Report for 1980 - Part 1

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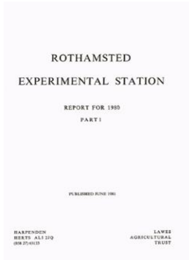
ROTHAMSTED

EXPERIMENTAL STATION

REPORT FOR 1980

PART 1

Broom's Barn Experimental Station

R. K. Scott

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Introduction

The year 1980 and the growth of the crop. After the generally dry summer of 1979, the soil did not return to field capacity until December but, by the end of February, excess winter rainfall was near average (120 mm) for Broom's Barn. On mineral soils

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the forecast for nitrogen fertiliser requirement of sugar beet following cereals was 100 kg ha^{-1}. At Broom's Barn, sodium, potassium and phosphorus were applied in the autumn and the sugar-beet fields were ploughed by the end of January. After a dry spell at the beginning of March the first beet was sown on 5 March in an experiment sited on the heavier part of the fields. Below the surface the soil was still very wet, there was little tilth and seeds were inadequately covered. A national survey at the beginning of March revealed that the wood mouse population was twice as great as in 1979 and that early-sown crops were at risk, especially if poorly covered. Mice quickly located seed sown on 5 March and 25% were taken or damaged. Nationally there was more damage than in any year since 1974.

Frequent rain during the middle 2 weeks of March prevented further drilling and nationally only 10% of the crop was sown by the end of the month. Drying weather in April then allowed rapid progress and over 80% of the crop was sown by the middle of the month. The area of crop affected by weed beet showed no further increase in 1980 (see *Rothamsted Report for 1977*, Part 1, 67).

Like the situation nationally, establishment of the Broom's Barn crop was satisfactory on the light soil, but very unsatisfactory on the heavy soil; the crop as a whole was the most patchy since experimental work began here. After the wet March, very dry, bright weather dried out the surface 10 mm of soil and on the heavy parts of the field the braird was extremely thin. Small changes in date and depth of cultivation and drilling, and the extent of compaction, critically affected establishment because the availability of water was marginal. In these dry conditions nitrogen broadcast in the seedbed considerably delayed seedling emergence and decreased establishment. The dry soil inactivated pre-emergence herbicides and, following the erratic emergence, the size of sugar-beet plants varied enormously when some of the weed seedlings were passing beyond the stage at which they were susceptible to post-emergence herbicides. Post-emergence herbicides were not used because of the danger that small beet seedlings, many of which were already under stress, could be severely affected by herbicides, especially as the weather was predominantly dry and bright. Our own crops were hand-weeded and nationally there were many reports of weed problems.

There was little rainfall during April, May and early June but several days of heavy rain from 11 June onwards gave a total of 157 mm for June and July compared with 44 mm during the same period in 1979. July was cooler than average and the Broom's Barn crop took longer to cover the ground than in the previous year. The soil moisture deficit did not increase until late in the season, reaching a maximum of 130 mm at the beginning of October. Previous experiments indicate that a deficit of this magnitude at this late stage does not limit sugar production. In contrast the deficit had reached 200 mm at the beginning of September 1979 and irrigation increased the yield of the Broom's Barn crop by 1·4 t sugar ha^{-1}. At the time of writing it seems that the national yield will be slightly less than in 1979, but achieved by a somewhat different route. In 1979 the crop made a better early start despite later drilling but was more severely restricted by water stress.

January and February 1980 were less cold than those of the previous 2 years but cold enough for Broom's Barn to forecast little early and damaging spread of yellows. In mid-March growers were advised not to apply granular pesticides with the seed at sowing solely for aphid and virus control. Although about 43% of the crop was treated with granular pesticide at drilling only about 5% was treated specifically to give protection against aphids and virus and less than 10% was sprayed with an aphicide. *Myzus persicae* appeared on beet plants in early July, but with a subsequent deterioration in the weather their distribution remained irregular. Broom's Barn's *Aphid Bulletins* aimed to discourage most growers from spraying against aphids. Although a few beet crops

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in the Felsted Sugar Factory area were badly affected by yellows, on average nationally only 2% of plants showed symptoms at the end of August and yield losses were small.

Serological techniques have been used to detect beet yellows virus using antiserum prepared by the Plant Pathology Department. The enzyme-linked immunosorbent assay (ELISA) detected BYV in field and glasshouse-grown plants and the latex test gave positive results when the latex was coated with protein A before linking to BYV antiserum. These techniques will play an important part in the future research programme on virus yellows.

Powdery mildew built up in most crops in East Anglia during August. A campaign had been mounted to educate growers in the benefits of spraying with sulphur to control the disease and despite the clash with cereal harvest on many farms and a shortage of sulphur in late August, about 15% of the beet crop in East Anglia was sprayed. Experiments showed that when the disease spread early in August a single spray with 10 kg wettable sulphur ha^{-1} could increase yield by from 12 to 26%. Sprays to control outbreaks of the disease in late August increased yield by 5–6%, still a good return on the cost of spraying.

The prolonged period of dry weather during most of April and May which affected plant establishment also decreased and delayed damage caused by soil inhabiting nematodes. Only three of the 17 Factory areas reported beet affected by Docking disorder (caused by *Trichodorus*, *Paratrichodorus* or *Longidorus*) and in most of the affected fields damage was slight.

This year for the first time, we found damage to sugar beet caused by the endoparasitic species *Radopholus ritteri*. Roots of several seedlings from Broom's Barn contained large numbers of this nematode associated with damage to cortical cells, resulting in brown necrotic lesions. This species has only been previously recorded from cereals, grasses and weeds in France and Italy.

Plant establishment

Group study area. The multidisciplinary study to determine the fate of sugar-beet seeds after sowing continued (see *Rothamsted Report for 1978*, Part 1, 60–61, and *for 1979*, Part 1, 57–58). In 1980, as in most years, seeds were sown on two occasions (26 March and 29 April) into moist soil but the subsequent low rainfall in April and May, with intense evaporation at times, caused rapid drying at seed depth. A summary of the measurements made is given in Table 1.

TABLE 1

Seed sown and seedling establishment at Broom's Barn in 1980

Number per 100 seed positions

Sowing date	Positions without seed	Seeds which remained intact	Seeds which germinated	Positions at which seedlings emerged	Positions at which plants established
26 March	1	9	90	75	44
29 April	2	10	88	78	74

Careful use of a well-maintained drill resulted in seed placed at 98·5% of target positions. About 90% of seed eventually germinated in the field compared with 93% in the standard laboratory test. However, although 75% of seed germinated reasonably quickly from both sowings, the remaining 15% did not so do until it rained, giving an extended emergence period and much variation in seedling weight. As in 1978 and 1979,

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12–15% of the seeds which germinated failed to grow further. Thus, seedlings emerged above soil level at only 75–78% of seed positions but there were no obvious reasons for this. The roots of many were damaged by the nematode *R. ritteri*. The major difference between sowings was in the extent of post-emergence losses. Various birds, followed by hares, grazed the seedlings and plants were lost from 31% of seed positions following the first sowing. Losses were less from the second sowing as alternative food was then available. Carbofuran in the seed furrow apparently made seedlings less palatable to birds and hares and halved the post-emergence losses.

There were large differences between treatments in their effects on the amount of soil moisture present at sowing or the rate at which the soil dried. For example, soil movement during seedbed preparation created dry and wet strips causing large row-to-row variations in speed of emergence; 5 mm irrigation applied 1 week after sowing allowed uninterrupted germination, gave quicker emergence and about 10% more seedlings.

Without irrigation, seedlings emerged from both sowings over a 4-week period. Seedlings were harvested individually from the first and second sowings on 4 and 17 June respectively. Their dry weights depended on emergence date and on whether or not they had been damaged by grazing. Seedlings from the first sowing weighed from 0·05 to 1·15 g when undamaged, from 0·02 to 0·45 g when partially grazed; those from the second sowing from 0·01 to 2·4 g (ungrazed). With such a range it was impossible to time post-emergence herbicide applications appropriately. These results contrast with those obtained under the continuously moist and largely pest-free conditions of 1979. (Bugg, Cooke, Dunning, Durrant, Jaggard, Scott and Webb, with Cooper, Johnson and Rudge)

Establishment Survey in 1980. To augment the information gained from the group studies, British Sugar fieldstaff surveyed the following aspects of the establishment phase in commercial crops grown on widely differing soils: (i) accuracy of seed spacing; (ii) accuracy of seed delivery; (iii) germination in the field; (iv) pre-emergence losses and their causes; (v) seedling emergence; (vi) post-emergence losses and their causes; (vii) final establishment. Items (i), (v), (vi) and (vii) were measured in 71 fields, and (ii), (iii) and (iv) in 13 fields.

The seed spacing obtained was within ±10% of target on 82% of fields but on the remainder up to 19% more or 27% less seeds were sown than intended. On average, seeds were not found in 4% of target positions; the range between fields was 1–9%. Of the seeds sown, 91% eventually germinated compared with 93% in the laboratory germination test. There was much variation (7–50 days) between fields in the time needed for all viable seeds to germinate. Normally, with early-sown sugar beet crops there is adequate soil moisture and it is temperature which governs the rate at which seeds germinate, but in 1980 availability of moisture was sometimes limiting. On average, seed germinated satisfactorily but failed to grow further at 18% of seed positions. A few of these had been eaten by soil pests, become diseased or were trapped under stones, but the majority appeared healthy—exactly as has been found over the last 3 years at Broom's Barn.

Although on average there were seedlings at 71% of seed positions, emergence in individual fields varied from 19 to 90%. Emergence was best where growers were able to prepare fine seedbeds but avoid excessive soil drying; poor emergence was most common on loam and clay soils where seedbeds had a high proportion of large aggregates. Overall, the difference between emergence on the best and poorest of the five or six rows estimated within a field was 22%; the value on the most uniform field was 7% and that on the most variable was 50%. There was more row-to-row variation on heavy than on sandy soils.

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Only on one of the fields were there no post-emergence losses. Bird grazing was the most common cause but other damaging factors were blackleg, herbicides, wind, rabbits, hares, slugs and millipedes. One crop had to be abandoned because of wind damage, and on four fields plants at over 25% of seed positions were killed by grazing. Excluding the abandoned crop, plant establishment varied from 17 to 87% (average 64%). The minimum 70% establishment which is necessary for maximum yield when 'drilling to a stand' was not achieved in over half of the fields surveyed.

This survey gave valuable information complementary to the study at Broom's Barn and showed that the results on our farm were typical of, and relevant to, a large area of the sugar-beet crop. In addition, the survey has helped assess where existing data allow advisers to make immediate recommendations for improvements and where problems exist which need further study. It emphasised the need for drill maintenance and greater care in the selection of drill components and speed of operation. Although there is little scope for improvement in the 90+% laboratory germination now obtained, additional tests may identify seed lots capable of better performance under adverse conditions. (Durrant, with Dunning and Jaggard)

Time and method of nitrogen application. The current recommendation is to broadcast nitrogen fertiliser 1–2 weeks before drilling, but this method has several disadvantages: the spreading machine compacts the soil where the crop is to be sown; there is a danger of leaching in wet springs; drilling is frequently delayed and, perhaps most important of all, the fertiliser often decreases the number of plants which establish.

Experiments in collaboration with British Sugar over the past 3 years have investigated alternative ways of applying nitrogen (*Rothamsted Report for 1978*, Part 1, 61, and *for 1979*, Part 1, 61). Conditions in 1978 and 1979 were not very testing because rainfall after drilling ensured good establishment, whatever the method of time of application, but the dry weather after drilling this year gave large and consistent effects on emergence and establishment in seven experiments.

Plants were counted when first emerging and when the crop was established. Broadcasting nitrogen fertiliser severely reduced the number of seedlings at the first count. The fertiliser had no adverse effect when placed near but not on the rows with the machinery described in previous reports. At the second count when plants were established the effect was less but in every trial there were least plants on plots receiving broadcast nitrogen. To avoid damage from broadcasting, nitrogen application must be delayed until the crop is established but previous experiments showed that this delay can significantly reduce plant size. It is concluded that plant stands would be improved if machines were developed to spread nitrogen fertiliser near but not on the rows immediately after drilling. This technique would also have the advantage of preventing soil compaction where the plants grow, avoiding delay in drilling and, in some springs, decreasing the likelihood of leaching of nitrate. Alternatively, the dressing might be split, broadcasting a small part on the seedbed and the remainder after the crop is established. This technique has not yet been thoroughly tested but in other experiments, where a range of amounts of nitrogen were applied in the seedbed, a broadcast dressing of 40 kg N ha^{-1} had little effect on establishment in any year. Provided the second dose of 85 kg N ha^{-1} is applied immediately the crop is established it seems likely that there would be sufficient nitrogen present throughout to ensure maximum growth. (Draycott, Last and Webb)

Soil insecticides. It is sometimes difficult to establish a beet crop in some areas of the Yorkshire Wolds and of the Fens due, at least in part, to the depredations of soil-in-

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habiting pests. In 1978–80 a series of field trials in each area compared the effects on plant establishment of a range of insecticide treatments applied so as to achieve different degrees of incorporation in the soil. Granule formulations were applied either (1) in the conventional manner at the base of the furrow with the seed, or (2) mixed with the soil infilling the furrow and covering the seed to decrease the danger of phytoxicity with some products. Band sprays 13 cm width were applied to the soil surface along the row immediately prior to sowing when they were incorporated in the soil by the passage of the drill, or immediately after sowing when they remain exposed but can in part be leached into the soil by rain. Standard commercial pelleted seed (incorporating methiocarb at 0·2% by weight of seed prior to pelleting) was used and the number of established plants was assessed by counts in late June.

Yorkshire Wolds. *Blaniulus* and *Onychiurus* were probably the most important pests at Holme-on-the-Wold (1978), *Scutigerella* and *Onychiurus* at Foxholes (1979 and 1980) and Grindale (1979), but it is difficult to apportion responsibility for plant losses between the different members of the soil pest complex.

In 1978, without granules or bandsprays, 57% of the seed sown gave established plants. Carbofuran granules (2·5 g a.i. per 100 m row) gave 70% plant establishment whether applied in the seed furrow or to the soil covering the seed. The best of the other granule treatments, aldicarb (5·0) in the seed furrow, bendiocarb (2·5) and fonofos (2·5) in the soil covering the seed, gave plant establishment of 64–67%. Chlorpyrifos granules (2·5) applied either way and fonofos granules (2.5) in the seed furrow decreased establishment. The most effective band sprays, gamma-HCH (1·9) pre-sowing and permethrin (0·17) post-sowing, both gave 66% established plants.

The two 1979 trials were very similar to each other and on average only 8% of the seed without granules or band sprays gave established plants. All granule treatments increased establishment (Table 2).

TABLE 2

Effects of soil applied granules on plant establishment—mean of two similar trials on Yorkshire Wolds, 1979

Chemical (g a.i. per 100 m row)	% establishment (mean of two sites) In furrow	In covering soil
Terbufos (1·5)	65	58
Carbofuran (3·0)	54	56
'FMC 35001' (3·0)	48	41
Aldicarb (3·0)	19	21
Bendiocarb (1·5)	17	18
Untreated	8	
SED±	4·1	

Band sprays were less effective. The best, 'FMC 35001' (for which the common name carbosulfan has been proposed) sprayed after sowing, gave 16 and 26% plant establishment when applied at 1 and 2 g a.i. per 100 m respectively.

The trial in 1980 tested a greater range of granules, most at two rates, but only 'FMC 35001' as a band spray post-drilling. In contrast to 1979, 75% of seeds gave established plants without granules or band sprays although the trials were in adjoining fields with similar pest populations. Even so, establishment was significantly increased ($P=0·05$) by: aldicarb (3) in the seed furrow; bendicoarb (2·3) in the covering soil; 'FMC 35001' 5% granules (4·5) in the covering soil; 'FMC 35001' 10% granules (3 and 4·5) in the covering soil, and 'FMC 35001' (4) band spray after sowing.

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Fens. Treatments had no significant effect in three out of four trials although establishment was not always satisfactory. However, at Whittlesey in 1979 where 33% of the seed gave established seedlings without treatment and symphylids, *Onychiurus*, *Atomaria* and *Brachydesmus* (listed in descending order of importance), were the major pests; all the granules and two of the spray treatments significantly increased seedling numbers (Table 3).

TABLE 3

Effects of soil applied granules and two band spray treatments on seedling establishment, Whittlesey, 1979

Chemical (g a.i. per 100 m row)	% establishment	
	In furrow	In covering soil
Granules		
Aldicarb (3)	54	45
Bendiocarb (1·5)	60	55
Carbofuran (3)	65	58
'FMC 35001' (3)	63	59
Terbufos (1·5)	61	58
Untreated	33	
Band sprays	Before sowing	
Quinalphos (1)	44	
'FMC 35001' (1)	44	
SED ±	5·4	

On the Yorkshire Wolds insecticides such as carbofuran, 'FMC 35001' and terbufos increased establishment and in 1979 allowed the crop to be grown where it would otherwise have failed. On the Fens factors other than pests often seem to be involved in poor establishment. (Winder, Dunning and Thornhill)

Soil pest damage studies. Soil inhabiting pests include leatherjackets, wireworms and slugs but recently our attention has been focused on collembola (*Onychiurus* spp.), symphylids (*Scutigerella immaculata*), millipedes (principally *Blaniulus* spp. but also *Boreioulus* and *Brachydesmus* spp.) and pygmy beetles (*Atomaria linearis*). Damage by this 'soil pest complex' presents more problems in control than other seedling pests because the predisposing factors are not understood. The severity of attack varies from field to field and chemical control often gives very variable results (see above). This was assumed to be because the location and activity of pests in the soil is affected by several factors and this has been studied in detail.

The first objective was to identify the areas and soil types where the pests are most prevalent. The current objective, through studies principally on *Onychiurus* and *Scutigerella*, is to identify better the fields at risk, and all the factors leading to damage, so that growers can apply control measures discriminately.

The answers to a questionnaire to all BSC fieldstaff in 1979 showed that the soil pest complex was only damaging on certain soil types; silt and organic silt in west Norfolk, north Cambridgeshire and the Holland district of Lincolnshire; alluvial silts in the Trent Valley; the 'warp' silts of the Humber estuary and on chalk and limestone overlain by loess, particularly in east Yorkshire. Damage was rarely reported from other soils.

Onychiurus and *Scutigerella* feed upon sugar-beet seedlings by biting holes in the radicle and hypocotyl, inhibiting lateral root production. Seedlings may be killed outright but often die from secondary infections. They are most vulnerable up to the cotyledon stage; their ability to resist this type of damage increases as they grow, and is complete at the four true leaf stage.

Soil arthropods of all groups were extracted using apparatus based on the 'Rothamsted

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controlled gradient' design. The efficiency ranged from 70 to 100%, estimated by floating out any remaining animals after extraction. In samples from 20 fields in 1979 and 1980 *Scutigerella* and *Onychiurus* only reached potentially damaging populations on the soils where damage was reported in the survey, but on these soils there were differences between sites in the densities and aggregations of animals. The pattern of aggregation of *Onychiurus* around seedlings, was affected by other foods; weeds were sometimes found to be attractive but the aggregations were mainly related to the level of soil organic matter (calculated by Kjeldahl digestion and organic carbon estimations). *Scutigerella* populations appeared not to be greatly affected by predatory soil animals, but there were generally fewer *Onychiurus* where predatory mesostigmatid mites were numerous; these form the largest group of collembolan predators in soils; *Onychiurus* density was most affected by the density of the egg-predatory *Rhodacaridae*.

Onychiurus and millipedes are numerous in soils over winter and during the subsequent spring. *Scutigerella* lives deep in the soil and only starts coming to the surface in late April. Early-sown seedlings are vulnerable to *Onychiurus* and millipedes but have become resistant before *Scutigerella* arrives in the seedbed in sufficient numbers to damage them. Late-sown seedlings grow quickly and are not damaged by *Onychiurus* and millipedes but are damaged severely by *Scutigerella* because they are vulnerable when the animals are most active. Analysis of the relationship between sowing date and seedling damage records since 1960 has shown that crop damage occurs in years with late sowings when symphylids were the major pest, or with the earliest sowings when *Onychiurus* and millipedes were major pests.

Although damage by the soil pest complex is confined to certain beet growing areas, it varies greatly between fields in these areas. Current work is examining how best to develop a simple method for individual growers to use in assessing the need for control treatments. (Brown)

Environmental and nutritional aspects of crop growth and productivity

Leaf cover assessments. Assessments of the potential for photosynthesis of a crop canopy are usually based on measurements of either leaf area index (L) or radiation interception. Most methods of measuring L are destructive and very time consuming. Moreover, results are difficult to use and interpret in any quantitative analysis of crop growth. Radiation interception measurements are straightforward to make now that solarimeter output can be conveniently integrated over time but the comparison of even a few treatments is expensive, especially in crops with wide rows where many tube solarimeters have to be used in concert to give representative readings. Also, if permanently positioned they can make the crop difficult to manage without risking breakages. We aimed to develop a simple, non-destructive measurement of the proportion of land area covered by leaves that could be readily interpreted and used quantitatively in analysis of crop growth.

A camera, fitted with a wide angle lens and a Kodak Wratten 88 filter, and loaded with 35 mm high-speed infrared film was positioned approximately 1·5–2·0 m vertically above the top of the crop canopy. A black and white picture of an area $1{\cdot}5 \times 1{\cdot}0$ m was taken, exploiting the differential reflection of infrared radiation from the leaves and the soil to give a high-contrast negative. Leaf cover was measured from the negative using the Quantimet image analysing computer. Strong contrast between the images of the leaves and soil was obtained in diffuse sunlight; in bright sunshine the subject had to be shaded with a loosely woven polypropylene screen.

Preliminary analyses indicate that the relationship between leaf cover and L can be described by an equation similar to that commonly used to describe the attenuation of

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radiation in crop canopies (Monteith, *Annals of Botany* (1965), **29,** 17–37) and that the percentage radiation interception is directly proportional to leaf cover.

In collaboration with Nottingham University and the ADAS Aerial Photography Unit, radiation interception, L, and photographic assessments of leaf cover are being compared with leaf cover assessments made by measuring, from a low-flying aircraft, the ratio of red to near-infrared light reflected from the surface of a beet crop. Leaves absorb most of the red light and reflected radiation is mainly near infrared whereas the opposite is true for a bare soil surface. If successful, this method could provide a cheap, non-destructive method of sampling large areas of crop. (Biscoe, Jaggard and W. R. Johnson)

Analysis of growth and yield of sugar beet from contrasting sites. Crops grown at Broom's Barn during 1978 and 1979 gave yields of both dry matter and sugar directly proportional to the amount of radiation intercepted (*Rothamsted Report for 1979*, Part 1, 60). The inference is that if radiation interception were increased, then dry matter and yield would also increase. To test this hypothesis a crop grown at Broom's Barn in 1979 was compared with one grown on the University of Wales experimental farm at Tenby, Dyfed, a site chosen because first, radiation receipts are, on average, 20% higher than in East Anglia, and second, springs are generally warmer which should encourage faster, early leaf growth. The same seed lot was used at both sites and crop husbandry was standardised. Fertiliser was applied at the recommended rate; both crops were sown at the first opportunity and irrigated to prevent water stress. Samples were taken for growth analysis measurements weekly until the end of July and then every 2 weeks until harvest at the end of November.

Both crops grew at similar rates until the end of August although the conversion rate of the Tenby crop (2·0 g dry matter MJ^{-1} radiation intercepted) was slightly higher than that at Broom's Barn (1·9 g MJ^{-1}). Thereafter the conversion rate was maintained in the crop at Tenby but decreased to 1·3 g MJ^{-1} at Broom's Barn. The crop in Wales intercepted 80 MJ m^{-2} more radiation than its counterpart at Broom's Barn, partly due to larger radiation receipts from June to November inclusive (1950 MJ m^{-2} compared to 1775 MJ m^{-2} at Broom's Barn) and partly because the leaf area index was larger during the autumn. This difference in intercepted radiation was equivalent to approximately 2 t ha^{-1} of dry matter—less than the 4 t ha^{-1} difference measured at final harvest.

Differences in the amount of radiation intercepted and the efficiency of its conversion contributed equally to the smaller dry matter production at Broom's Barn but the reasons for the lower efficiency of conversion are not immediately obvious. One factor known to influence the photosynthesis of sugar-beet leaves and hence the efficiency of dry matter production is their nitrogen status (Nevins & Loomis, *Crop Science* (1970), **10,** 21–25). When this was examined further it was found that the crop at Tenby had continued to take up nitrogen throughout the season but at Broom's Barn uptake ceased at the beginning of September, at the time when the conversion rate decreased. Continuing the approach adopted by Bürcky and Biscoe (*Rothamsted Report for 1978*, Part 1, 65) the distribution of nitrogen within plants was measured at Broom's Barn by analysing separately roots, laminae, petioles and dead leaves; a similar analysis of the Tenby crop is not yet complete. Some nitrogen will be lost in detached leaves but estimates suggest that at Broom's Barn this would only be about 10% of the total uptake. From September onwards the amount of nitrogen in the laminae decreased and there was a concurrent increase in the amount in the storage root. As there was no net uptake by the crop during this period it appears that nitrogen moved from the laminae to the root. While this was taking place the leaf area decreased rapidly which contributed to the smaller amount of radiation intercepted at Broom's Barn. The reasons for the decrease in conversion

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efficiency have still to be wholly resolved, but for cereals a loss of nitrogen from the laminae has been shown to reduce photosynthetic rates (Migus & Hunt, *Canadian Journal of Botany* (1980), **58,** 2110–2116).

The crops yielded 13·1 and 11·2 t sugar ha^{-1} at Tenby and Broom's Barn respectively, equivalent to 81 and 70 t roots ha^{-1} at 16% sugar. The ratio of sugar to total dry matter at harvest was 0·5 for both crops. The roots of the crop at Tenby had the greater concentration of the soluble impurities which influence the efficiency with which sugar can be extracted and crystallised, 4·88 g per 100 g sugar, compared to 3·58 at Broom's Barn, which is equivalent to an additional 2·5% of the sugar being unextractable. The crop at Tenby produced 1·9 t ha^{-1} more sugar than its counterpart at Broom's Barn, associated with continued fast growth during the autumn, but taking account of the decreased juice purity reduces the difference to about 1·6 t sugar ha^{-1}. (Biscoe, Draycott, Edwards, Glauert, Jaggard, Messem and Last, with Milford, Botany Department)

Nitrogen and irrigation. Large factorial field experiments were carried out at Broom's Barn in each of the years 1973–78, testing the effect of from 0 to 207 kg nitrogen ha^{-1} on growth, nitrogen uptake and yield with and without irrigation. A view held by many growers is that more nitrogen fertiliser is required when the crop is irrigated and the main objective was to quantify the nitrogen requirement of the crop when cultural methods were optimised as far as possible. Little was known of the effect of nitrogen fertiliser on the number and weight of seedlings established so measurements were made on the seedlings at weekly intervals.

Three of the 6 years were characterised by dry weather after sowing and in these nitrogen fertiliser broadcast before seedbed preparation decreased establishment by about 15%. In the other years, when the soil was frequently wetted by rainfall after sowing, it had no effect. When the crop was sampled shortly after establishment was complete plants were usually heaviest when 124 kg N ha^{-1} was given.

The soil profile was analysed each year in 30 cm horizons to 150 cm deep. The ammonium and nitrate nitrogen present were determined and the nitrogen potentially available was estimated in an incubation test. The amount available varied from 70 to 220 kg N ha^{-1} on plots given no fertiliser and, as expected, was largely determined by drainage during the winter because nitrate is leached rapidly. Plots given 207 kg N ha^{-1} were also sampled and analysed to determine whether all the applied fertiliser could be accounted for in May. Recovery was 80–100%, suggesting that little had been lost from the top 150 cm of soil as a result of spring rainfall and drainage but there was clear evidence that in wet springs much of the nitrogen was moved out of the plough layer into the subsoil.

Despite efforts to produce a high yield of sugar each year virus yellows infection and adverse weather resulted in a yield range of 5·5–10 t sugar ha^{-1}. Irrigation improved yield considerably in 1973 and 1975 and almost doubled yield in the extremely dry summer of 1976. Only in that year was there any evidence that irrigation could affect nitrogen fertiliser requirements: without irrigation, nitrogen fertiliser did not increase yield but, when irrigated, the crop responded to about 80 kg N ha^{-1}. In no year was there evidence that irrigating increased the requirements above the recommended dressing of 125 kg N ha^{-1}. (Draycott, Last and Messem)

Diseases and pests

The ecology and control of *Myzus persicae* and the effectiveness of its natural enemies. The control of virus yellows currently relies mainly on an aphicide 'spray warning scheme' operated within a partially integrated control programme. Recommendations concerning

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control are made on a regional scale based on an assumed relationship between aphid numbers in randomly selected fields and the risk of a yellows outbreak.

The factors influencing disease levels in individual fields include sowing date and plant population which affect the extent of immigration of winged aphids, and host-plant conditions and the occurrence of natural enemies which influence the rate of disease spread following initial infections. Both the incidence of virus yellows and the degree of control achieved therefore vary considerably from field to field. Factors affecting disease spread were studied, particularly the effect of host-plant physiology and natural enemies following initial infections by alate aphids.

A field study of the population dynamics of *M. persicae* has established the relationship between the growth stage of plants and leaves and their potential for supporting aphids. This leads to the characteristic distribution of *M. persicae* on sugar-beet leaves. Populations decline very rapidly at a clearly defined stage in plant growth correlated with a drop in the level of amino acids (important aphid nutrients) which may also be responsible for the fall in aphid fecundity that has been recorded.

Changes in nutrient levels may also explain the frequent movements of aphids from leaves and plants. In a controlled environment study relating the movements of *M. persicae* to leaf growth and development, aphids dispersed when the leaf changed from being a net 'importer' to being a net 'exporter' of nutrients, possibly because of a fall in food availability. (Study made in co-operation with Hill, Biochemistry Department, and Milford, Botany Department)

The largest and most abundant predators in sugar-beet fields are carabid beetles which are well adapted to living under the beet canopy and are very active at the time of aphid migration and dispersal. In the present study adult beetles were found to forage actively following their emergence from pupae, and they encountered aphids that were walking from plant to plant, even when aphids were few. Analysis of carabid gut contents showed that they also consumed a large range of alternative foods, such as earthworms, and the abundance of these had an important effect on both the numbers of predators and the numbers of aphids that they consumed.

A trapping survey, relating the abundance of predacious carabid beetles to numbers of all aphids on beet at 30 sites in East Anglia, revealed that after taking account of factors such as crop cover, soil type and the use of broad spectrum insecticides, the extent of predation was one of the most important variables influencing aphid abundance. Manipulations of beetle density in field experiments demonstrated that they can decrease both the rate of interplant movement of *M. persicae* and the rate of population increase and dispersal of *Aphis fabae*, a serious pest in some years.

This work has established probable causes for the frequent movements of *M. persicae* between sugar-beet leaves and plants, and for the sudden decline of aphid numbers on the crop in July. The results support the theory that, following the introduction of yellows by winged aphids, subsequent movements of wingless nymphs are mainly responsible for producing the characteristic radial spread of virus from initial foci of infection. These studies also show that natural enemies are of considerable significance in reducing the rate of dispersal of aphids and thus disease levels. Taking account of these factors should allow more localised decision making giving improved virus control and less unnecessary use of aphicides. A revision of assessment methods for resistance of sugar beet to aphids may be necessary to include the stimulus for aphid dispersal. (Jepson)

Virus yellows and aphid study areas 1978–80. Variation in the success of virus yellows control in recent years is thought to be due to the development of aphid resistance to insecticides and to lack of understanding of some factors in the ecology of aphids and their predators. It was therefore decided to observe the immigration, build-up and decline

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of the aphid population, its interaction with predators, and the spread of virus yellows on insecticide-free areas of sugar beet at Broom's Barn. From observations made over several contrasting seasons we seek to establish the relationships between the size and timing of aerial aphid population movements and the initial foci of virus infection, study virus spread in terms of aphid population dynamics, and establish the relative importance of different predators in controlling aphids and limiting virus spread. The results should lead to improved control measures; for example, they will relate the development of aphid populations to virus dispersal, which could affect the timing of aphicide application enabling growers to use them more efficiently and increase crop yield.

The timing of the flight of potentially viruliferous aphids was studied using a suction trap (Rothamsted Insect Survey) operating at 12·2 m which is non-selective and samples the general rather than the local aerial population, a yellow cylindrical sticky trap at 1·5 m which samples the local aerial population but does not necessarily show whether the aphids were potential colonists, and three 17 cm diameter yellow water traps at crop height in the study area sampling aphids likely to land on the crop. Pitfall traps were used to study the activity of predators on the ground. Aphids and predators on sugar-beet plants were counted frequently from crop emergence until late July.

No *M. persicae* were trapped in May and June 1978 and 1979 and few were found on sugar-beet plants. In contrast, many were caught in May and June 1980 (see Table 4), the first being caught by the suction trap on 19 May, slightly earlier than by any of the yellow traps. Although there were few wingless *M. persicae* on beet plants in June 1980, they increased to 22·6 (a high number) per plant on 10 July, decreasing slowly to 15·5 on 20 July and rapidly to none by 5 August.

TABLE 4

Numbers of winged M. persicae *trapped in May and June 1978–80 at Broom's Barn*

(Total numbers of aphids caught in parentheses)

	Sticky trap		Water traps		Suction trap	
1978	0	(136)	0	(14)	0	(1371)
1979	0	(287)	0	(42)	0	(2079)
1980	20	(432)	49	(103)	60	(5114)

Anystid mites were the most numerous aphid predators found on beet plants; they were present at all counts made from late June to August and were seen eating *M. persicae*, *A. fabae* and *Macrosiphum euphorbiae* nymphs, thrips and cunaxid mites. Syrphid larvae were numerous late in 1978 and 1979 and may have been the main cause of the rapid decline of *A. fabae*, but few were seen in 1980. Spiders, coccinellids (both larvae and adults), anthocoriid bugs and other predators also occurred in each year of the study.

Although carabid beetles are not specific predators, the voracity of, for example *Pterostichus melanarius*, the main carabid predator of aphids, may affect the rate of aphid population decline, which is thought to be initially stimulated by changes in the host plant. The relative abundance and activity of the most important predators in the 3 years is being related to differences between the aphid populations.

The variation in control of yellows by aphicide sprays may be partly due to their adverse effects on predators, and this is being tested. The first results, with *P. melanarius* only, suggest that at field spray strength solutions of acephate and pirimicarb are harmless but deltamethrin and demeton-S-methyl are lethal.

The most important element of the observations concerns the relationship between aphid dispersal and virus distribution, which was mapped at regular intervals in the study

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area. Yellows was scarce in 1978 and 1979 when *M. persicae* were few; the large numbers of *A. fabae*, which reached peak populations of 428 and 1630 per plant in July 1978 and 1979 respectively, clearly spread little virus. In 1980 there was a moderate attack of yellows, with 0·8% of plants showing symptoms on 31 July, 9% on 18 August, 20% on 29 August and 22% on 24 September.

As we cannot, at present, relate the date on which a plant first shows symptoms of virus yellows to the date on which it was infected (*Rothamsted Report for 1979*, Part 1, 63) the timing of yellows spread must be deduced by looking for changes in the aphid population preceding the appearance of symptoms. The few plants showing symptoms in mid-July in 1980 were probably infected during early June, by the spring immigration of *M. persicae* from their winter hosts, shown by the trap catches. The main increase in virus yellows in late August could have been associated with either the rapid increase in the proportion of plants infested with wingless *M. persicae* between 17 and 25 June, the peak numbers of winged *M. persicae* trapped at the end of June, or both of these. Other factors, such as the increased movements of aphids due to disturbance by predators will eventually have to be considered in the analysis.

The analysis so far has shown the need to record the age distribution of the aphid population and the distribution of aphids on and between beet plants in more detail, to identify infected plants before symptoms appear, to distinguish between the two yellowing viruses and to determine the time needed for symptoms to appear in plants infected at different stages of growth. Further work on the interactions between winged and wingless aphids and their plant hosts and predators, and the rate of virus spread in whole fields, together with a study of factors which affect aphid immigration, such as plant density, plant age and field boundaries, will enable us to predict more successfully disease levels and the need for control measures and their timing. (Dunning, Heathcote, Smith and Thornhill)

Rotational aspects of sugar-beet growing

Chalkland problems. At five sites on calcareous soils near Cambridge, where early growth of beet is often slow, the effects on sugar-beet growth and yield of soil sterilisation with methyl bromide, pre-drilling broadcast application of carbofuran and large dressings of superphosphate were observed. None of the sites contained detectable populations of *Helicotylenchus* (which damaged plants on a similar soil type in 1976) but other common plant-parasitic nematodes (e.g. *Tylenchorhynchus*, *Pratylenchus*) were all well controlled by soil sterilisation. At two sites (a and b) on chalky outcrops, plant emergence and establishment were poor, there was considerable bird damage to the plants which did become established and there was little response to any of the treatments. At a third site (c), the crop always appeared healthy and although soil sterilisation increased root weight early in the season, this did not improve final yield (all treatments yielding around 43 t roots ha^{-1}). At the remaining two sites (d and e) soil sterilisation increased seedling vigour; this early advantage was maintained and root yield was increased from about 37 t ha^{-1} in untreated plots to about 54 t ha^{-1} in sterilised plots. Neither carbofuran nor additional superphosphate had a consistent effect on plant growth or yield.

Soil samples taken on 18 June and plant samples taken on 17 June from three of the sites were analysed by ADAS, Cambridge. Amounts of available P, K and Mg in soil from control plots from sites c, d and e did not indicate a nutrient deficiency problem. However, levels of P in plants were low from control plots at sites d and e, which contained least available soil P, and these levels were increased by both superphosphate fertiliser and soil sterilisation.

Seedling roots from untreated and sterilised plots were examined for fungi by Salt (Plant Pathology Department). *Phoma* was present on roots at all sites and was not

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decreased greatly by soil sterilisation. *Pythium* spp., *Cylindrocarpon* spp. and *Penicillium* spp. were decreased by soil sterilisation and *Fusarium* spp. and an unindentified white mycelium, possibly a *Mortierella* sp., were increased. Only one isolation of *Rhizoctonia* was recorded (site a).

None of these results provides a complete explanation for the slow growth of beet on chalk soils, or for the increase in growth rate and yield which often follows soil sterilisation. Further plots have been sterilised prior to growing sugar beet in 1981 and the effect of this treatment on soil pathogens (with special emphasis on fungi), soil nutrients and plant growth will be monitored. (Cooke)

Brooms' Barn Farm

The new rotation (*Rothamsted Report for 1979*, Part 1, 65) of sugar beet followed by spring barley, winter oats, winter wheat and winter barley was implemented in 1980. The autumn of 1979 allowed us to drill most winter cereals into good seedbeds. All were treated with residual herbicide in autumn which controlled weeds well except in winter barley where a further spray was required in spring.

Two fields of winter wheat on light soil (Flint Ridge and Dunholme) were sown at the beginning of October but a heavier field (The Holt) was not sown until early March and this was reflected in a much lower yield. The light soil crops received 43 kg N ha^{-1} applied from the air on 17 February. A later application of 88 kg N ha^{-1} on 9 April made during dry weather appeared to have no effect on growth, and soil analysis showed that it had remained in the dry surface soil and was unavailable to the crop. Irrigation applied in April, May and June increased yield from 6·3 to 7·2 t ha^{-1}. Yields over both fields averaged over 7·5 t ha^{-1} which are some of the largest recorded at Broom's Barn.

This was the first year that winter barley and winter oats had been grown. Growth regulators were applied to both and all crops stood well until harvest. The yield of winter barley, grown with 103 kg N ha^{-1}, was 6·8 t ha^{-1}, much higher than the spring barleys grown here previously. The two fields of winter oats, sown with the variety Peniarth at the end of September, averaged a yield of 6·6 t ha^{-1}.

Whereas the autumn-sown crops seemed to escape the worst effects of spring drought, the spring barley was badly affected with poor establishment and slow early growth. Hackthorn was irrigated with 50 mm water and this greatly improved the crop. In view of the poor start, recovery once rain came was remarkable and yields reached between 4·9 and 5·6 t ha^{-1}.

Sugar beet. All except one experiment was sown with pelleted monogerm seed; 75% of the crop was spaced at 17·5 cm or more. Most of the crop was band-sprayed at drilling with chloridazon while experiments with non-standard row widths were sprayed overall. A granular insecticide on 60% of the crop insured against an early attack of yellows arising from trials artificially infected; only selected experiments were sprayed later with insecticide. The rains in mid-June returned the soil to field capacity before the critical 35 mm deficit was reached and no irrigation was used on the commercial crop.

Harvesting started on 9 October in good conditions which quickly deteriorated, but the bulk was lifted during a dry spell in November and was finished on 19 December. Deliveries to the factory finished on 2 January 1981. Yields averaged 33·7 t clean roots ha^{-1} at an average sugar content of 17·4%, ranging from 16·2 to 18·8%. Mean dirt and top tares were 12 and 7%. National yields averaged 35·14 t ha^{-1} at 16·96% sugar content.

Livestock. During October 1979, 82 cross-bred heifers were bought and fattened in the yards on *ad lib* silage and a restricted concentrate ration of equal parts rolled barley

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and pulp nuts. They were sold during April, May and June. The yards were re-stocked with 71 cross-bred heifers and 30 cross-bred steers during October and November. The feeding ration is now 33% brewers grains and 66% pressed beet pulp fed *ad lib*, with fresh straw always available. (Draycott and Golding)

Staff and visitors

During the year R. A. Dunning was awarded a special merit promotion to Senior Principal Scientific Officer in recognition of his services to the sugar-beet industry. V. B. Anne Willington was appointed to work on the effects of sugar beet on subsequent cereal crops in the rotation in a post funded by ICI Ltd.

Members of Broom's Barn Staff took an active part in the work of the International Institute for Sugar Beet Research and the International Organisation for Biological Control. R. K. Scott, with Professor J. L. Monteith, prepared a review of the effects of weather on crop growth for the ARC Research and Policy Advisory Committee.

An Open Day at Broom's Barn on 24 June was attended by 700 advisers and growers. The Annual Open Meeting of the Sugar Beet Research and Education Committee was held at Broom's Barn in July. Four scientific meetings were held during the year. A 2-day course on sugar beet for ADAS Advisers was held at Broom's Barn in January, a 1-day training course for Ministry of Agriculture beet cyst-nematode surveyors in June, and a 3-day course on sugar-beet problems and practice for British Sugar fieldmen in September. The Station contributed exhibits of current research to the Spring and Autumn Sugar Beet Demonstrations near Driffield, North Humberside.

Dr N. J. Mendham of the University of Tasmania, Hobart, worked at Broom's Barn from March to August. Parties who visited us during the year included a group of research institute directors from the Middle and Far East under the auspices of FAO; a joint group from the NFU Sugar Beet Committee and the Co-operative Committee of the European Beet Growers Association; members of the French Union Nationale des Co-operatives Agricoles de Transformations de la Betterave; bank managers; farmers and farm managers from the UK and France; ADAS Advisers, and students from the Universities of Newcastle, Leeds and Reading.

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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