0·3% of ear area infected).

Foot rots were frequent (Table 4) more so after barley than after oats; early sowing increased both eyespot and sharp eyespot in the spring but only sharp eyespot in the summer. Benomyl greatly decreased the incidence of eyespot but doubled that of sharp eyespot which was also somewhat more severe with growth regulator and propiconazole.

Take-all was the most damaging disease (Table 4) being very severe after barley but, as expected, only slight after oats. Late sowing and the early timing of the split nitrogen application both decreased take-all severity but pesticide slightly increased it. (Prew, Field Experiments)

The microflora of ripening ears. Bacteria, always more numerous than fungi, increased continuously from $9{\cdot}7 \times 10^8$ to $1{\cdot}9 \times 10^9$ propagules g^{-1} between GS 76 and harvest. The total fungal populations on the ripening ears increased from $1{\cdot}8 \times 10^7$ colony forming units (CFU) at GS 76 to a maximum of $2{\cdot}6 \times 10^7$ CFU at GS 87 subsequently decreasing to $1{\cdot}3 \times 10^7$ CFU g^{-1} of ears by harvest (Table 5). At GS 76, pink and white yeasts were the major components of the mycoflora together with smaller numbers of the yeast-like fungi *Aureobasidium pullulans* and *Hyalodendron* spp., and such filamentous fungi as *Cladosporium* spp., *Fusarium* spp. and *Verticillium lecanii*. Unlike previous years (*Rothamsted Report for 1981*, Part 1, 24), *Fusarium* spp. (mainly *F. culmorum* and *F. avenaceum* with some *F. poae*) were particularly numerous, increasing from $7{\cdot}1 \times 10^4$ at GS 76 to $1{\cdot}1 \times 10^6$ CFU g^{-1} by harvest. Other filamentous fungi isolated included *Alternaria alternata*, *Botrytis cinerea*, *Epicoccum purpurascens* and *Mucor* spp.

Fungicide application at GS 76 decreased total fungal populations, particularly of pink yeasts and yeast-like fungi, for 2 weeks only. Four weeks after application there was little difference between fungicide-treated and untreated ears. *Fusarium* spp. were slightly less numerous on fungicide-treated ears but the difference was only significant ($P<0{\cdot}05$) in samples taken at GS 90. *A. alternata*, *Cladosporium* spp. and *V. lecanii* were unaffected by the late fungicide treatment. (Magan and Lacey, Plant Pathology)

TABLE 5

The effect of fungicide (F with,— without) on the microflora of ripening ears of winter wheat assessed by dilution plating. (Means of 16 plots)

Date Growth stage	25 June 76		8 July 87		22 July 90		4 August 92	
	—	F	—	F	—	F	—	F
	(No. of colony forming units $\times 10^{-6}$ g^{-1} of ears)							
Yeasts	12·6	12·7	15·6	9·6	11·3	8·4	3·9	5·3
Yeast-like fungi	2·5	1·3	3·8	2·8	2·5	2·7	1·5	2·8
Filamentous fungi	3·7	3·9	5·8	2·8	6·3	6·8	6·4	4·3
Bacteria	977	761	443	360	569	440	1154	1319

Additional investigations on tiller survival. Some of the ways in which tiller production and survival are controlled by nitrogen are understood. However, where nitrogen supply has been close to optimal in the multifactorial and related experiments on different soils, there have been large variations, between sowing dates and seasons, in the maximum number of shoots produced and also unrelated variations in the percentages of those surviving to form ears.

Neither the causes of these differences in tillering nor their relevance to the variations in grain yield are understood, although the better-yielding crops tended to have more

https://doi.org/10.23637/ERADOC-1-129

ears. A better understanding of why maximum shoot number ranged from 808 to 1871 m^{-2} and percentage survival ranged from 29 to 56% in these experiments should help explain why grain yield ranged from 7·8 to 11·1 t ha^{-1}. So, the observations on shoot numbers in the field this season (p. 20) were supplemented by ones on the history of individual tillers.

Tillers appeared in the expected sequence except on some of the early-sown plots. Tillering stopped at the end of January and, when 40 kg N ha^{-1} was applied on 2 February, the next three tillers in the expected sequence did not appear but higher order ones emerged during March, between the double ridge and terminal spikelet stages of apical development. These soon died. The only tillers to survive until anthesis and produce ears were some of those in the axils of the first three leaves on the main shoot. During the month before anthesis varying numbers of these died, depending on previous crop, sowing date and time of nitrogen application, to give mean numbers of shoots per plant that ranged from 1·4 to 2·0.

The factors affecting tiller survival in cv. Avalon are also being studied in microplots, in an open-sided cage, where the environment at different growth stages can be manipulated experimentally (*Rothamsted Report for 1981*, Part 1, 59). Plants were grown at a density of 247 m^{-2}, and supplied continuously with nutrient solution as in 1981 so that tiller survival was not limited by shortage of nitrogen. Assimilate supply was altered by increasing the light intensity using high-pressure sodium lamps to supplement solar radiation. Daily visible radiation was increased by about 60% during periods of 2–3 weeks at three stages: double ridge stage/end of tillering, the start of tiller death, and when about half of the tillers had died. Increasing light intensity at all stages increased growth rates, net assimilation rate and leaf areas during the treatment period, but when the plants returned to ambient light conditions growth rates decreased and the advantages compared with the control gradually decreased. Increasing light at the first two stages delayed tiller death, but the effects did not persist through to anthesis. When light was increased later in the tiller death phase, before the first three primary tillers had begun to die, tiller death was decreased particularly with tillers 1 and 2. At anthesis, 5 weeks after the end of the treatment, both total crop dry weight and number of ears were increased by about 20% compared with the control. At maturity, the numbers of ears and grains per ear were greater than in the control but the grains were smaller. Grain yield was not affected by any of the treatments and averaged 729 g dry weight m^{-2}. (Thorne and Wood, Physiology and Environmental Physics)

Growth and yield of winter wheat on contrasting sites Woburn and Rothamsted

With the completion of 3 years' study of factors limiting yield of winter wheat following potato crops at Rothamsted and its continuation with preceding crops of oats or barley as one of its treatment comparisons, study of the effects of soil differences was concentrated on wheat grown following potatoes on sandy or clay soils at the Woburn farm. At Rothamsted a wheat experiment was grown following potatoes in Pastures field for comparison with wheat in the factors limiting yield experiment on a similar soil following oats, which were expected to leave less nutrient residues.

Woburn. Experiments were grown on Cottenham series sandy silty loam in Butt Close and on Blithe series sandy-clay loam (over clay) in Broad Mead. In each, 32 plots in a half replicate of a 2^6 design were given the treatments shown in Table 6 and six extra plots sown on each of the two sowing dates were given a range of N dressings, from 0 to 240 kg ha^{-1} on sandy soil and from 0 to 150 kg ha^{-1} on clay soil, to confirm optimum N rates. The N rates tested differed between sites to take account of differing availability

https://doi.org/10.23637/ERADOC-1-129

TABLE 6

The effect of six factors on grain yield (t ha⁻¹) of Avalon winter wheat on two soils at Woburn in 1982. Means over all other treatments. Differences in parentheses

Factor tested	Soils: Sandy (Butt Close)	Soils: Sandy clay (Broad Mead)
(1) Sowing date		
Early (E), 23 September	7·57	8·22
Late (L), 23 October	7·43 (−0·14)	7·76 (−0·46)
(2) Nitrogen in spring, kg ha^{-1}		
120 sandy soil, 30 clay soil	6·69	7·67
180 sandy soil, 90 clay soil	8·32 (+1·63)	8·31 (+0·64)
(3) N timing, first application date		
Ear initiation of E, 11 March	7·55	7·97
Ear initiation of L, 15 April	7·45 (−0·10)	8·01 (+0·04)
(4) Winter N 1 February (additional to (2))		
Without	6·91	7·85
With 60 (sandy) or 30 (clay) kg ha^{-1}	8·09 (+1·18)	8·13 (+0·28)
(5) Irrigation to limit deficit to 37 mm		
Without	7·16	8·00
With	7·84 (+0·68)	7·98 (−0·02)
(6) Aldicarb (5 kg ha^{-1}) to seedbed		
Without	7·40	7·72
With	7·60 (+0·20)	8·26 (+0·54)

of soil N. The spring nitrogen applications other than the lower rate to the clay soil (which was all given in May) were divided between a main application on 11 March or 15 April, which differed between N rates, and a second application on 11 or 25 May respectively of 40 kg ha^{-1} to sandy soil or 30 kg ha^{-1} to clay soil. The dates of the main applications of early and later N treatments coincided approximately with the early spikelet initiation stage of early-sown and later-sown wheat respectively. Herbicides, summer aphicides and foliar fungicides as necessary to control weeds, pests and diseases and chlormequat growth regulator were applied as basal treatments. Eight extra plots at one end of the Butt Close site were used for studies of root growth (see Soils and Plant Nutrition Department report, p. 260) and transparent shelters were erected over small areas of crop at each site to exclude rain for part of the season for studies of maximum water extraction by crops (see Soils and Plant Nutrition Department report, p. 260). The cultivar Avalon was the same as in the Rothamsted factors limiting yield experiment and the husbandry and sampling programme also closely followed that experiment, so permitting some comparison between them. The Woburn experiments were sampled on 4 January, 2 March, 14 April, 11 (early sown) or 25 (late sown) May, 10 (early sown) or 16 (late sown) June, 12 July and 11 August, and combine harvested on 12 August.

Irrigation was first applied on 17 May, at which time the soil water deficit estimated from potential evapotranspiration and rainfall had reached 78 mm, and 73 mm water was given up to 10 June (25 mm more to Broad Mead), compared with an accumulated deficit of 94 mm. Rain made further irrigation unnecessary until July, when 37 mm was given between 13 and 19 July; making a total of 112 mm on Butt Close (25 mm more on Broad Mead) by ripening, compared with an accumulated deficit of 140 mm (30 July).

Yields at maturity. Grain yields did not reach such high values as were recorded previously in this series of experiments, but reached or exceeded those in the factors limiting yield experiment at Rothamsted (this *Report*, p. 19). On the sandy soil the best four-plot mean yield was 9·4 t ha^{-1} (all grain yields at 85% DM) with winter N plus the higher rate of spring N and irrigation. On clay soil, where irrigation had negligible effect, it was 8·9 t ha^{-1} from early-sown wheat with the higher rate of spring N and seed-

https://doi.org/10.23637/ERADOC-1-129

bed aldicarb. On both sites spring N rate had the greatest treatment effect (Table 6). The larger N effect on sandy than on clay soil reflected the much smaller amounts of available soil N on sandy soil, shown by its yield without N of 1·9 t ha^{-1}, compared with 7·4 t ha^{-1} on clay soil. The responses to still higher N rates on extra plots suggested that the higher N treatment rate on clay soil was adequate but on sandy soil was perhaps 30 kg ha^{-1} less than required for maximum response. This partly accounts for the beneficial effect on sandy soil only of previous N in February, but although its effect in conjunction with the lower rate of spring N was no greater than an extra 60 kg N ha^{-1} in spring, it did increase yield with the higher spring N rate more than expected from the N response curve. Irrigation increased yield only by 0·6 t ha^{-1} on sandy soil, probably because no great water stress developed during this season. Aldicarb increased yield on the clay soil only: the reason is not yet established.

Components of yield. The yield increases from winter N on sandy soil and from the higher rate of spring N on both soils were almost all attributable to greater numbers of ears: (on sandy soil 467 m^{-2} with winter N, cf. 386; and 469 m^{-2} with the higher spring N rate, cf. 384; on clay soil 527 m^{-2} with higher spring N rate, cf. 475). There was some contribution from slightly more spikelets per ear. Irrigation on sandy soil also increased numbers by 67 m^{-2}, but surprisingly it decreased 1000-grain weight with the earlier timing of N application. On clay soil aldicarb increased ear numbers by 34 m^{-2}. Other treatments affected particular components of yield, but in opposite directions, so that they cancelled out. For example on sandy soil early sowing increased numbers of ears by 42 m^{-2} but this was offset by fewer spikelets (−1·2 per ear) with fewer grains per spikelet (−0·1). Similarly, greater numbers of spikelets per ear following earlier N were offset by fewer and lighter grains. Aldicarb increased numbers of grains per spikelet and per ear with winter N or the lower rate of spring N, but otherwise decreased them, so that interpretation of its effect is difficult. On clay soil there were more ears from the earlier sowing, especially with the lower rate of spring N and (in the absence of irrigation) heavier grains, but these effects were offset by fewer grains per spikelet and per ear. Irrigation decreased the number of grains per spikelet and per ear, but this was compensated by heavier grains, at least in later-sown wheat. Yield component responses support the contention that the main limiting factor on sandy soil was mineralizable N. Winter N or early spring N, which were given before the main flush of tillering of later-sown wheat was completed, increased ear numbers; with early-sown wheat only winter N had an effect. Supplying fertilizer N before or at an early stage of spikelet initiation enabled more spikelets per ear to mature than if it was withheld until later. Whether the subsequent smaller and fewer grains per ear could be attributed to competition for N or for assimilates is not yet determined. (Welbank, Physiology and Environmental Physics; Widdowson, Penny, Darby and Hewitt, Soils and Plant Nutrition)

Growth of the crop. Plant numbers were very similar from the first sowing (263 m^{-2} on sandy soil and 259 on clay soil), but many fewer (193) on sandy than on clay soil (253) from the second sowing. By early January there were 1053 shoots m^{-2} from the early sowing on clay soil, compared with only 787 on sandy soil, with correspondingly greater dry weights and leaf areas. The later sowing had formed few tillers, but dry matter and leaf areas on sandy soil were only about 70% of those on clay soil. Differences in growth between soils were thus manifested at an early stage. At the next sampling in March shoot numbers of early-sown crops had not increased by many, but their dry matter differential had increased relatively to 131, cf. 25 g m^{-2} and leaf area index (LAI) differential to 1·4, cf. 0·4. On the later-sown, tillering had increased shoot number on clay soil to 741 m^{-2} (2·9 per plant), cf. 544 on sandy soil (2·8 per plant). The dry matter

https://doi.org/10.23637/ERADOC-1-129

differential was 19·9, cf. 12·9 g m^{-2} and LAI 0·31, cf. 0·25, both roughly proportional to plant number. Winter N applied in early February began to show effects on sandy, but not clay, soils and increased dry matter and LAI of both early- and later-sown crops, although not enough to eliminate the soil differences. By the third sampling in April the effects of both winter N and early application of spring N were apparent on sandy soil. Early-sown wheat had shoot numbers increased from 670 m^{-2} to 1500 by winter N alone and to 1750 m^{-2} with early N in addition. Corresponding increases in shoot dry weight and LAI were from 82 g m^{-2} to 260 and 290 g m^{-2} and from 1·3 to 2·1 and 3·0. These values approached those on clay soil, where the early-sown crop had 1420 shoots m^{-2} with a dry weight of 380 g and a LAI of 3·8 with no treatment effects significant. From the later sowing the responses were somewhat different: only winter N significantly affected wheat on sandy soil, increasing shoot numbers from 800 to 1230 m^{-2} and dry weight from 62 to 114 g m^{-2}; on clay soil winter N had no effect, but there were 1810 shoots m^{-2} with aldicarb compared with 1450 without and the early application of spring N increased tillering by 100 m^{-2} on plots that had received aldicarb; the explanation is not yet established. The average total shoot dry matter was 156 g m^{-2} and LAI 1·8.

At the May sampling wheat on clay soil still showed little response to N treatments, except for a small increase in LAI of late-sown wheat from 6·6 to 7·4 with the higher rate of N. Many shoots had died, but the early sowing still retained 900 m^{-2} compared with 630 from the later sowing. The earlier effect of aldicarb on shoot numbers now showed in a greater dry weight (600, cf. 530 g m^{-2}). By this time the crop on sandy soil responded to all nitrogen treatments. Winter N had most effect, increasing numbers of surviving shoots from 425 to 634 m^{-2} with corresponding dry weights of 325 and 514 g m^{-2} and LAIs of 3·0 and 4·8. Early N application increased shoot numbers, dry weights and LAI compared with later application timing; the comparative values were respectively, 592, cf. 466 m^{-2}, 495, cf. 344 g m^{-2} and 4·4, cf. 3·5. Responses to the higher rate of N occurred only with the earlier timing of application, where shoot numbers were increased from 500 to 690 m^{-2} and LAI from 3·6 to 5·2 (the late N had not then all been applied). A difference between sowing dates at sampling was largely caused by the later sampling date for the late-sown crop. At this stage crop growth on sandy soil was on average 30 to 50% less than on clay soil, where the overall means were 770 shoots m^{-2} with a dry weight of 565 g m^{-2} and LAI of 6·6, but the best treatment combination on sandy soil (winter N plus the higher rate of spring N applied at the early timing) produced 790 shoots m^{-2} with a dry weight of 631 g m^{-2} and LAI 6·1 (means of four plots), matching average growth on the clay site, where treatment differences rarely reached significance. It thus appears that inferior growth on sandy soil at this stage was accounted for by less soil fertility which could be overcome by applying adequate fertilizer N during and after the winter.

At anthesis (June) effects of different sowing dates were confounded with the effects of sampling them on different dates and are not considered further. On clay soil more shoots survived with the higher rate of spring N than with the lower (560, cf. 460 m^{-2}) and this advantage was greater when the N had been applied at the later timing. The greater number of shoots had a greater dry weight (1110, cf. 1020 g m^{-2}, unaffected by timing of N) and greater LAI (8·7, cf. 6·9). Winter N increased LAI by 8% and aldicarb increased shoot dry weight and LAI by approximately 10%; irrigation, as expected, had no significant effect on this site. On sandy soil winter N and the amount and timing of spring N all affected crop growth and irrigation increased shoots surviving (from 380 to 430 m^{-2}). Shoot number was increased (from 335 m^{-2}) by both winter N and the higher rate of spring N irrespective of time of application with an extra 60 kg N ha^{-1} giving about 70 shoots m^{-2} more.

Shoot dry weight was consequentially increased (from 789 g m^{-2}) by extra N, by

https://doi.org/10.23637/ERADOC-1-129

165 g m^{-2} when it was applied in winter, by 186 g m^{-2} when applied in spring with the earlier timing, but by only 61 g m^{-2} with the late timing, perhaps because its effects had been operative for less time. LAI was also increased by additional 60 kg ha^{-1} applications of N, irrespective of when it was given, from 4·1 with the lower spring N rate alone to 6·6 with both winter and additional spring N together. Again, crop from the most beneficial treatment combination (the same as in May) matched the best on the clay soil in dry matter (1170, cf. 1190 g m^{-2}), including dry matter in the ears (296, cf. 284 g m^{-2}), although having somewhat fewer shoots (ears) (458, cf. 587 m^{-2}) and smaller LAI 6·9, cf. 9·2).

At the final sampling before ripeness, in July, the effects of sowing date became apparent on both sites in greater shoot dry matter yields from the earlier sowing, but smaller LAI as leaf senescence was more advanced. More green leaf survived following earlier irrigation on both sites but ear numbers and total dry weights were increased only on sandy soil. The higher rate of spring N also reduced leaf senescence on both sites and on sandy soil more effectively when applied late, while winter N also delayed senescence on this soil. It therefore seems that the disadvantage of late N application for pre-anthesis growth was offset for final yield by better retention of leaves after anthesis. Shoot dry weights and leaf area from the best combination of treatments on sandy soil at that stage (winter N plus higher rate spring N with irrigation) were 1770 g m^{-2} (ears 950 g m^{-2}) and LAI of 3·9 compared with 1720 g m^{-2} (ears 890 g m^{-2}) and LAI of 5·2 from one of the best treatment combinations on clay soil (higher spring N rate applied early with aldicarb). (Welbank, Physiology and Environmental Physics; Widdowson, Penny, Darby and Hewitt, Soils and Plant Nutrition)

Nitrogen taken up by the wheat. Dry matter samples from each experiment were analysed and N uptakes calculated for all seven sampling occasions. In October the sandy soil on Butt Close contained little residual NO_3-N to 90 cm depth, whereas the sandy-clay soil on Broad Mead contained a great deal; >250 kg N ha^{-1} (see Soils and Plant Nutrition Department report, p. 261). These differences in soil N were reflected in %N in the plants until spring. During March and April nitrogen fertilizer was applied and thereafter %N was greater on Butt Close, presumably reflecting the larger fertilizer dressings (180 *v.* 90 kg N ha^{-1}) given there. Until April the amount of N taken up by the wheat was always larger on the richer clay soil, especially when early-sown. Thus on 6 January the above-ground parts of comparable early-sown crops contained 7·7 *v.* 20·2 kg N ha^{-1} on the two fields; the later-sown only 2·1 *v.* 3·1 kg N ha^{-1}. By 2 March relative uptakes by the September sowings were 19·3 *v.* 69·1 kg N ha^{-1} and of the October sowings 6·8 *v.* 11·0 kg N ha^{-1}. After fertilizer N had been given differences between the two fields diminished, presumably as a result of our attempt to equalize total nitrogen supplies. Thus by anthesis the mean uptake by the above-ground portions of the crops were 147 kg N ha^{-1} from the sandy soil and 162 kg N ha^{-1} from the clay. It appears therefore that our attempt to equalize nitrogen supplies was successful, for even though N uptakes from the final crop samples are not yet available, we assume that the very similar grain yields (Table 6) on these very disparate soils confirm this. (Widdowson, Penny, Darby and Hewitt, Soils and Plant Nutrition)

Rothamsted. This experiment in Pastures field was on Batcombe series flinty silty loam over clayey substrata sown with cv. Avalon in a half replicate of a 2^5 design (16 plots), with extra plots testing a range of N dressings from 0 to 175 kg ha^{-1}. Other plots on the same site were used for root growth studies and six plots were sown with cv. Hustler, used in previous experiments on this theme. Treatments tested were two sowing dates, fertilizer N at 70 or 140 kg ha^{-1}, early *v.* later timing of N applications, irrigated *v.*

https://doi.org/10.23637/ERADOC-1-129

unirrigated, and with seedbed application of aldicarb *v.* without. Sowing dates, timing of N applications and all husbandry operations were the same as for the factors limiting yield (Great Knott I) experiment and growth regulator, spring and summer fungicides tested in that experiment and summer aphicide were applied basally on Pastures. The above-ground parts of the crop were sampled on the same dates as wheat after oats in the Great Knott I experiment in December, March, April, June and August, but not in May or July, and combined on 20 August. Samples were sometimes measured less intensively than in other related experiments.

Results of this experiment are compared with those from 16 plots in the Great Knott I experiment given similar, but not always identical, timing of N, irrigation, and aldicarb treatments. However, none of these factors significantly affected grain yield either in the Pastures experiment or in the comparison plots of the Great Knott I experiment; only sowing date and total amount of N affected yield. Mean grain yields from September sowing after potatoes (7·9 t ha^{-1}) were the same as, and from October sowing less than (7·3, cf. 8·2 t ha^{-1}), in the comparison plots after oats. Eighty kg ha^{-1} less N was applied in Pastures, because the soil contained more available N in winter, and in neither experiment were N treatment rates sufficient to reach the maximum of the response curve. For similar amounts of N (140 kg ha^{-1} on Pastures and 150 on the comparison plots), Pastures yields were 0·5 t ha^{-1} more from the earlier sowing and 0·2 t less from the later, but there was no indication that the greater N residues left by potatoes than by oats might lead to appreciably greater maximum yields; indeed, inspection of results from N-scale plots suggested that, although the yield without added N was greater following potatoes, the maximum response to N might have been less than on the site after oats.

In the cultivar comparison Hustler yielded 9·1 t ha^{-1}, 0·6 t more than Avalon, when

TABLE 7

The effects of seven factors on grain yield (t ha^{-1}) of Igri winter barley, sown on 22 September or on 22 October 1981. Means over all other treatments

	Sowing date	
	22 September	22 October
(1) Aldicarb (5 kg ha^{-1}) to seedbed		
Without	8·37	6·85
With	8·52	6·73
(2) Seed treatment ('Baytan')*		
Without	8·46	6·83
With	8·42	6·75
(3) Chlorpyrifos in autumn		
Without	8·46	6·92
With	8·42	6·66
(4) Fungicide sprays ('Sportak')† in spring and summer		
Without	8·18	6·63
With	8·70	6·94
(5) Nitrogen timing		
22 March	8·33	6·92
19 April	8·55	6·65
(6) Nitrogen amount (kg ha^{-1})		
50	8·43	6·93
100	8·45	6·65
(7) Growth regulator ('Terpal')‡		
Without	8·22	6·64
With	8·66	6·94
Mean Yield (SED 0·067) SED 0·094 (29 d.f.)	8·44	6·79

* 'Baytan', a.i. triadimenol+fuberidazole
† 'Sportak', a.i. prochloraz
‡ 'Terpal', a.i. mepiquat chloride+ethephon

https://doi.org/10.23637/ERADOC-1-129

sown early and 7·0 t ha^{-1}, 0·1 t more, when sown late. (Welbank, Physiology and Environmental Physics; Widdowson, Penny, Darby and Hewitt, Soils and Plant Nutrition)

Factors limiting yield of winter barley

The experiment on winter barley, reported last year (*Rothamsted Report for 1981*, Part 1, 29–32), was repeated with the addition of a test of an eighth factor (chlorpyrifos) to control stem borers. The eight factors (Table 7), each at two levels, were tested in factorial combination (2^8) using a quarter-replicate design, arranged in 2 blocks of 32 plots. Also included were two plots in each block, sown either on 22 September or 22 October, but otherwise untreated, to act as controls.

Nitrogen in the soil. The barley cv. Igri followed early potatoes and so the soil was rich in NO_3-N. On 6 October (emergence of the first sowing) there were 130 kg NO_3-N ha^{-1} to 90 cm. On 9 November (emergence of the second sowing) there were 115 kg ha^{-1} under it, but only 84 kg NO_3-N ha^{-1} under the first sowing.

The soils were sampled again on 2 February, 8 March and 19 April. There was less NO_3-N under the early- than the later-sown barley at all sampling dates, presumably reflecting a larger root system. Thus on 8 March only 16 kg NO_3-N ha^{-1} remained under the September-sown crop and this mainly in the 60–90 cm horizon, whereas there were still 110 kg ha^{-1} under the October-sown crop, of which the largest part remained in the 30–60 (36 kg ha^{-1}) and 60–90 cm (56 kg ha^{-1}) horizons. On 19 April none was measurable under the September-sown barley, but there were still 56 kg ha^{-1} under the October-sown, of which 38 kg ha^{-1} were in the 60–90 cm horizon. (Widdowson, Darby and Bird, Soils and Plant Nutrition)

Growth of the crop. Aldicarb diminished early losses of plants from the first sowing in one area of the experiment so chlorpyrifos was included as an additional factor to control stem borers. Thus, on 7 October there were 213 plants m^{-2} on the early-sown and on 1 December 235 plants m^{-2} on the later-sown plots.

Destructive samples were taken on three occasions for dry weight, shoot and plant number (Table 8). On 8 March plant number on the September-sown plots was significantly larger with aldicarb than without (195 *v.* 129 m^{-2}), but not on the October-sown plots (157 *v.* 160 m^{-2}). Shoot number was similarly increased by aldicarb. Total dry weight was greatly increased by early sowing (Table 8), but decreased by the 'Baytan' seed treatment, significantly so on plots sown in September. On 19 April the only treatments significantly increasing either shoot number or yield were early nitrogen and

TABLE 8

Changes with time in total dry weight (g m^{-2}) numbers of plants and shoots (m^{-2}) of winter barley cv. Igri, sown on 22 September (E) or 22 October (L). Means over all other treatments

		Sampling date				
		7 October (E) 1 December (L)	8 March	19 April	21 May (E) 1 June (L)	27 July
Total dry Weight	E	—	82·5	434	804	1242
	L	—	14·0	132	757	1004
Number of Plants	E	213	162	204	—	—
	L	235	158	203	—	—
Number of Shoots	E	—	1387	1928	794	—
	L	—	417	1435	682	—

https://doi.org/10.23637/ERADOC-1-129

September sowing. At ear emergence, early N significantly increased yields of the September- but not of the October-sown plots. Ear numbers (mean 738 m^{-2}) were significantly increased by early sowing (794 *v.* 682 m^{-2}), with smaller non-significant increases from nitrogen fertilizer, aldicarb and chlorpyrifos and a decrease from the 'Baytan' seed treatment.

The growth regulator was applied at GS 31, on 30 April to the September-sown and on 13 May to the October-sown plots. On 17 June it had reduced straw length (to base of ear) from 100 to 92 cm and from 95 to 88 cm on the two crops respectively. Even so the barley lodged before harvest and estimates made on 16 June showed significantly more with the later sowing and with increased N and very significantly less (56% *v.* 11% lodging) with the growth regulator. A cage was erected on 26 and 27 May and a bird net put over the experiment on 28 May. This prevented damage by sparrows and other birds. (Widdowson, Penny, Darby and Hewitt, Soils and Plant Nutrition)

Development of the crop. Ear development of the early-sown barley crop was more advanced than that of the late-sown in spring. Thus on 8 March the main stems of the early-sown plants had started to form glumes, a stage somewhat before formation of the grain and anther primordia. By contrast the main stems of late-sown plants had only reached early double ridges, which marks the transition from vegetative to reproductive growth. By 19 April the early-sown plants had almost completed ear development, with anthers and ovaries formed, awns four times the length of the spikelets and some terminal spikelets dying. Late-sown plants were at the stage of forming anthers. There were no measurable differences in development, in the small samples taken, between treatments within a sowing date at either sampling.

Anthesis of early-sown plants was on 21 May and of late-sown plants 10 days later. The rate of development of grain primordia in the late-sown crops may therefore have been faster than in the early-sown during the period 19 April to anthesis. Possibly fast development inhibits the growth of late-developing primordia: if so this would explain the smaller number of grains per ear in late-sown compared with early-sown crops (20·5 and 22·5 respectively). The weight per grain was not changed by sowing date or, presumably, by rate of ear development. (Lawlor, Physiology and Environmental Physics)

Yields at harvest. Yields of the September- and October-sown plots are presented separately in Table 7, because sowing date was the factor that had by far the largest effect on growth (Table 8) and subsequent grain yield (+1·65 t ha^{-1}). Because of this, the other seven factors tested often produced opposing effects on the two crops. Thus aldicarb increased the yield of the September- but decreased the yield of the October-sown plots, presumably reflecting the fact that it had prevented losses in plants from the earlier sowing. By contrast the 'Baytan' seed treatment benefited neither sowing, whereas the prochloraz sprays significantly increased yields of both, but more so of the September-sown plots (0·52 *v.* 0·31 t ha^{-1}). Extra nitrogen did not affect the grain yield of the September-sown crop, but it significantly decreased the yield of the October-sown, perhaps reflecting increased lodging. Also, the time at which the nitrogen was best applied differed with sowing date: late N increased yield more than early N on the plots sown in September but early N increased yield more than late N on plots sown in October. The growth regulator also increased yields, but by more on the September-sown plots. This effect can be explained not by an increase in ear number nor in thousand-grain weights (40·4 *v.* 40·5 g) but, as we have found before, by an increase in grains m^{-2}. (Widdowson, Soils and Plant Nutrition; Jenkyn and Plumb, Plant Pathology; Lawlor, Physiology and Environmental Physics; Ross, Statistics and Scott, Insecticides and Fungicides)

https://doi.org/10.23637/ERADOC-1-129

Fungal diseases. Powdery mildew (*Erysiphe graminis* f. sp. *hordei*) was again the principal leaf disease in this experiment. However, in contrast to the previous year, the disease developed very little during the autumn and only trace amounts were seen in early-sown plots in late October. In subsequent months, in spite of some extremely cold weather, the disease increased so that by February it was common in untreated early-sown plots but much less so in those sown with 'Baytan'-treated seed (1·7 and 0·3% area affected, respectively, on third youngest leaves). Mildew in untreated late-sown plots was still very slight (0·1% on third youngest leaves). There had been little increase in the disease by early April when it was still more severe in early-sown than in late-sown plots. The seed treatment was then still providing some control of the disease, decreasing amounts on third youngest leaves from 1·1 to 0·7% in early-sown and from 0·6 to 0·1% in late-sown plots. In mid-May the disease was still slight but by then it had become more severe on the late-sown than on the early-sown plots. There was no longer any detectable effect of 'Baytan' but mildew was decreased by the prochloraz sprays. It was more severe in plots given 100 instead of 50 kg N ha^{-1} and in those given N on 22 March instead of 19 April. Leaf diseases were finally assessed at about GS 75–77 on 14 and 22 June, respectively, for early- and late-sown plots, when mildew was again more severe in the latter. Although the disease was decreased by prochloraz sprays (from 6·2 to 3·2% on second youngest leaves from early-sown and from 14·9 to 9·5% on those from late-sown plots) the efficiency of control was disappointing. Mildew was again increased by extra nitrogen but there was no significant effect of nitrogen time.

Net blotch (*Pyrenophora teres*), leaf blotch (*Rhynchosporium secalis*) and brown rust (*Puccinia hordei*) also occurred but none became severe. As expected in barley following potatoes, stem base diseases were also slight. There was, nevertheless, less eyespot (*Pseudocercosporella herpotrichoides*) in late-sown than in early-sown plots. This disease was controlled by prochloraz sprays which decreased numbers of straws infected from 6·8 to 0·1% in early-sown and from 2·3 to 0·6% in late-sown plots. Prochloraz also decreased the small amounts of brown foot rot (*Fusarium* sp.) (from 1·8% straws infected to 0·2%) but tended to increase sharp eyespot *Rhizoctonia cerealis* (from 1·0% straws infected to 2·3%). (Jenkyn and Fox, Plant Pathology)

Infertile spikelets. A feature of many winter barley crops in 1982 was that an unusually large proportion of spikelets failed to produce grain. This is unexplained but, in our experiment, they were visibly more numerous in the late-sown than in the early-sown plots. Samples, each of *c.* 70 ears, were therefore taken from all plots and numbers of grains and infertile spikelets counted. Average numbers of grains per ear were largely unaffected by treatments except aldicarb which, in early-sown plots only, decreased numbers from 22·0 to 20·0 grains per ear (−9·1%). However, this probably reflects the tendency for aldicarb to increase shoot and ear numbers in these plots. Numbers of infertile spikelets at the base of the ear averaged 0·54 per ear and were also little affected by treatments. Infertile terminal spikelets were fewer (average 0·20 per ear), but were increased by late sowing, extra nitrogen and the growth regulator. Those in the middle part of the ear (i.e. bounded top and bottom by at least one grain) were most numerous, averaging 0·78 per ear. They were greatly increased by late sowing (from 0·49 to 1·06 per ear) but also by extra N (from 0·65 to 0·90 per ear) and by later N (from 0·65 to 0·90 per ear). Of the total potential grain sites, 5·2 and 8·0% failed to produce grain in the early- and late-sown plots, respectively. Applying 100 instead of 50 kg N ha^{-1} increased the average proportion which failed to produce grain from 5·8 to 7·4% respectively. (Jenkyn, Plant Pathology)

Aphids. Vacuum samples showed that aphids, mainly *S. avenae* and *R. padi* with a few *M. festucae*, were present in early-sown plots at the beginning of November, where aldi-

https://doi.org/10.23637/ERADOC-1-129

carb had not been given, but in smaller numbers than on wheat (this report p. 22) ($1{\cdot}7\ m^{-2}$ compared to $7{\cdot}2\ m^{-2}$). The severe weather in December reduced these numbers to $0{\cdot}76\ m^{-2}$ by 6 January, and another bout of bad weather in January wiped them out completely, in contrast to the early-sown wheat crop where aphids survived throughout the winter. This confirmed our observations in 1981 that aphids were less able to survive on barley than on wheat under identical weather conditions. (Dewar, Entomology)

Barley yellow dwarf virus (BYDV). As predicted (*Rothamsted Report for 1981*, Part 1, 195–7) there was negligible infection on any plot and BYDV was not expected to have affected yield. When meaned over all other treatments aldicarb-treated plots yielded no more than those untreated. Table 7 shows that aldicarb slightly increased the yield of early-sown plots ($+0{\cdot}15\ t\ ha^{-1}$ or 1·8%) but decreased that of late-sown plots ($-0{\cdot}18\ t\ ha^{-1}$ or 1·8%); the incidence of BYDV offers no explanation for this interaction. (Plumb, Plant Pathology)

Pests. Larvae from several species of Diptera including *Delia coarctata* (wheat bulb fly), *Delia platura* (bean seed fly), *Opomyza florum* and *Lyriomyza* spp. were found in plant and soil samples from November to April. Numbers of larvae in plants were lower than expected from a count of eggs in the soil (5 million eggs ha^{-1}) and at no time were more than 5% of shoots damaged. In early-sown untreated plots on 7 October, there were only 197 plants m^{-2} compared with 230 plants m^{-2} in the aldicarb-treated plots. Aldicarb continued to have a beneficial effect on plants until March, but no correlation could be made between the treatment and damage by pests. In late-sown plots chlorpyrifos applied on 13 November decreased shoot attack by stem borers in March from 3·5% to 0·5%.

Slug populations were very low and no more than 5% of leaves were shredded at any time. In February, dead plants severed below ground level which had symptoms of pest damage, were found to be the result of frost lift after the severe winter conditions. (Scott, Insecticides and Fungicides; Fletcher and Ashby, Entomology)

Winter and spring field beans (*Vicia faba*): effects of pests and pathogens

The series of simple experiments studying the combined effects of pests and pathogens on both winter and spring beans was continued, on new sites.

As hitherto, standard practice was compared with sets of treatments likely to give economic responses, and with sets of treatments expected to give the best possible control irrespective of cost. The sets differed according to the crop.

For winter beans standard practice was foliar sprays of benomyl ($0{\cdot}56\ kg\ ha^{-1}$) on 19 May and 7 June. 'Economic' control included these sprays plus a seed treatment with benomyl and thiram (at 1·2 g of each per kg of seed) and phorate ($2{\cdot}2\ kg\ ha^{-1}$) as granules applied to the foliage on 2 April. 'Full' control included these foliar sprays and the seed treatment plus aldicarb ($10\ kg\ ha^{-1}$) worked into the seedbed, carbofuran ($2{\cdot}2\ kg\ ha^{-1}$) as granules applied to the foliage on 2 April and additional foliar sprays, of fosetyl-Al ($2{\cdot}2\ kg\ ha^{-1}$) on 8 February, benomyl ($0{\cdot}50\ kg\ ha^{-1}$) on 8 February, 14 April and 5 May and propiconazole ($0{\cdot}13\ kg\ ha^{-1}$) on 15 June. The treatments were arranged in six blocks of three plots.

For spring beans standard practice was no pesticides—black bean aphids were too few to warrant control. 'Economic' control included phorate ($2{\cdot}2\ kg\ ha^{-1}$) combine drilled with the seed, a foliar spray of pirimicarb ($0{\cdot}14\ kg\ ha^{-1}$) on 15 June and a foliar spray of benomyl ($0{\cdot}50\ kg\ ha^{-1}$) on 2 July. 'Full' control included all these treatments plus aldicarb ($10\ kg\ ha^{-1}$) worked into the seedbed and additional foliar sprays of fosetyl-Al ($2{\cdot}2\ kg\ ha^{-1}$)

https://doi.org/10.23637/ERADOC-1-129

on 1 June, of benomyl (0·56 kg ha^{-1}) on 30 July and of propiconazole (0·13 kg ha^{-1}) on 30 July and 13 August. A test of irrigation was also included, with provision to lessen a soil moisture deficit of 50 to 25 mm pefore podset, 80 to 55 mm thereafter, but only 25 mm of irrigation was required. The treatments were arranged in four blocks of two plots, for irrigation, split into three sub-plots for chemical treatments.

TABLE 9

Effects of irrigation and control of pests and pathogens on grain yield of Minden (spring) and Throws M.S. (winter) beans (t ha^{-1})

	Pest and pathogen control		
	'Standard'	'Economic'	'Full'
Spring beans			
Unirrigated	3·5	3·9	4·4
Irrigated	3·8	4·1	4·4
SED 0·12 (12 d.f.)			
Winter beans			
Unirrigated	3·0	3·0	3·0
SED 0·16 (10 d.f.)			

Grain yields (Table 9) of spring beans were significantly increased by 'economic' control and further increased by 'full' control. Irrigation increased spring bean yields on average by 0·2 t ha^{-1}. Winter bean yields were unaffected by the treatments. (Bardner and Fletcher, Entomology; McEwen and Yeoman, Field Experiments; Griffiths, Insecticides and Fungicides; Beane and Williams, Nematology; Legg, Physiology and Environmental Physics and Bainbridge, Cockbain and Lapwood, Plant Pathology)

The season and plant growth. Both experiments were sown at Rothamsted; the winter bean cv. Throws M.S. on 23 September, the spring bean cv. Minden on 25 March. They were harvested on 12 August and 2 September respectively. October and November were generally dry with average temperatures; this was followed by prolonged cold weather with much snow and ground frosts on most nights. Towards the end of February the weather became warmer and wetter than average; this persisted until mid-April when it became dry and warm until followed by an exceptionally wet June and early July. Late July and August were warmer and drier than usual.

Winter beans established well with a population at the beginning of December of 38 m^{-2} with no effects from treatments. Although chocolate spot became aggressive in late winter and early spring no plants were killed and by maturity there were 66 stems m^{-2} with no effects from treatments. Total above-ground dry matter, measured on 7 July, was 10·5 t ha^{-1} from 'standard' increased by 0·6 and 1·7 t by 'economic' and 'full' respectively. Lodging occurred in July, preventing the application of late sprays from side paths.

Spring beans also established well with a mean population in early May of 53 plants m^{-2} with no effects from treatments. Irrigation was required only in mid-May when 25 mm was applied. Total above-ground dry matter, measured on 10 August, was 8·6 t ha^{-1} from the unirrigated 'standard' treatment. The mean effects of 'economic' and 'full' treatments were increases of 1·7 and 2·1 t ha^{-1} respectively, that of irrigation was 0·2 t ha^{-1}. (McEwen and Yeoman, Field Experiments)

Weevils (*Sitona lineatus*). On winter beans leaf notches (symptoms of adult feeding) were counted on the last expanded leaf on 1 June and showed 11·3 notches per leaf on both 'standard' and 'economic' control, lessened to 0·8 on 'full'. This suggested that

https://doi.org/10.23637/ERADOC-1-129

phorate used in 'economic' had not been taken up in the dry period following application unlike the more water-soluble carbofuran used in 'full'. However, numbers of weevil larvae per root, counted on 16 June, showed a reduction from 17·7 in 'standard' to 5·3 in 'economic' indicating useful control although less effective than 'full' which had only 0·9.

Spring beans had 15·8 notches on the last expanded leaf on 18 May and 5·5 larvae per root on 30 June; both 'economic' and 'full' virtually eliminated this damage. (Bardner and Fletcher, Entomology)

Midge (*Resseliella* sp.). A cecidomyid midge, *Resseliella* sp., has been considered as a possible pest on winter beans in Eastern England because of its prevalence and the numbers of larvae found under the epidermis of stems. In mid-June 76% of the stems on 'standard' were infested, lessened to 46 and 20% by 'economic' and 'full' treatments. None was found on spring beans. (Bardner and Fletcher, Entomology)

Viruses and Vectors. Because of lodging one plot only of each treatment was examined. No viruses were detected in the winter beans in mid-April and fewer than 1% of plants were infected with the aphid-borne bean leaf roll virus at the end of June.

In the spring beans the pea aphid, *Acyrthosiphon pisum*, and bean leaf roll virus were more common than in 1981 but were well controlled by the insecticides in 'economic' and 'full'. At the beginning of June the numbers of adult *A. pisum* (alatae and apterae) ranged from 1·1 to 3·8 m^{-1} row in 'standard' and 0 to 0·6 m^{-1} row in 'economic'; none was found in 'full'. At the end of flowering the mean incidence of bean leaf roll was 16% in 'standard' and 2% in both 'economic' and 'full'; corresponding results for bean yellow mosaic and pea enation mosaic viruses (both aphid-borne) were, respectively, 0·5, 0·1 and 0·2%, and 0·6, 0·3 and 0·2%. No weevil-borne viruses were detected. (Cockbain, Plant Pathology)

Foliar fungi. Chocolate spot (*Botrytis fabae*) first became general on winter beans in January when about 0·5% of leaf area was affected by spotting. Wet weather in February favoured disease development and many 'aggressive' lesions formed. The effect of the benomyl seed treatment clearly persisted for a long time; on 16 March the area of lower leaves on untreated and treated crop affected by 'aggressive' lesions was 26 and 10% respectively while on 30 April, on mid-leaves, comparable amounts were 2·3 and 1·2%. Benomyl sprays applied during the winter gave no additional effect.

Dry weather in late April and most of May almost arrested the disease but the heavy rainfall in late May and June again favoured development. Benomyl sprays partially contained the disease but by late June spotting affected 3·2% of upper leaves and 8·2% of mid leaves. Lower nodes were defoliated.

Rust (*Uromyces fabae*) became established unusually early and by mid-June 1% of leaf area was affected; this subsequently developed into a severe epidemic which, with chocolate spot, killed all foliage by mid-July despite some temporary benefit from delay by the single spray of propiconazole applied in 'full'. This exceptionally severe attack may have originated from a small area of land in an adjacent field, which was sown in mid-August with field beans to test the ability of a precision drill to sow the large-seeded type. Because of summer sowing the plants in this area became severely infected with rust. Although they were destroyed in October we believe they may have been a source of early infection of the multidisciplinary experiment which led to the unprecedented later attack. We think this a likely explanation because the attack started near the drill-test area and because the same variety sown only 3 weeks after the multidisciplinary experiment but in a field 500 m distant was little affected by rust.

On spring beans chocolate spot was found on lower leaves in June but did not exceed

https://doi.org/10.23637/ERADOC-1-129

4% of leaf surface with spots. By 10 August 'standard' had 8% aggressive lesions on the five topmost leaves, lessened to 4 and 0·8% by 'economic' and 'full' treatments. Rust was first seen on 12 July; assessment on 10 August showed 6, 5 and 3% spotting of the topmost leaves respectively, for 'standard', 'economic' and 'full'. All plants became defoliated in mid-August. (Bainbridge and Lapwood, Plant Pathology)

Root fungi. In mid-February the disease ratings of winter bean roots were, for 'standard', 'economic' and 'full' respectively, 30, 31 and 21% for tap roots and 20, 18 and 18% for lateral roots. Disease ratings were similar in mid-March but by mid-June had increased to 39, 33 and 27% for tap roots and 37, 33 and 27% for lateral roots. Further sampling was thwarted by lodging and premature defoliation by rust.

On spring beans on 17 June the disease ratings for 'standard', 'economic' and 'full' respectively, were 20, 12 and 18% for tap roots and 21, 21 and 21% for lateral roots. Ratings had approximately doubled by early July, more (to 53%) for 'standard' and by 10 August had reached respectively, 66, 28 and 34% for tap roots and 79, 79 and 78% for lateral roots. (Lapwood, Plant Pathology)

Nematodes. On winter beans *Pratylenchus* spp. were the most abundant of the plant parasitic nematode genera found but reached a maximum of only 49 g^{-1} of fresh root weight on 'standard' when sampled in May, lessened to 8 g^{-1} by the 'full' treatment. Numbers in soil in May were 608 l^{-1} lessened to 225 l^{-1} by 'full'. Numbers in roots and soil were not affected by 'economic'. The *Pratylenchus* population was composed primarily of *P. neglectus* (66%), which causes little damage, with smaller numbers of the more damaging species *P. thornei* (17%) and *P. pinguicaudatus* (16%).

On spring beans numbers of *Pratylenchus* in roots were fewer with a maximum of 6·6 g^{-1} of fresh root on 'standard' in May, lessened to 1·6 for 'economic' and eliminated by 'full'. Numbers in soil in May were 625 l^{-1} lessened to 462 l^{-1} by 'economic' and to 144 l^{-1} by 'full'. *P. neglectus* represented 81% of the population, the remainder being *P. pinguicaudatus* (10%) and *P. thornei* (9%). (Beane and Williams, Nematology)

Conclusions. The winter bean experiment strikingly demonstrated the need to control all pests and pathogens if full yields are to be obtained. Although our treatments gave good control of weevils, midges and nematodes and some control of chocolate spot and root diseases the potential yield benefit was entirely lost as a result of failure to control rust.

On spring beans 'economic' control cost £32 ha^{-1} and gave an increased yield over 'standard' of 0·4 t ha^{-1} (worth £70) on the unirrigated crop. This increase is attributed to good control of weevils and bean leaf roll virus together with partial control of chocolate spot and *Pratylenchus*. 'Full' control cost an additional £555 ha^{-1} (chiefly for aldicarb) and increased yields by a further 0·5 t ha^{-1} on the unirrigated crop. This treatment did not improve control of weevils or bean leaf roll virus but gave better control of chocolate spot and rust to which the increase is attributed. The control of rust was imperfect, however, and even with 'full' control plants were defoliated 3 weeks earlier than in an average season. Larger yields would have been expected if leaf health had been maintained longer. Work reported in the Plant Pathology Department report (p. 202) showed that a similar rust attack in an adjacent field lessened spring bean yields by at least 1·0 t ha^{-1}.

Leafless peas: effects of pests and pathogens

The previously reported series of experiments on leafless peas at Rothamsted and Woburn (*Rothamsted Report for 1980*, Part 1, 29–33) continued in simplified form in 1981 and 1982.

https://doi.org/10.23637/ERADOC-1-129

Treatments tested were none, phorate at 2·2 kg ha^{-1} combine-drilled and aldicarb at 10 kg ha^{-1} worked into the seedbed. All seed was treated with thiram. A planned treatment against powdery mildew (*Erysiphe polygoni*) was not applied because in both years the disease did not appear until the crop was nearly mature.

The ranking of treatment effects was consistent at both sites and in both years (Table 10), with a mean yield increase of 0·5 t ha^{-1} from phorate, 0·8 t ha^{-1} from aldicarb, although the size of the response was greater in 1982. (Fletcher, Entomology; McEwen and Yeoman, Field Experiments; Whitehead, Nematology; Cockbain, Salt and Lapwood, Plant Pathology)

TABLE 10

Effects of phorate and aldicarb on grain yield of leafless peas cv. Filby (t ha^{-1})

	1981		1982		
Treatment	Rothamsted	Woburn	Rothamsted	Woburn	Mean
None	2·7	1·9	2·4	1·8	2·2
Phorate (2·2 kg ha^{-1})	3·0	2·1	3·4	2·3	2·7
Aldicarb (10 kg ha^{-1})	3·2	2·3	3·5	3·0	3·0
SED (10 d.f.)	0·14	0·19	0·33	0·53	

The seasons and plant growth. The experiments were sown to cv. Filby on 8 April and 15 April 1981; 15 April and 31 March 1982 at Rothamsted and Woburn respectively. They were harvested on 25 August and 17 August 1981; 3 September and 10 August 1982.

From a seed rate of about 250 kg ha^{-1} about 80 plants m^{-2} established at both sites in 1981. Bird damage in 1982 led to much smaller established populations of 24 m^{-2} at Rothamsted and 35 m^{-2} at Woburn. The effects of treatments on plant numbers were small and inconsistent.

In both years warm, wet weather soon after sowing aided rapid establishment: thereafter the seasons differed greatly. In 1981 wet weather continued until a brief dry but dull period in June and early July. August was warm, wet at first and then dry and sunny. In 1982 late April and May were dry, June and early July exceptionally wet, the remainder of the growing season warm and dry. Phorate and, to a greater extent, aldicarb increased crop growth and prolonged flowering but did not affect lodging which was sufficiently severe to necessitate hand harvesting and threshing in a stationary combine.

Nitrogen offtake in the grain was determined. Effects were consistent over sites and years; there was a mean offtake of 54, 66 and 74 kg of N ha^{-1} for none, phorate and aldicarb treatments respectively. (McEwen and Yeoman, Field Experiments)

Weevils (*Sitona lineatus*). Numbers of adults invading the crop were not great, perhaps because earlier-sown field beans captured much of the incoming population. In both years adult feeding activity, measured by counting the characteristic U-shaped notches on the vestigial stipules, was greater on untreated plots at Rothamsted than at Woburn (Table 11). Damage by both adults and larvae was similarly and significantly lessened by phorate and aldicarb. (Fletcher, Entomology)

Migratory nematodes. Plant parasitic migratory nematodes in the soil were counted after flowering. Numbers were extremely few in both years at Woburn, never more than 350 l^{-1} soil in untreated plots. Numbers were similar at Rothamsted in 1982 but in 1981 1775 l^{-1} were found, mostly *Tylenchorhynchus* spp., in untreated soil. Phorate had no

https://doi.org/10.23637/ERADOC-1-129

TABLE 11

Effects of phorate and aldicarb on Sitona lineatus *on leafless peas cv. Filby*

	Incidence of adults: nos. of notches per plant			
	1981		1982	
Treatment	Rothamsted	Woburn	Rothamsted	Woburn
None	9·2	1·7	19·7	7·2
Phorate (2·2 kg ha^{-1})	1·8	0·7	0·5	0·8
Aldicarb (10 kg ha^{-1})	0·7	0·6	0·3	0·7
SED (10 d.f.)	0·72	0·32	0·83	0·75

	Incidence of larvae on roots: nos. per plant			
	1981		1982	
	Rothamsted	Woburn	Rothamsted	Woburn
None	2·2	1·1	1·0	1·0
Phorate	0·1	0·0	0·0	0·1
Aldicarb	0·0	0·0	0·0	0·0
SED (10 d.f.)	0·25	0·27	0·08	0·16

effect on this population but aldicarb lessened the total to 530 l^{-1}. (Whitehead, Nematology)

Viruses. Pea enation mosaic virus was identified at Rothamsted and Woburn each year and in each experiment the level of infection was assessed in untreated plots only. In July 1981, 16% infection was detected in shoot samples at Rothamsted and 2% at Woburn. In July 1982, 30% infection was detected at Rothamsted and 16% at Woburn. Bean leaf roll was also detected in 3% of shoots at Rothamsted in 1982. No other viruses were detected. (Cockbain, Plant Pathology)

Fungal diseases. In 1981 at Rothamsted disease ratings on roots at the end of June were 46, 33 and 37% for none, phorate and aldicarb respectively. *Fusarium* spp. were prevalent in discoloured roots but not affected by treatments. *Rhizoctonia solani* was more common on untreated plots. At Woburn the disease ratings were 19, 27 and 16% respectively in early July. *Fusarium* spp. were isolated from 73% of discoloured roots: few other fungi were found.

In 1982 the disease ratings at Rothamsted in early July were 11, 5 and 5% respectively, with foot rot lesions present on 32, 42 and 45% of the plants. On the same date at Woburn the ratings were 28, 20 and 17% with foot rots on 90, 82 and 72% respectively.

In both years downy mildew (*Peronospora schachtii*) was not found and powdery mildew (*Erysiphe polygoni*) arrived too late to cause yield loss. (Salt (1981) and Lapwood (1982), Plant Pathology)

Conclusions. Previous work showed substantial yield increases from aldicarb and this was confirmed in these experiments with a mean increase of 0·8 t ha^{-1}. However aldicarb, at the rate used, would be prohibitively expensive (£500 ha^{-1}) for commercial pea production. Forunately the much cheaper material phorate (£20 ha^{-1}) was nearly as effective (0·5 t ha^{-1}) and accordingly economically viable.

The reasons for the yield increases, and the superiority of aldicarb, are not clear. Previous work suggested that a major component of yield increases was control of *Sitona* and data on control of adults in the most recent experiments support this view but numbers of larvae were not correlated with yields. Nematodes were generally too few for control to have influenced yields except perhaps in 1981 at Rothamsted. Control

https://doi.org/10.23637/ERADOC-1-129

of pea enation mosaic virus was not assessed but was unlikely to have been better with aldicarb, which is less persistent and therefore less likely to give prolonged control of aphid vectors, than phorate. Disease ratings of roots suggested that improved root health may have contributed to yield increase but there was no consistent difference between the effects of aldicarb and phorate.

In these and earlier experiments the yields of leafless peas have been consistently less than the yields of comparably treated spring-sown field beans and lodging has always caused serious problems at harvest.

Experiments on intensive potato production

Some 59% of all potatoes grown in the United Kingdom are produced by only 11·5% of the growers. This concentration of the crop into fewer, larger production areas on soils best suited to the crop is likely to continue. Growing potatoes more frequently on the same soils may exacerbate pest and disease problems, so a multifactorial experiment was started at Woburn in 1982 to study and attempt to control factors limiting to main-crop potatoes grown frequently on the same land. Pests and diseases are monitored on the growing crops and harvested tubers and tuber yields and quality are assessed.

Experimental layout. The experiment is in Lansome field, Woburn Experimental Farm, on sandy loam (Flitwick and Stackyard series of brown earths over sandy colluvium and Cottenham series brown sand over Lower Greensand). There are two randomized blocks of 12 plots, which accommodate four rotations of differing length—(a) Désirée potatoes in the 5th, 6th or 7th years of the experiment (6, 7 or 8-course rotation), (b) Désirée potatoes in a four-course rotation, (c) Désirée potatoes in a two-course rotation, and (d) Désirée potatoes alternating with Maris Piper potatoes in successive two-course rotations. Désirée potatoes are susceptible to both species of potato cyst-nematode (*Globodera rostochiensis* and *G. pallida*) and Maris Piper potatoes are resistant to *G. rostochiensis* pathotype Ro1 (the common pathotype at Woburn) but susceptible to *G. pallida*. Spring barley (cv. Triumph) is grown in the years between potato crops.

Each potato whole plot is subdivided into eight sub-plots to accommodate all the combinations of: (a) untreated, (b) oxamyl (soil nematicide-insecticide) at 5 kg a.i. ha^{-1} applied as 10% granules to the soil surface and incorporated into the seedbed by spiked rotavator, (c) iprodione at 100 g a.i. and imazalil at 10 g a.i. t^{-1} to seed tubers (systemic fungicides), and (d) methiocarb (molluscicide) applied to the soil surface as 'Draza' slug pellets at 5·5 kg ha^{-1} on several occasions in the summer.

Basal treatments. Amounts of N, P, K and Mg fertilizers appropriate for high yielding crops are applied each year. An initial dressing of 7·5 t ha^{-1} of magnesian limestone followed by 816 kg ha^{-1} of (0:14:28) P-K fertilizer was ploughed-in in November 1981. In spring, barley seedbeds received 628 kg 'Nitro-chalk' ha^{-1} and potato seedbeds 2959 kg of (10:10:15) N-P-K+Mg fertilizer ha^{-1}.

All potato plots are treated with aphicides and fungicides. Phorate granules at 1·5 kg a.i. ha^{-1} were applied in the seed furrows. Pirimicarb ('Aphox') was applied on 16 June and on 2 and 27 July to control aphids and 'Dithane 945' (mancozeb) or 'Patafol-plus' (mancozeb+ofurace) to control late blight (*Phytophthora infestans*) on 16 June, 2, 13, and 27 July and 11 and 23 August.

Potato plots are irrigated from overhead oscillating spraylines to control scab (*Streptomyces scabies*), to which both cultivars are very susceptible, and to ensure satisfactory bulking of the tubers. Irrigation is applied to decrease a deficit of 38 to 19 mm up to the onset of tuber initiation, of 19 to 13 mm from the onset of tuber initiation for 4–6 weeks and from 50 to 25 mm thereafter.

https://doi.org/10.23637/ERADOC-1-129

The keeping qualities of the tubers and the development of disease during storage are being studied.

Volunteer potatoes in barley plots are sprayed with glyphosate about 10 days before harvesting the grain. Volunteer Pentland Crown tubers in the potato plots yielded very few tubers in 1982. (Whitehead, Williams and Beane, Nematology; Hide, Lapwood and Govier, Plant Pathology; Henderson, Entomology; Scott and Etheridge, Insecticides and Fungicides; Addiscott, Soils and Plant Nutrition)

Potato cyst-nematodes and tuber yields. Although all plots of the experiment are infested with potato cyst-nematodes, numbers vary greatly between sub-plots (3–111 eggs g^{-1} dry soil before planting in 1982). In untreated sub-plots, yields of total tubers decreased with increase in nematode numbers from about 60 t ha^{-1} in the least-infested to about 20 t ha^{-1} in the most heavily-infested sub-plots. Similarly, the proportion of small tubers increased with increase in nematode numbers and the tubers were pitted and coloured russet-brown by nematode attack. Such tubers are likely to shrivel in dry storage. In untreated sub-plots, numbers of potato cyst-nematodes increased greatly, the increase being inversely related to the numbers in the soil at planting. Oxamyl incorporated in the seedbed prevented nematode injury to both roots and tubers and increased the mean yield of tubers from 37·7 to 60·4 t ha^{-1}, irrespective of nematode numbers (Table 12). (Whitehead, Williams and Beane, Nematology)

TABLE 12

Effects of sub-plot treatments on yield of Désirée potatoes and on potato cyst-nematode increase

Treatment	Tubers (t ha^{-1})	Nematode increase*
Untreated	40·4	21·2
Methiocarb (M)	33·0	10·2
Iprodione-imazalil (I)	38·3	12·3
M+I	39·2	15·8
Oxamyl (O)	58·3	1·0
O+M	60·4	1·2
O+I	63·3	1·2
O+M+I	59·6	1·5
SED	4·6 (32 d.f.)	4·2 (33 d.f.)

* Nematode eggs g^{-1} dry soil after harvest: before planting.

Aphids. Fifty potato leaves were examined for aphids on each of the six whole plots at regular intervals from the middle of June to the end of August. Insecticidal treatment was very effective: on one occasion only (19 July), a few *Myzus persicae* were found on a single leaf. (Etheridge, Insecticides and Fungicides)

Slugs. Slug traps were put in all 48 sub-plots at fortnightly intervals from 2 July to 10 September. No slugs were found during this period, no slug damage was observed on the harvested tubers and methiocarb applied to the soil surface on six occasions between 2 July and 10 September did not affect tuber yields significantly. A few tubers were damaged by cutworms. (Scott, Insecticides and Fungicides; Henderson, Doran and Mama, Entomology)

Virus diseases. Six rows of potato plants in each of the six whole plots were inspected for virus infection on 16 June. Only one leafroll-infected plant was found in the total of over 3000 plants examined. (Govier, Plant Pathology)

https://doi.org/10.23637/ERADOC-1-129

Fungus diseases. The Désirée seed tubers, with which the experiment was planted, were examined for fungi. Silver scurf (*Helminthosporium solani*) was found on 90%, black scurf (*Rhizoctonia solani*) on 4% and skin spot (*Polyscytalum pustulans*) on 2% of the tubers.

In August, stem canker (*R. solani*) was present but not severe. Iprodione seed treatment lessened incidence of the disease from 28 to 12% stems infected. The uneven distribution of the disease in the field suggests uneven distribution of the fungus in the soil. Black-leg (*Erwinia carotovora* subsp. *atroseptica*) was noted in the wettest of the six whole plots.

Tubers harvested in October were infected with black dot (*Colletotrichum coccodes*) and black scurf but silver scurf was rare. Common scab (*Streptomyces scabies*) was effectively controlled by irrigation. (Hide and Lapwood, Plant Pathology)

Conclusion. In 1982, the principal pests in the experiment were potato cyst-nematodes, which markedly reduced yield and quality of harvested tubers. Oxamyl controlled the nematodes satisfactorily and greatly increased tuber yield and quality. Virus diseases, late blight, aphids and slugs were rare or well-controlled by basal treatments. Silver scurf was prevalent on seed tubers but rare on progeny tubers. Some stem canker occurred in the field and black scurf and black dot were prevalent on the harvested potatoes.

https://doi.org/10.23637/ERADOC-1-129