Report for 1979 - Part 1

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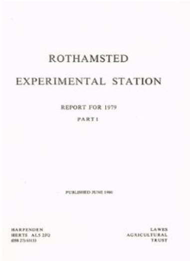
ROTHAMSTED
EXPERIMENTAL STATION
REPORT FOR 1979
PART 1

Broom's Barn Experimental Station

R. K. Scott

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BROOM'S BARN EXPERIMENTAL STATION

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Introduction

The year 1979 and the growth of the crop. After a severe winter which resulted in an estimated 93 000 t of beet in the West Midlands not being processed, the start of sowing for the 1979 crop was much delayed by frequent rain. March was the wettest for 50 years and no field work was possible during the month. The first beet was sown at Broom's Barn on 12 April with the soil still very wet. As sowing progressed onto the heavier soil at the west of Hackthorn, the seed was laid into a smeared furrow and was barely covered

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on the wetter patches of the field. With drier weather rapid progress was made and on the heavier soil of Little Lane there was sufficient tilth to ensure that the seed was uniformly covered. Nationally only 7% of the crop was sown by 14 April compared with 80% by the same date in 1977 and 1978 and 100% in 1976.

Nitrogen was applied late in February and at the beginning of March to some sugar-beet fields. Measurements showed that much of it had been leached into the subsoil before sowing could begin and on sandy loams/loamy sand soils we recommended, for the first time, that a further 40 kg N ha^{-1} should be applied immediately after sowing. Rain after sowing maintained the moisture supply to the germinating seeds and emerging seedlings and fertilisers did not depress emergence. Despite the difficulties at sowing, plant populations were generally better than usual. However, the rain caused widespread loss of soil structure which resulted in retarded root growth, and induced mineral deficiencies later in the season. Had soils dried out rapidly, 'crusts' would have formed with disastrous effects.

Because of prolonged cold periods during the winter the danger of a severe attack of yellows was remote, and in early March Broom's Barn advised sugar-beet growers not to apply granular pesticides at sowing for green aphid and virus control. In the event about 40% of the sugar-beet area was treated with granular pesticides at sowing, but a large proportion of this was aimed at nematodes and other soil-inhabiting pests. Pests were particularly active on some soils, e.g. establishment was less than 10% on untreated plots in experiments on the Yorkshire Wolds where, although some pesticides were relatively ineffective, carbofuran gave 60% establishment.

The wet spring again favoured nematode activity and, despite the widespread use of granular pesticides (aldicarb, oxamyl, carbofuran), a greater area of Docking disorder was reported than in any previous year except 1969. This was attributed to nematicides leaching below the seedling rooting zone, decreasing their efficiency. In June, 3368 ha were reported affected, mostly in the northern and western areas. However, most of this damage was considered 'slight' (anticipated yield loss less than 10%) and pesticides undoubtedly prevented an even greater loss of yield, especially in the more intensive sugar-beet growing areas in East Anglia where they are used on almost all fields susceptible to the disorder.

After a slow start leaf area expanded more rapidly than in 1978 due to warmer conditions in June and July. From late June onwards the soil water deficit increased steadily to reach 150 mm by the end of July. August rain prevented further increase until September, when it increased to reach a maximum of 190 mm by the middle of the month. Non-irrigated crops wilted frequently and there was a good response to irrigation. July, August and September weather was brighter than in the previous year and an irrigated crop at Broom's Barn yielded 11·2 t sugar ha^{-1} compared with a similar crop in 1978 which hardly experienced water stress and yielded 8·1 t sugar ha^{-1}.

A few *Myzus persicae* were found on the beet crop at Broom's Barn from the beginning of July, none having been found earlier on beet or overwintering weeds, but never more than 8% of plants became infested. *Aphis fabae* were found on beet from the end of May, as anticipated from surveys of overwintering eggs, and reached potentially damaging numbers by mid-July. Their numbers peaked at the end of the month but the population then declined rapidly. By the end of August neither *M. persicae* nor *A. fabae* could be found on the crop. Many growers were advised by the British Sugar Corporation field staff to spray against black aphids and about 51% of the national crop was sprayed at least once. From late July there were reports of a few isolated plants showing virus yellows and, at the end of August, small patches of infected plants could be found in many areas. The few fields badly affected were near beet-seed crops or plant breeders' trial fields.

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Plant clinic. Giving advice to individual farmers on specific problems as they arise, usually through the intermediary of the sugar factory field staffs, has always been an important part of the work of the Station. Many telephone calls and letters and some visits are entailed. In spring and summer samples of stunted, damaged or diseased sugar-beet plants are sent to us for diagnosis of the cause and recommendations for treatment where possible. From an average of 80 samples per year between 1973 and 1976, the numbers received have recently increased to 182 in 1977, 207 in 1978 and 143 in 1979. The most common problems encountered are suspected nematode damage (principally Docking disorder), herbicide damage, fertiliser problems and deficiencies.

This service is important, both for beet growers and for ourselves, since it brings us into contact with new problems as they arise. However, it causes difficulties because most of the samples are received in the seven weeks from late May to early July which is also a peak period for field work on our research programme. The logistics of handling these samples has been reviewed and modifications to procedure, staffing and equipment are proposed. We hope this will enable us to improve the service, which needs prompt replies to be of value, while minimising its disruptive effect on our research.

Plant establishment

Some of the problems of establishing the sugar-beet crop, together with the remedial research strategy, were outlined in last year's *Report*, Part 1, 59–60. The multidisciplinary study to identify the conditions for seeds either to produce an established plant or fail to do so, was continued in 1979. Experiments at Broom's Barn show that if a sowing in the second half of March gives reasonable establishment it will outyield a later sowing even though plant establishment usually improves with later sowing. Therefore in 1979 it was intended to monitor the seedbed environment and compare the performance of seeds sown in mid-March with those sown 4 weeks later. Because of frequent rain, the first sowing could not be made until 17 April; the second was on 16 May. In addition to the main study area, plots given widely differing treatments were included to quantify the effects of varying aggregate size distribution, supplementing or reducing rainfall, and controlling pests and pathogens by soil sterilisation or applying pesticides.

The fate of seeds sown on 17 April and 16 May is summarised in Table 1. Careful excavation of the drill furrow indicated that the machine failed to deliver a seed to 4% of positions. For the second year running the proportion of seeds which germinated was similar to that which germinated in the standard laboratory test; during both sowings the soil was predominantly wet. The reason why 10% of the seeds which germinated did not grow into emerged seedlings is not clear since all the radicles appeared healthy. One possible explanation, suggested by field observations with supplementary water and supported by results of laboratory experiments is that, although most seeds can germinate apparently normally under very wet conditions, vigour is impaired since 10–15% make no further growth.

Pest and disease damage was only found after most seedlings had emerged. Some plants

TABLE 1

Seed sown and seedling establishment at Broom's Barn in 1979

Sowing date	No seed found	Seeds which remained intact	Seeds which germinated	Seedlings which emerged	Plants which established
	Number per 100 seed stations				
17 April	5	6	89	81	79
16 May	3	3	94	83	80

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were affected by the fungi *Rhizoctonia* and *Pythium*, whilst others were grazed by mice, birds, slugs, millipedes or pygmy beetles. Up to 33% of seedlings from the first sowing and 25% from the second sustained some damage but only 2% of the seedlings which emerged subsequently died. The 80% establishment achieved in this study was substantially better than in many other experiments in 1979 and 25% higher than the average of over 200 field experiments between 1970 and 1977.

Each year in every crop there is much variation in seedling size and this makes the timing of herbicide sprays very difficult to judge. Seedlings were harvested individually on 13 June from the first sowing and on 28 June from the second sowing. Variation in emergence date was more important than seed depth or inter-seedling spacing in determining seedling weight. The first seedlings to emerge were the largest and seedling weight and emergence date were related in a linear manner. From the first sowing the first seedlings to emerge were 50 times heavier than the last and there was a factor of 15 between the first and last seedlings to emerge from the second sowing. Clearly it would be advantageous if seedling emergence could be accelerated and synchronised.

Overall, results from this study in 1979 have quantified conditions which give successful seedling establishment and set a base line for comparing results under less favourable conditions. (Bentley, Bugg, Dunning, Durrant, Jaggard, Scott & Webb, with Cooper, Johnson, Payne, Podlaski and Sanderson)

Vigour testing. Bulks of sugar-beet seed of the same variety that have similar laboratory germinations sometimes differ when grown in the field. A test of seed lot 'vigour' which could predict field establishment would be a useful adjunct to the statutory germination test. A project in co-operation with British Sugar, the National Institute of Agricultural Botany and Stirling University was started in 1979. The 25 bulks of seed issued to growers in 1979 were sown at seven representative sites. Seedling emergence varied between sites from 80 to 54%, and between bulks from 76 to 54%. In general, the ranking order of bulks was consistent between sites. The standard germination test between filter paper at 20°C counted after 14 days ranked seed lots more closely to their field performance than other tests used, although it over-estimated the number of seedlings (range 98 to 85%). It appears that a more careful examination of the standard germination test may be the most useful way of predicting field performance. (Longden)

Insecticide/herbicide/rotation interactions. This was the third year of an experiment made jointly with the Entomology Department which is one of a series organised by the International Organisation for Biological Control (IOBC) on integrated control of seedling pests of sugar beet (*Rothamsted Report for 1977*, Part 1, 99; and *for 1978*, Part 1, 98). It tests the effects of all combinations of continuous beet or a beet/cereal rotation; HCH at 1 kg a.i. ha^{-1} applied overall, aldicarb applied in the seed furrow at 0·8 kg a.i. ha^{-1} in 1977/78, 1·2 kg in 1979, or no insecticide; chlorizadon applied overall, or no herbicide; on the soil fauna throughout the season and on sugar beet establishment.

The effects of treatments on pest damage were assessed by seedling establishment counts and on the soil fauna by pitfall trapping and soil sampling. The no-herbicide treatment allowed natural weed populations to develop during the beet seedling stage but this did not significantly affect seedling establishment; herbicide decreased weed populations on average by 75%. The effects of rotation and insecticides on seedling establishment are shown in Table 2 (counts are the mean of herbicide and no-herbicide treatments).

The decline in establishment under continuous beet was due mainly to increasing damage by *Atomaria linearis*. The average numbers of *A. linearis* per seedling (extracted from 5 cm diameter soil cores centred on a seedling) in mid-May on the no-insecticide

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TABLE 2

Effect of rotation and insecticide on seedling establishment (%)

	1977 Beet after barley	1978 Beet after beet	1979 Continuous beet	1979 Beet after wheat
No insecticide	82	35	5	53
HCH (overall)	85	61	28	66
Aldicarb (seed furrow)	82	48	66	67

continuous beet plots increased from 0·4 in 1977 to 2·5 in 1978 and 5·7 in 1979. By contrast on the no-insecticide plots of beet after wheat there were only 0·7 per seedling in 1979. The increased activity of *A. linearis* in the continuous beet plots in 1979 was also shown by the pitfall trap catches; 109 *A. linearis* per trap were caught in the 8 weeks after sowing in the beet after wheat plots whereas 560 were caught in the beet after beet plots. In 1978 only 172 were caught in the same period in the beet after beet plots.

In 1978 and 1979 both insecticides decreased the numbers of *A. linearis* trapped in the early part of the eight week period (not recorded in 1977), and this was reflected in improved establishment (Table 2). In all 3 years fewer of the beneficial or neutral staphylinid beetles were caught on the HCH plots than on the controls at the beginning of the trapping period and more at the end, but aldicarb had no consistent effects. HCH decreased the number of carabid and staphylinid larvae caught each year but had varying effects on the carabid beetles, increasing the catch of some species, decreasing others. In 1979 aldicarb decreased the number of earthworms and polydesmid millipedes caught; such an effect was not observed in 1977 and 1978. The results on microarthropods are given in the Report of the Entomology Department (p. 81) and a full report of the results of this trial, in comparison with the same one in five other countries is, being prepared for IOBC. (Thornhill and Dunning)

Environmental and nutritional aspects of crop growth and productivity

Group study area. The rate of dry matter production and sugar yield of beet is being investigated in relation to the amount of radiation intercepted by the crop (*Rothamsted Report for 1978*, Part 1, 64). Following the initial study made last year a more detailed series of measurements were made in 1979 to examine the effects of nitrogen fertiliser and irrigation on crop growth and sugar yield. Four plots sown on 13 April on the same field at Broom's Barn received either nil or a dressing of 125 kg nitrogen ha^{-1}, each with either natural rainfall only or rainfall supplemented with irrigation to maintain a soil moisture deficit less than 50 mm. Other fertiliser and cultivation treatments were normal for Broom's Barn. Plots and soils were sampled, at first weekly and then every 2 weeks from early June until mid-November. The total solar radiation (400–3000 nm) was measured throughout the growing period using solarimeters above and below the leaf canopy of each plot, with electronic integrators, and radiation intercepted by the crop was calculated as the difference between these two values.

Radiation interception and sugar production. By the middle of June plots which had not received nitrogen had smaller leaf area indices and dry weights than those which had, and this effect continued throughout the season. The weather during July and August was relatively dry and bright and irrigation was applied four times. Supplementary watering almost eliminated wilting and greatly reduced leaf senescence, particularly where nitrogen had been applied. As a result the plot to which both nitrogen and irrigation were applied (N+I) intercepted between 85 and 90% of the total solar radiation from mid-July until

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early August, while other plots intercepted between 50 and 75%. When rain relieved the drought stress the plot with an adequate supply of nitrogen produced new leaves. Throughout September and October this and the N+I plot intercepted approximately 90% of the available radiation; plots not given nitrogen intercepted no more than 65%.

The available analyses (to the end of August) indicate that all plots converted intercepted radiation to dry matter at a rate of 1·77 g MJ^{-1} compared with 1·98 g MJ^{-1} for a crop sown on 24 April 1978 which did not suffer water stress and had the same nitrogen dressing. Final yields in the 2 years differed considerably. In 1979 the N+I plot produced 22·3 t dry matter ha^{-1} and 11·2 t sugar ha^{-1}; corresponding yields in 1978 were 17·1 and 8·1 t ha^{-1}. The difference between years was largely the result of differences in the amounts of solar radiation intercepted between emergence and harvest, 1110 MJ m^{-2} in 1978 and 1417 MJ m^{-2} in 1979, due almost entirely to brighter weather during July, August and September. This analysis suggests that crops grown in a high-radiation environment, e.g. southwest Wales, should yield more dry matter and sugar than those grown in East Anglia. An experiment is being carried out in collaboration with University College of Wales, Aberystwyth, to test this hypothesis.

A major problem when analysing crop growth in relation to radiation intercepted is the large error in growth analysis measurements towards the end of the growing season. This makes it impossible to detect differences between sampling dates of less than 5% which occur when the crop is growing slowly. To overcome this a mobile infra red gas analysis system has been built to measure photosynthesis, respiration and transpiration in the field. A semi-closed system is used with a perspex enclosure that will cover six plants at normal spacing. The air in the enclosure is maintained at ambient temperature and humidity and the flow through the system can be altered so that measurements can be made throughout the season. The sensitive and non-destructive nature of the enclosure technique will enable detailed measurements to be made of the effect of environmental variables on dry matter production late in the autumn. Field tests in autumn 1979 showed that the system is very sensitive to changes in carbon dioxide exchange by sugar beet.

Crops given nitrogen and irrigation in 1978 and 1979 partitioned their dry matter differently. In 1978 sugar, as a proportion of root dry weight, increased until approximately 15 August, and thereafter remained constant at 74%. In 1979, sugar became a constant 77% of root dry matter from about 20 July. The cause of these changes is unknown, but they may have considerable implications for the amount of sugar which can be produced given similar amounts of radiation intercepted.

Irrigation. Rainfall from March to May was 195 mm compared to the long-term average of 125 mm, and the soil moisture deficit was negligible until the middle of June. By the end of June the deficit was 35 mm on plots which had not received nitrogen fertiliser and 50 mm on plots with 125 kg N ha^{-1}. Rainfall during the summer was below average so that deficits increased quickly during July to reach 130 and 165 mm respectively. A maximum deficit of 190 mm was reached in the middle of September.

Irrigation was applied three times in July and once in late August; 139 mm to the plot without nitrogen and 169 mm to that with nitrogen. Plots given nitrogen used 23·5 mm of water to produce each tonne of dry matter, whereas without nitrogen 29·3 mm t^{-1} was used. The measured responses of the plots were examined in relation to the incremental gain, k (*Rothamsted Report for 1978*, Part 1, 93) in both root and sugar yield per unit of applied water. For plots given nitrogen, irrigation increased the root yield (fresh weight of roots) by 18% and the k-value was 0·07 t ha^{-1} mm^{-1}. This is about 60% less than the maximum values recorded for potatoes, but five times greater than the largest value for spring beans at Rothamsted and Woburn. Both with and without nitrogen the k-value

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for sugar yield was 0·01 t ha^{-1} mm^{-1}, indicating the potentially large returns that can be expected from irrigating sugar beet.

Relationships between soil mineral nitrogen and uptake by the crop. Immediately following each harvest, soil from each plot was sampled from both the plough layer (0–25 cm) and the subsoil (25–60 cm) and the total mineral nitrogen (ammonium plus nitrate) analysed. In mid-June about 80% of the nitrogen applied was still in the top 60 cm of soil. Most of it was in the plough layer but about 30 kg N ha^{-1} had been leached by spring rainfall into the subsoil. In June and July, soil mineral nitrogen decreased rapidly on all plots; uptake was restricted by shortage of water on the non-irrigated plots. While the dry weather continued in August, the crop removed little soil nitrogen unless irrigated. Rainfall in August increased nitrogen uptake and soil mineral nitrogen decreased during August and September. By the end of September, all plots contained about 40 kg N ha^{-1}, equivalent to the amount found in June in plots given no nitrogen. During October and November, soil mineral nitrogen changed little.

With both nitrogen and irrigation the amount of nitrogen taken up by the crop from June to November reflected changes in soil mineral nitrogen. Rates of nitrogen uptake and removal from the soil were similar and only 25 kg N ha^{-1} was taken up from below 60 cm and/or released by mineralisation. This was not so where no nitrogen was given, particularly when the plot was irrigated. On these plots there was either much more uptake from below 60 cm or more mineralisation or both, because the crop contained 70 kg N ha^{-1} more than was accounted for by the change in soil nitrogen.

The distribution of nitrogen within the plant was also studied by dividing plants into roots, petioles, laminae and dead leaves. The laminae and petioles contained most of the nitrogen during June and July, reaching a maximum at the end of July. The amount then declined until harvest, particularly steeply in plants given nitrogen and irrigated. The amount in the roots increased slowly throughout the life of the crop, reaching a maximum of 70 kg N ha^{-1} at harvest. The dead leaves contained very little nitrogen, at most about 20 kg N ha^{-1} at the end of October, leaving 20 kg N ha^{-1} unaccounted for, presumably either lost in leaves which had fallen off the plants, remobilised into the plant or leached back into the soil from the dead leaves. (Biscoe, Draycott, Glauert, Jaggard, Last, Messem and Scott with Booth, Harris and Denise Webb, and with Milford, Botany Department)

Time and method of nitrogen application. Experiments were continued to determine when and how to apply nitrogen fertiliser so that leaching is prevented as far as possible and phytotoxic effects on germinating seeds are avoided. In 1979 one experiment was made at Broom's Barn and seven at outside centres by British Sugar field staff comparing broadcast nitrogen application at different times with placed application at or shortly after sowing. At Broom's Barn a machine has been developed to apply nitrogen on the soil surface to the side of the rows at sowing. The British Sugar experiments tested a prototype commercial machine which also applies the nitrogen to the soil surface but as a separate operation from sowing.

Rain delayed sowing until mid-April and further rain after sowing gave good germination, emergence and establishment in all the experiments. Under these conditions of late sowing and plentiful moisture it was expected that the toxic effect of nitrogen would be minimal and seedling counts confirmed this. Nitrogen broadcast 2 weeks before sowing had no effect on establishment; broadcast immediately before or after sowing it delayed emergence but had no effect on the final number of established plants. Applications via the special machines caused no delay in emergence or decrease in establishment.

Broadcasting 2 weeks after sowing was tested for the first time, at Broom's Barn only,

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because growers have asked if this is a safe time to apply nitrogen to sugar beet. Results from the one experiment suggest that germinating seeds are more vulnerable to phytotoxicity and the nitrogen significantly delayed emergence and decreased establishment. The Broom's Barn experiment also tested nitrogen applied after the crop had established. At this stage the fertiliser had no effect on the number of plants.

At Broom's Barn the amount of mineral nitrogen in each plot was determined in June. There was no evidence of loss of nitrogen through leaching on any treatment. In all the experiments plants from plots given nitrogen were much larger than those given none, often with double the dry weight in June. Where the nitrogen was given via one of the special machines, the plants were similar in size to those given broadcast nitrogen, showing that it was available to the crop at the early stages of growth. When nitrogen application was delayed until after emergence, the plants were smaller than those given nitrogen near sowing time. These investigations are continuing as more information is, needed in a year when establishment is poor, because it is then that the greatest advantage of placed application is expected. (Draycott, Last and Webb)

Manganese deficiency and seed pelleting. Experiments have shown that a foliar spray with manganese increases yield of deficient crops. No soil treatment which is economic on an agricultural scale has yet been discovered to protect seedlings from deficiency until they are large enough to spray, but incorporation of a suitable manganese carrier in the seed pellet has been developed instead. Pellets containing 50% w/w MnO in the pelleting clay were used for the first time by a few growers in 1978 and were on sale to all growers in 1979. In 1979, 1500 ha of sugar beet were grown from manganese pelleted seed. Test strips of untreated and treated seed were sown side-by-side by several growers, and there were three field trials (Woodwalton Fen near Peterborough on a very deficient soil; Arthur Rickwood Experimental Husbandry Farm on a moderately deficient soil; and Broom's Barn where the soil contains a good supply of manganese). Periodic sampling of these crops confirmed that the manganese provided by the pellet increased the dry weight of plants by up to 50% where untreated plants were severely deficient. On fields where the crops showed no signs of deficiency, the pellets containing manganese had no beneficial or harmful effect. No further work on manganese is planned for the immediate future. (Farley)

Diseases and pests

Studies continued on aphid and predator populations overwintering on beet, cabbage, rape and weeds. *M. persicae* was found on all overwintering hosts in November. A few survived snow and low temperature in late November and December and an extended period of very cold snowy weather in January, but disappeared during a further cold snowy spell in late February. They were not found again on either the crop plants or weeds before June when the area was ploughed.

Changes in aphid and predator populations, and the development of virus yellows in 0·5 ha sugar beet root crop not treated with insecticide, were again monitored (*Rothamsted Report for 1978*, Part 1, 68). *M. persicae* did not appear until July. Moderate populations then developed on isolated plants, but the average infestation remained low. There was little spread of virus yellows into or within the area and by mid-September only 0·01% of plants were infected.

A. fabae was first found in the root crop in late May and a small population persisted until July when, in warm dry weather, it increased rapidly reaching a peak of 1630 aphids per plant by 30 July. With the onset of cooler wet weather numbers of *A. fabae* declined very rapidly and none were found after the end of August. The most important cause of

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the decline was the rapid spread of *Entomophthora* spp. but the rain itself, which knocked many aphids off the plants, also contributed to the decline and syrphid larvae, coccinellids, hymenopterous parasites, anthocorid bugs and large carabid beetles were also numerous. (Heathcote, Thornhill and Smith, with Hinckes)

Inoculation with virus yellows. To interpret epidemiological studies in years when yellows is prevalent a better understanding of factors affecting the development of symptoms in infected plants is needed. A study was therefore started on the development of symptoms of beet yellows virus (BYV) and beet mild yellowing virus (BMYV) on sugar beet infected with either virus. A first series of plants was inoculated in the field (using five viruliferous aphids caged on each plant) at the 4–6 leaf stage on 6 June. Further series were inoculated at 2 week intervals up to 30 July. Plants infected at the 4–6 leaf stage developed symptoms typical of each virus but by the end of July the symptoms on these plants had become indistinguishable. Symptoms resulting from later inoculations were affected by water stress and it was not possible to identify the two viruses by symptoms alone.

The time between inoculation and symptom appearance increased with age of the plant. Of plants inoculated with either virus at the 4–6 leaf stage, 90% developed symptoms within 3–4 weeks. Those inoculated 4 weeks later, at the 12–14 leaf stage, took 8–9 weeks for 60% to show symptoms. Thus some plants were infected but without yellowing symptoms for long periods, showing that the time when a plant shows symptoms is a poor indication of when it became infected. The significance of this in studies of the epidemiology of virus yellows requires further study and it also raises questions of the importance of these symptomless infected plants. Do they act as sources of virus? Is yield affected before symptoms appear? What effects do other factors, such as temperature, light intensity and plant age have on the way in which plants react to virus infection? (Smith and Byford)

Control of *A. fabae*. Demeton-S-methyl, demephion, pirimicarb, acephate and ethiofencarb are recommended for the control of *M. persicae* and virus yellows in sugar beet. *M. persicae* were scarce in 1979 but *A. fabae* were common and we were able to evaluate these insecticides and the experimental product 'Hoe 25682' against them in five trials in collaboration with British Sugar.

Plots were sprayed once in the period 22 June–20 July 1979. The numbers of *A. fabae*/plant at treatment were: Brigg, S. Humberside 420; Scole, Norfolk 45; Babraham, Cambs.

TABLE 3

Average percent decrease in numbers of A. fabae *following insecticide sprays in 1978 and 1979*

	Application rate g a.i. ha^{-1}	Percentage decrease in *A. fabae*			
		1978		1979	
Days after spraying:		5-7 days	13-14 days	5 days	10 days
Product					
Demeton-S-methyl	244	70	57	96	90
Demephion	252	86	73	97	89
Pirimicarb	140	76	80	96	95
Pirimicarb	280	—	—	98	95
Acephate	450	20	38	77	69
'Hoe 25682'	300	68	63	95	91
Ethiofencarb	500	55	52	90	85

Spray applied in 500 litres water ha^{-1}

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95; Kelvedon, Essex 448; Foulden, Norfolk 1. *A. fabae* were counted on all plots 5 and 10 days after treatment, except at Foulden where, because aphids were few, only the 5-day count was made. Six of the treatments were also tested in 1978 at Bury St. Edmunds, Suffolk where there were nine wingless *A. fabae* at spraying, and Maldon, Essex where there were 78. The average decrease in *A. fabae* populations for each year are given in Table 3 (omitting Foulden, 1979). Acephate was less effective than the other products tested. (Winder and Dunning)

Powdery mildew and sulphur sprays. In the dry summers of 1975 and 1976 *Erysiphe betae* was unusually prevalent in beet crops in England and caused yield losses estimated at up to 15%. In 1977 wet weather in August delayed the spread of the fungus until September, but nevertheless sulphur sprays significantly increased yield at Broom's Barn (*Rothamsted Report for 1977*, Part 1, 66).

In 1978 the fungus appeared late at Broom's Barn and no plants were heavily infected. However, single sprays of 9 kg a.i. sulphur ha^{-1} applied between 19 August and 8 September increased sugar yield on average by 6%. Sulphur applied at 4·5 or 2·3 kg ha^{-1} gave similar yield increases but 13·5 kg ha^{-1} sulphur did not increase yield.

One of the objectives of the 1979 experiments was to test the possibility that sulphur might have some effect on the growth of beet in addition to controlling *E. betae*. At three sites in the York sugar factory area where powdery mildew does not usually occur, the susceptible variety Nomo was given one spray with 8 kg a.i. sulphur ha^{-1} on each of three occasions between 8 August and 5 September. No powdery mildew was found in the trials and all spray treatments at all sites slightly decreased sugar yield, on average by 4%.

At Broom's Barn single sprays of 8 kg a.i. sulphur ha^{-1} were applied weekly from 27 July to 21 September to Nomo and the less susceptible variety Sharpe's Klein Monobeet. Powdery mildew appeared near the trial by 15 August on scattered infected plants and small patches of infection were found in the trial by 23 August. During drier weather the disease then spread rapidly and most plants in unsprayed plots were infected by mid-September. The proportion heavily infected was only slightly lower in Sharpe's Monobeet than in Nomo. Final yields suggested that the timing of the spray was less critical with the less susceptible variety, because the yield of Sharpe's Monobeet increased on average by 8·5% following sprays applied at any time between 7 August and 14 September but a similar response was achieved with Nomo only by sprays between 15 and 29 August.

In an experiment at Easthorpe, Essex, responses were even larger than at Broom's Barn although mildew was neither earlier nor more severe. Sulphur at 8 kg a.i. ha^{-1} applied on 15 or 29 August increased sugar yield by 25% and 28% respectively. Spraying twice did not give more sugar than a single spray.

Experiments between 1975 and 1979 have clearly shown the benefits of using fungicides, particularly sulphur, to control powdery mildew in East Anglia, and these benefits are not confined to the more mildew-susceptible varieties. Future work should seek to determine the proportion of the crop in which mildew control is profitable, the most efficient fungicides to use, and should check whether the possible small adverse effects vary with different sulphur formulations or different varieties. (Byford, Bentley and Hinckes)

Rotational aspects of sugar-beet growing

Broom's Barn Farming policy review. One of the main tasks of the members of the Rotation Group in 1979 was to review the farming of the past 20 years and make recommendations to the Farm Advisory Committee for the future so that Broom's Barn Farm fits the needs of the new research programme.

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The farm was taken over in October 1959 and for the first few years the cropping was as simple as possible to get the land uniform for experimental work. It was decided that farmyard manure (FYM) should be produced on the farm both for experimental and farm use and this was done by fattening single-suckled cattle under cover on a basic diet of silage made from a break crop. It was considered necessary to have a wide rotation to avoid residual effects of fertiliser, pesticide and cultivation treatments in experiments on one beet crop affecting the next.

From 1965 a five-course rotation of sugar beet, spring barley, grass, winter wheat and spring barley was adopted on the light land, and a four-course rotation omitting the second spring barley on the four heavy fields. Grass was replaced by spring beans or a cereal crop in the four-course rotation after 1967. FYM has been applied after the grass breaks and before winter wheat, but with only 80 cattle each year there has not been enough for more than about 20 t ha^{-1} on the areas which have received it. Deep cultivation to 33–38 cm and lately subsoiling to 46–60 cm have been done in conjunction with land levelling, and lime application where necessary, following the grass breaks.

Future policy, 1980 onwards. Beet cyst-nematode is present on the farm so there will need to be a minimum of three, and preferably four, crops which are not hosts of the nematode between sugar-beet crops. The experimental programme requires parts of each sugar-beet field to be harvested too late to allow a satisfactory seedbed to be prepared for a winter cereal, so in future sugar beet will always be followed by spring barley.

For several projects, e.g. the study areas of the groups dealing with plant establishment and crop growth and studies on the occurrence and activity of soil-resident aphid predators and soil-inhabiting pests, it is necessary to be able to experiment on the same soil type each year. Sugar beet will therefore continue to be grown each year on both heavy and light soil, but all fields will have the same rotation so that soil differences are not confounded with effects of previous cropping.

The present boundaries will be retained giving five large fields of about 9 ha and five small fields of 4·5 ha. The five large fields, three of which are on the light soil (L) and two on the heavy soil (H), are already in a five-course rotation, and the five small fields will be returned to the same rotation. The sequence in which fields will be paired is as follows:

Phase	Large		Small	
1	White Patch	(H)	Hackthorn	(L)
2	Dunholme	(L)	New Piece	(H)
3	Flint Ridge	(L)	The Holt	(H)
4	Brome Pin	(L)	Bullrush	(H)
5	Little Lane	(H)	Marl Pit	(L)

One of the problems on the farm has always been the clash between the labour requirements of silage making and work on sugar beet. To avoid this, grass will not be grown in future. Sugar beet will follow two successive cereals, which is typical of 80% of the national crop. There is evidence of take-all in second wheats at Broom's Barn, although, on the limited data available, effects on yield are small compared with Rothamsted and Woburn. Winter oats are immune to the race of take-all found in the Eastern Counties and the cropping sequence will be sugar beet, spring barley, winter oats, winter wheat, winter barley.

In view of recent evidence of the value of FYM it is clearly important to continue to apply it here since Broom's Barn, like Rothamsted and Woburn, is one of the few centres where this type of investigation can be done over a sufficiently long period for meaningful results to be obtained. It is essential that the manure used on the farm is home-produced for in no other way can a uniform material, free from wild oats, be ensured. To produce

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sufficient for both sets of fields it is intended to increase the cattle from 80 to 120 and, in the absence of grass in the rotation, the ration will be beet pulp, brewers' grains and straw. (Cooke, Draycott, Golding, Jaggard, Scott and Webb)

Beet cyst-nematode (*Heterodera schachtii*). In 1978 two new experiments were started in an area of Broom's Barn which was found the previous year to be infected with *H. schachtii* (*Rothamsted Report for 1977*, Part 1, 68) and which was subsequently fenced to decrease movement of infested soil to other parts of the farm.

The first experiment investigates the relationship between root yield (y) and initial population of *H. schachtii* (P_i). In spring 1978, P_i in 33 plots varied between 0 and 2925 eggs 100 g^{-1} soil. Plant establishment was not affected by the nematode but root yield was greatly decreased in the most heavily infested plots. The tolerance level (T) below which yield was unaffected was estimated to be 40 eggs 100 g^{-1} soil. Average root yield (y_{max}) in plots where $P_i < T$ was 58·1 t ha^{-1}, and the relationship between y and P_i where $P_i > T$ was well described by the equation

$$y = y_{max}\, Z^{P_i - T}$$

where $Z = 0{\cdot}9993$.

The second experiment tests the effect of different crop rotations on the rate of increase of *H. schachtii* in plots inoculated with infested soil in April 1978. All plots were sampled in May 1979 but on none had detectable populations developed. (Cooke with Chwarszczynska and Cooper)

Fungal parasites of *H. schachtii*. In October 1979 the parasitic fungus *Nematophthora gynophila* (see p. 146) was found on several females of *H. schachtii* on sugar-beet roots in a plot which had grown sugar beet continuously for 15 years but which is not part of either of the above experiments. The plot will be used for an experiment to investigate the relationship between *N. gynophila* and population changes of *H. schachtii*. (Cooke, with Crump and Kerry, Nematology Department)

Chalkland problems. In three experiments on calcareous soils in 1978 plant establishment was improved and yield increased by granular pesticides; in addition, sugar yield in these experiments appeared to respond to plant populations above the recommended density of 75 000 ha^{-1}. An experiment on a similar soil type in 1979 specifically investigated the effect on yield of plant densities up to 130 000 ha^{-1} with and without the granular pesticide carbofuran. In this experiment there was no evidence of pest activity and neither plant establishment nor yield were significantly affected by carbofuran; the yield response curve was similar to that on non-calcareous soils with an optimum plant density of around 75 000 ha^{-1}. So although in some years there may be a yield advantage from high plant populations on calcareous soils, probably as a result of the increased early leaf cover, this is not a consistent effect.

In 1976 poor growth of sugar beet on a calcareous soil was attributed to damage by a large population (greater than 3000 litre^{-1}) of the spiral nematode *Helicotylenchus vulgaris*, (*Rothamsted Report for 1978*, Part 1, 61.) In 1979, observation areas were laid down in six fields of similar soil type, chosen without regard to their nematode content, to investigate the effect of soil sterilisation and a granular pesticide on nematodes and root growth. Each area comprised three plots; one untreated, one sterilised on 30 April or 1 May with methyl bromide, and one treated with 0·6 kg carbofuran ha^{-1} in the seed furrow at drilling (8 or 9 May). All plant parasitic nematodes were virtually eliminated by methyl bromide but even in untreated plots there were few *H. vulgaris* (0–450 l^{-1} in April–June). Carbofuran sometimes improved plant establishment but had little effect

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on yield. Methyl bromide applied so soon before drilling was phytotoxic, decreasing plant establishment by 20% and worsening root shape, but it improved plant vigour and often greatly increased root yield; this yield increase was not related to nematode or soil arthropod numbers. Further work will include a more intensive investigation of the relationship between sterilisation with methyl bromide (applied in October 1979, to decrease the likelihood of phytotoxicity), soil fungi and the nutrient status of plants and soil. (Cooke, with Chwarszczynska and Cooper)

Weed beet

Surveys. Since 1977 about 850–900 random fields representing 2·0–2·5% of the national crop have been examined each year by British Sugar fieldmen. Table 4 shows the increase in the proportion of the areas with weed beet. (Maughan)

TABLE 4

Percentage of the crop in each British Sugar Region with weed beet

	1977	1978	1979
West Midlands Area	9·2	15·1	24·5
Yorkshire Area	4·8	13·8	21·4
Northern Region	9·8	12·2	25·1
Central Region	12·9	21·6	29·5
Southern Region	23·4	21·4	22·2
National	14·7	18·1	24·5

Population dynamics. A model of the population dynamics of weed beet has been constructed to predict the number of years needed for the weed to disappear once introduced, given different initial multiplications reflecting different levels of bolter control by farmers, and different annual mortality rates resulting from cultivations which leave seeds at different depths in the soil. To test the model, a long-term weed beet experiment has been started at Broom's Barn. Following an initial introduction of 1000 viable seeds m^{-2}, it is evaluating all combinations of nil or unrestricted seed multiplication in the sugar-beet crop, low or high seed mortality (induced by deep or shallow cultivations), and one beet crop in 3 years or one in 6 with barley as the intervening cereal. There will be fully phased entries to both rotations. The number of weed beet seedlings appearing in each crop will be recorded and seed populations in different parts of the soil profile will be estimated before each beet crop. The first meaningful results should be available after 1985, when there will have been one complete rotation. (Longden with Johnson)

Broom's Barn Farm

Following heavy snow early in the year, ploughing was not finished until the end of February and spring cultivations did not start until 10 April. Although growth was slow in the cold spring, the crops caught up through the summer and average yields were obtained.

Cereals. Spring barley sowing did not start until 10 April, but was completed in one week. All seed was ethirimol-treated, the only fungicide used this year on barley. All winter wheat had an autumn application of a reduced rate of terbutryne for broad leaved weed control and all barley was sprayed with a hormone herbicide in late May. No aphicide was necessary. The undersown ley on Flint Ridge established well but again reduced the barley yield. Take-all was negligible on all wheat fields except New Piece, which grew its third successive wheat crop, where 69% of roots were infected.

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The barley was harvested first, starting on 15 August and, with only a short hold-up due to rain, the cereal harvest finished by 4 September. There were no serious losses from shedding.

TABLE 5

Cereal crops on Broom's Barn Farm and their yield

	Area (ha)			Yield (t ha^{-1} at 85% DM)
Brome Pin	9·1	Barley	Georgie	4·54
Flint Ridge	8·8	Barley	Ark Royal (undersown)	3·77
Bullrush	4·6	Barley	Ark Royal	4·59
Windbreak	2·2	Barley	Ark Royal	4·61
Marl Pit	1·5	Barley	Ark Royal	4·29
The Holt	4·0	Wheat	Mardler (2nd)	5·62
White Patch	9·2	Wheat	Maris Huntsman (1st)	6·76
New Piece	5·2	Wheat	Hobbit (3rd)	6·49
Marl Pit	3·4	Wheat	Hobbit (3rd)	5·02

Sugar beet. All the fertiliser except nitrogen, which was placed between the rows at drilling, was ploughed down in autumn 1978. Seedbeds were wet and difficult to prepare and the first sowings were not made until 12 April, but most was finished by early May except small areas for late sowing in trials. Most of the crop was sown with pelleted monogerm seed; 55% spaced at 16 cm or more. The crop was band sprayed with chloridazon except for experiments with non-standard row widths which were sprayed overall; subsequent weed control was mainly by hand and tractor hoeing. Granular insecticides were applied to 50% of the crop at drilling and pirimicarb was sprayed in mid-July to control black aphids, except on trials on aphids and yellows. Irrigation of 160 mm was applied to half the crop.

Harvesting started on 10 October in very wet conditions and continued slowly in poor conditions to finish on 10 January. Deliveries to the factory continued beyond the end of the year. Yields averaged 35 t clean roots ha^{-1} at an average sugar content of 17·5% (ranging from 16·2–18·5%). Mean dirt and top tares were 13% and 4%. National yields averaged 35·9 ha^{-1} at 17·0% sugar content.

Livestock. Seventy-one cross bred heifers were bought during November 1978, fattened in the yards on *ad lib* silage and a restricted concentrate ration of 50% rolled barley and 50% pulp nuts, and sold during May and June. The yards were restocked with 82 cross bred heifers in October. (Golding)

Staff and Visitors

During the year Katrina E. Bentley, R. F. Farley and B. J. Hutchison resigned; Deborah Colombo, a CASE Student jointly with Newcastle upon Tyne University, was appointed to work on Beet Cryptic Virus. K. W. Jaggard was awarded the Ph.D. degree by Nottingham University.

The staff of Broom's Barn played a full part in the work of the International Institute for Sugar Beet Research and the International Organisation for Biological Control, and also contributed to the British Sugar Staff Conference in February.

Three scientific meetings were held at Broom's Barn in 1979 and a symposium on the 'Need for Chemical Control of Bolting, Flowering and Seed Production of Sugar Beet' was held in November. At the end of January Broom's Barn provided the venue and many of the speakers for a two-day course on sugar beet organised by ADAS, and a 2-day course on sugar beet problems and practice for British Sugar fieldmen was held in

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September. During the spring and autumn 12 British Sugar trainee fieldmen spent 2-week periods at Broom's Barn gaining experience of field experimentation. The Station contributed exhibits of current research at the Spring Sugar Beet Demonstration at Grantham and the Terrington Experimental Husbandry Farm Open Days, and an exhibit of weed-beet work was also shown at the Royal Show and the Suffolk Show.

Dr. S. Z. Podlaski of Warsaw University worked with the Plant Establishment Study Group from March to July. Parties who visited us during the year included members of the IIRB Pests and Diseases Study Group; Directors of Finnish sugar companies; a group of ADAS staff from Shropshire; farmers from France and Germany; and students from the Universities of Essex, Newcastle and Nottingham.

The work of Broom's Barn is undertaken for the Sugar Beet Research and Education Committee. W. J. Byford assisted in compiling this report.

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