Rothamsted Experimental Station Report for 1987

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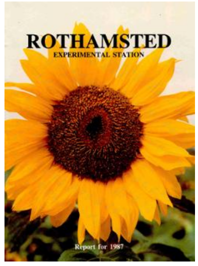

Broom's Barn Experimental Station

K. W. Jaggard

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25 years research at Broom's Barn

This year Broom's Barn celebrated its 25th anniversary, the official opening by the Rt. Hon. Sir Christopher Soames having taken place on 27 July, 1962. The Station moved to Suffolk from its 'temporary' accommodation on a disused wartime airfield at Dunholme near Lincoln in order that good facilities could be provided for research into both the control of pests and diseases and the requirement for fertilizers for the beet crop. Since then, the sugar-beet research has expanded considerably, in line with the increase in staff from 26 to 50. Research on site has also diversified into other crops, first with a major grant from ICI to study the growth of late-sown winter wheat crops in the early 1980s, and now as the home of the East of England Weed Research Unit of Long Ashton Research Station. Since 1962, research at Broom's Barn has been the spur to many major changes in production practices in the beet industry. These changes have included:

a) use of methiocarb seed dressing;
b) addition of manganese to the seed pellet;
c) use of hymexazol seed treatment;
d) use of a thiram steep suitable for beet seed;

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e) use of magnesium fertilizers, particularly on the basis of soil analysis;
f) widespread use of autumn application of fertilizers allowing earlier sowing;
g) reduced use of P and K fertilizers in response to soil analyses;
h) reduced cultivation and use of bed systems to avoid soil compaction;
i) use of soil-applied pesticides to control Docking disorder and other soil pests;
j) use of early-season irrigation;
k) use of fungicides to control powdery mildew;
l) introduction of systems for early prediction of regional and national yields.

In addition to our research programme, we provide a number of specialist services to the industry (such as the Virus Yellows Warning Scheme) which ensure that the results of our work are incorporated into farm practice as quickly and accurately as possible (see *Rothamsted Report for 1985*, 54-55).

Happily, the Station's facilities are continuing to expand. Early in 1988 a suite of rooms for growing plants in controlled environments should be completed. Previously, Broom's Barn staff had access to facilities of this type only by carrying out their experiments at Rothamsted. The new rooms here should speed up our testing of ideas about inter-relationships between the weather, plant growth and disease development.

1987 and the growth of the crop

Seed quality for the 1987 national sugar-beet crop was the best ever. The germination percentage of commercial bulks, measured by a standard laboratory test, varied between 91 and 97% and averaged 94%. Also, growers showed a greater preference to use high germination cultivars than in recent years. Wet, cold conditions in March and early April delayed drilling of the crop even further than in 1986; by 11 April only 4% had been sown compared with 20% in the previous year. However conditions then improved and the proportion of the crop which was sown increased to 44% by 18 April, 92% by 25 April and 99% by 2 May.

Mice and capping reduced the emergence of some of the early-sown crops and 230 ha were resown by 2 May, 109 ha as a result of damage by fieldmice. Emergence of later-sown crops was generally rapid and problem-free. However wind damage, herbicides and pygmy beetles caused some loss of plants and a total of 2220 ha were resown by mid-June, compared with about 7250 ha in both 1986 and 1985. There was some severe damage by soil pests such as springtails and millepedes in the Bardney and York sugar factory areas. Bird grazing was more apparent than in previous years but most reports were of slight damage, except in the King's Lynn factory area where 15% of the crop suffered moderate damage from pheasants; this is a recurrent problem on estates with game shooting interests. Despite these problems, plant establishment nationally was the best recorded. The British Sugar Beet Crop Survey, which collects information on about 700 randomly selected crops each year, indicated that establishment averaged 72% compared with 67% last year. An adequate plant density (>75 000 plants ha^{-1}) was achieved on 81% of fields, 19% more than in 1986.

Although the early spring weather prevented any drilling at Broom's Barn until mid-April, the whole of the crop, except those areas intended for late sowing, was drilled by the end of the month. Plants started emerging approximately ten days after the mid-April sowings, decreasing to seven days after sowings made late in the month. Early growth was very slow; many cotyledons were deformed with blackened tips or edges, and some seedlings had damaged root systems. This poor seedling performance was attributed to damage by a combination of the herbicides chlorsulfuron (applied in autumn 1984) and a small dose of chloridazon (applied as a pre-emergence treatment in spring 1987). Establishment on the station's lighter field averaged 80%, with a small number of seedlings still showing symptoms of herbicide

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damage in late May. On the heavier field establishment was approximately 70%, but plant size was much more variable following a protracted emergence period.

The prediction of bolting in the national crop, based on the number of days after sowing when the maximum air temperature did not exceed 12°C, was made on 11 May. Because many crops were sown late, a weighted mean of less than 1% bolting by the end of August was predicted for the national crop. At the end of August an average of 0.4% bolters was recorded in the Crop Survey, and even crops sown between 11 and 20 March only contained 1.6% bolters. Nevertheless, this slight infestation was widespread and some bolters were found in 36% of fields.

The Crop Survey also showed that 18% of the total sugar-beet area had volunteer beet seedlings between the rows in May; this continues the upward trend of recent years. By June, 27% of fields had misplaced beet seedlings. In the monitoring study undertaken by Broom's Barn, 49 of the fields which had weed beet infestations in 1975 or 1976 were growing sugar beet again in 1987 and were examined in detail. The infestation had declined in 15 fields, remained similar in 17 and increased in 17. Clearly the problem is not disappearing and many farmers still have much work to do to eradicate weed beet, which we have shown recently to reduce sugar yield by 0.47% for each 1% of bolted plants. The Crop Survey showed that measures to control bolters were used on 66% of fields, many more than in recent years, suggesting that farmers are at last responding to the problem. A three-year programme against weed beet, to which Broom's Barn contributes technically, has been initiated by British Sugar, the National Farmer's Union and ADAS.

The great majority of the area at risk from Docking disorder (caused by the ectoparasitic nematodes *Trichodorus* spp. *Paratrichodorus* spp. *Longidorus* spp.) is treated at drilling with granular pesticides. The cool, showery weather in May, 1987, provided reasonably favourable conditions for the nematodes, and 6625 ha of sugar beet grown on light, sandy soils reportedly showed symptoms of nematode damage. However, largely as a result of pesticide treatment, this damage was usually very slight and yield losses were small.

Most beet-growing areas had their wettest summer for many years and there were few reports of even mild water stress. Indeed, there were more reports of mid-season waterlogging, especially on compacted land. The only significant dry spell occurred in the first half of July. At that time Broom's Barn Irrigation Bulletins recommended applying 25 mm of water on sandy loams. However, the ensuing rainfall would have obliterated any benefit and there was no occasion for further irrigation except on very light land.

During the summer months Broom's Barn was one of the wettest places in the country. The June-August rainfall (303 mm) was double the long term average and exceeded the previous highest (which occurred in 1968) by 57 mm. The two sugar-beet fields were at or near field capacity for the whole of June and again at the end of August. The maximum soil moisture deficit, reached in mid-July, was only 60 mm whereas in an average year it would be 140 mm. The summer was also cooler and duller than usual. The mean air temperature in June was 1.3°C below average and total solar radiation was down by 26% in June and by 15% in June, July and August combined. Each year at Broom's Barn we monitor the growth of a plot of sugar beet which is intended to act as an indicator of the performance of the national crop. The seed is sown on about the average drilling date and, as far as possible, recommended husbandry is used thoughout. Despite the earlier emergence of the crop this year than last, the cold weather throughout May and particularly June slowed expansion of the leaf canopy, losing the advantage of earlier emergence. For example, on Midsummer Day leaves covered only 33% of the ground surface, compared with 42% at the same time in 1986. This, and the low radiation receipts, meant that the crop intercepted only 1200 MJ m^{-2} radiation this season, compared with 1500 MJ m^{-2} in 1986, resulting in lower dry

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matter yields during the summer. However, the crop was always efficient at converting radiation to dry matter, having healthy foliage, free from water stress on all except two or three days in mid-July. Nevertheless, the cool, dull conditions resulted in a sugar yield in the indicator plot at Broom's Barn of only 9.6 t ha^{-1} compared with 11.3 t ha^{-1} in 1986.

Following yet another severe winter (38 ground frosts in January and February) during which aphid populations in monitored oilseed crops declined dramatically during January, we forecast less than 1% virus yellows incidence at the end of August. Migrations of *Myzus persicae* were not detected in the suction traps in the beet-growing area until mid-May and numbers found on crops remained low until late June/early July when a warm spell stimulated immigration and rapid reproduction. Postcards warning of the need for insecticide sprays were sent out by British Sugar during the following two weeks to all growers, except those in the Kidderminster and Allscott factory areas. In the event, the national incidence of virus yellows at the end of August was slightly above that forecast at 2.3%, with most occurring in the Bardney (6.8%) and Ipswich (5.3%) factory areas. The level of infection varied between fields in association with sowing date. Contrary to previous experience, the most heavily infected fields were sown in March or early April; fields sown later, or those treated with aldicarb, had little or no virus. These observations suggest that infective aphids migrated into the beet crops around late April or early May just after the early-sown crops had emerged, but before the effects of aldicarb had worn off. The last week of April and 8 and 9 May were hot; this encouraged aphids to migrate but in insufficient numbers for them to be detected in the suction traps. Most of the virus was beet mild yellowing virus (BMYV) and it probably originated from mangold or fodder beet clamps which were still present at that time, and which harboured large numbers of viruliferous aphids. Virus symptoms did not become easily visible until late July/early August suggesting that extensive secondary spread took place during late June/early July when most aphids were found. Clamps of fodder-beet roots seem to be more common now than in recent years, and they may resume the importance they had as a virus source prior to the 1970s.

Black aphids, *Aphis fabae*, were, as forecast by Imperial College, much less numerous than the previous year. Populations were kept in check by the many predators present in late July. No worse than moderate damage was recorded, and that in only a small proportion of the Bardney and Peterborough factory areas during July.

Aphicides were sprayed onto about a third of the beet area and only a small proportion (<3%) received two or more sprays. The most popular insecticide was pirimicarb, reflecting recommendations issued by Broom's Barn on the basis of the performance of this chemical.

The first occurrence of rhizomania in England was recorded in a crop at West Stow, Suffolk, in late August. Quarantine conditions were imposed on the farm by the MAFF Plant Health Division and all beet crops on the farm were destroyed by spraying with glyphosate. An intensive survey of all 300 sugar-beet crops (totalling 3000 ha) within a 10 km radius of the infected field, failed to reveal any further outbreaks of the disease. The results of tests being conducted at the MAFF, Harpenden Laboratory, on soil samples from fields immediately adjacent to the infected field are awaited. The source of contamination has yet to be identified but the extent of the disease in the field suggests that it was present in at least two previous beet crops. Following the outbreak, measures were taken to prevent introduction of the disease to Broom's Barn. These included the construction of a wheel dip for vehicles entering and leaving the Station and disinfection procedures for all staff making field visits.

As in the preceding two years, powdery mildew was not found in the crop until late in the season, and its incidence remained low. Only the Ipswich factory issued a spray warning, on 25 August. Downy mildew on the other hand, probably because of the wet conditions in early summer, was more common than for many years. In the Peterborough and Spalding factory areas the disease was found in approximately 80% of crops, though in only a few

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of these were more than 10% of plants infected. The disease incidence in these areas may be linked to the high concentration of beet seed crops, on which the fungus can survive throughout the winter. In 1987 metalaxyl-based fungicides were used widely to combat downy mildew in root crops.

Throughout the growing season the Broom's Barn Plant Clinic received about 190 samples with requests to help with the identification of problems occurring in the crop or to check for pests. Most were from British Sugar fieldstaff or growers, but 26 were from other advisers. The most important sample was that received from the field at West Stow which was diagnosed as having rhizomania; a diagnosis subsequently confirmed by the MAFF, Harpenden Laboratory. Many of the other samples reflected the poor growing conditions of early summer and growers' fears about the effects of herbicide residues from previous crops. These were often difficult to diagnose accurately because the symptoms can have many other causes. The most common problems were; herbicide toxicity (46 samples) including residues from previous crops (29), soil acidity (19), waterlogging and anaerobic conditions (17), Docking disorder (24) and soil pests (13).

On the basis of a simple model of the conversion of radiant energy to sugar, Broom's Barn predicted at the end of June that the UK crop would yield 7.0 t ha^{-1} of sugar. This prediction was adjusted downwards throughout July and early August to 6.7 t ha^{-1}, on the basis of duller than average weather. For the first time the predictions were based on measurements of reflectance from the land surface. These measurements were made from a helicopter on transects containing approximately 300 beet fields scattered throughout the beet-growing regions. The reflectance measurements were used to estimate the extent and condition of the crop foliage. Because the measurements were made thoughout the country, it was possible to predict yield for British Sugar on a regional basis: this year we expect similar yields throughout that company's northern, central, southern and western districts. We await the outcome of the harvest to see if this proves correct.

A recent analysis of data from long term experiments at Broom's Barn suggests that a crude prediction of sugar concentration can be reached simply on the basis of a negative correlation with September and October rainfall. At Broom's Barn, rainfall during that period was 155 mm, and we predicted sugar concentrations of between 16.5 and 17.0%, approximately 3% lower than in the last two years.

Plant establishment

Wheeling effects. Soil compaction caused by the passage of tractor wheels during seedbed preparation can affect seedling establishment and subsequent root development. These effects were measured in experiments in the three years to 1986. Four treatments were applied in a latin square design prior to seedbed cultivation so that after drilling there were plots with a) wheelings between the rows, b) wheelings under the rows, c) wheelings between and under the rows, and d) no wheelings.

In 1984, emergence was quicker where there had been no wheels under the rows but the final establishment was higher on the other treatments. Here the wheels had compacted the soil causing the drill to penetrate less than intended and many seeds were shallow and poorly covered. The water content of the soil around the seeds was insufficient to allow germination until rain fell. At harvest, root shape was much poorer where wheels had passed both between and under the rows and sugar yield was lower at 9.0 t ha^{-1} compared with 11.0 t ha^{-1} on the unwheeled plots.

In subsequent years, differences in establishment, root shape and yield were small and measurements of soil bulk density showed that differences in compaction were also small. In these years the experiment was not cultivated and drilled at the first opportunity and the soil was drier when the wheeling treatments were applied.

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The results show that the passage of tractor wheels when the surface is dry, but most of the plough layer is wet, causes compaction leading to poor yields. However, wheelings caused by even large tractors will not always be damaging; when the soil had an extra two or three days' drying there was little compaction and no yield loss. (Gummerson)

Insecticide seed treatments. All sugar-beet seed is treated with the insecticide methiocarb at 2 g kg^{-1} of seed, incorporated in the seed pellet. In addition, about two-thirds of the crop is treated at sowing with carbamate or gamma-HCH pesticides; either against known soil pest problems or as an insurance against possible attack. Work to develop a more effective seed treatment, which would obviate the need to apply this extra treatment in all but the worst cases, has continued.

Nine trials in 1985, five in 1986 and ten in 1987, were carried out in co-operation with British Sugar, mostly at sites where pest attack was expected. They tested the carbamates, carbosulfan and furathiocarb, and the pyrethroid, tefluthrin, at rates between 4 and 120 g a.i. per unit; one unit consists of 100 000 seeds and weighs approximately 1 kg. Improvements in plant establishment were obtained at sites where pest attack occurred; results varied, but the carbamates were usually most effective at 30−60 g a.i.per unit and tefluthrin at 4−30 g a.i. per unit.

A series of trials is planned with British Sugar testing single rates of furathiocarb and tefluthrin in comparison with the standard methiocarb treatment over a wide range of sites with the intention of replacing the current treatment in two or three years time. (Winder)

Environmental and nutritional aspects of crop growth and productivity

Seedling variability. Variation in size of sugar-beet seedlings in the field is partly due to small scale heterogeneity in the seedbed. In 1986, the variability of same-day emerged seedlings was found to be lower where the nutrient supply was better (*Rothamsted Report for 1986*, 59-60). In 1987 extra nutrients were applied soon after emergence in order to overcome possible heterogeneity of nutrient supply, while in a separate experiment extra water was applied to determine whether seedling variability could be affected through the soil moisture supply. As in 1986, the principal measure of seedling variability was the coefficient of variation of total leaf area, CV(L). This was measured on a Broom's Barn sandy loam, on chalkland at Swaffham Prior and on fen peat at Arthur Rickwood Experimental Husbandry Farm (AREHF).

The differences between the three sites were as expected. Thus CV(L) was lowest at the most fertile site (AREHF) and highest at the least fertile (Swaffham Prior). For example, at around 40 days after emergence (DAE), CV(L) was 28% at AREHF, 34% at Broom's Barn and 45% at Swaffham Prior. Later, after inter-plant competition had occurred, the situation changed. At final harvest, the coefficient of variation of root dry weight, CV(W), for the plants whose seedling CV(L) had been recorded previously, was 55% at AREHF, 36% at Broom's Barn and 47% at Swaffham Prior. Thus, despite being the least variable initially, the AREHF plants were the most variable at final harvest. This was unexpected but might be due to the unusually high potential for top growth on peat soils which could intensify inter-plant competition and exaggerate variation in plant size.

At Broom's Barn and Swaffham Prior, a starter dose of N, P_2O_5, K_2O and Na (equivalent to overall rates of 12, 36, 36 and 16 kg ha^{-1} respectively) was applied from a knapsack sprayer close to the row at about ten DAE. Although this treatment increased total leaf area at Broom's Barn by 23% at 43 DAE, it did not reduce seedling variability either there or at Swaffham Prior. Earlier and more accurate placement of the starter may therefore be needed. The availability of water in the seedbed at Broom's Barn was also modified by the use of mobile rain shelters. Under the shelters there were two treatments, with and without weekly

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watering, while outside the shelters there was a single rainfed treatment. Although the watering treatment increased total leaf area by 17% at 38 DAE, it had no effect on seedling variability. The rainfed seedlings were slightly less variable than the sheltered plants but it was not clear whether this was due to the availability of water (the rainfed plots were the wettest) or due to some other effect of the mobile shelters.

Variation among seedlings is also due to inherent differences between seeds. In order to separate this from the variation caused by seedbed heterogeneity, CV(L) was measured in a glasshouse experiment where variation in the microenvironment was minimized by using well-mixed soil supplied with ample water and nutrients. For seedlings derived from the same seedlot as used in the field studies in 1986, CV(L) in the glasshouse was only 16% and 22% at 7 and 42 DAE respectively. In contrast, CV(L) values recorded in the field in 1986 ranged from 18–21% and 26–50% at about 7 and 42 DAE respectively. Although the post-emergence applications of extra nutrients and water did not reduce seedling variability in 1987, there is clearly scope for achieving such reductions provided the appropriate seedbed treatments can be found. It is hoped that further work with seedbed cultivations, starter fertilizers, early irrigation and possibly other practices will eventually lead to worthwhile reductions in seedling variability. (Brown and Dunham)

Straw incorporation. In 1987 the British Sugar Beet Crop Survey showed that 89% of beet was grown after a white-straw crop. The straw on this area was disposed of by baling and removal for animal bedding, etc. (60%), by burning (14%) or by ploughing in (15%).

Growers have been concerned that incorporated straw would both decrease the yields and increase the optimum nitrogen fertilizer dressing of the following sugar-beet crop. Evidence from other crops suggests that the latter effect is unlikely in today's conditions, where there are often large nitrogen residues in the soil after cereal crops. It seemed more likely that the breakdown of incorporated straw would lockup nitrate and ammonium ions and therefore tend to reduce the amount lost by leaching during winter. Nevertheless, a series of experiments was started at Broom's Barn in 1984 to provide evidence specific to beet.

In each of the last three years a comparison was made between straw removed by baling and straw chopped, incorporated and ploughed in. Each year 8 t ha^{-1} of straw dry matter was chopped and incorporated. In the following spring the plots were split for five nitrogen fertilizer treatments, ranging from 40 to 200 kg N ha^{-1} in equal increments. In all three experiments the optimum dose of nitrogen fertilizer was approximately 120 kg N ha^{-1} and this was not affected by the incorporation of straw. At this and greater doses the yields with and without chopped straw were never significantly different; both averaged 10.9 t ha^{-1} of sugar over the three experiments. However, chopped straw did reduce the yield of plots given only 40 kg N ha^{-1} and therefore increased the response to fertilizer.

The experiment in 1987 also included one plot to which a double dose of straw (16 t ha^{-1}) was added. This area was very difficult to plough, but optimum fertilizer dose and yield seemed unaffected by the treatment. Again, the response to applied N was increased by the additional straw.

In some circumstances the presence of much straw can lead to large pest populations and damage to young plants. The bulk of these experiments were treated with a granular pesticide at sowing, but untreated plots were included within the design. The experiments were on sandy loam soil at Broom's Barn, and straw-bait traps and soil cores showed that few pests were present and that their numbers were unaffected by the straw treatments. The pesticide had no significant effect on beet population density or yield.

The straw treatments are continuing throughout the four cereal crops of the rotation, and the nitrogen fertilizer response experiments, plus and minus pesticide, will be repeated when the sites are next in beet, in 1990, 1991 and 1992. (Jaggard, Dewar and Webb)

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Remote sensing of the sugar-beet crop. Studies have been carried out over the past three years to determine whether remote sensing offers a suitable tool for monitoring the sugar-beet crop. There have been three main areas of investigation: i) the use of reflectance data in a basic yield estimation model; ii) experiments to determine changes in the yield/reflectance relationship which might influence the yield model; iii) an assessment of satellite remote sensing systems, and experiments related to the use of satellite imagery.

Ground radiometers have been used to provide data on percentage crop cover in trial plots for several years and a yield prediction model was developed using reflectance data as an input. This work has been extended to field surveys using a radiometer mounted in a helicopter. The results of these surveys have been used as an aid in annual yield prediction for the national crop. In 1987 the helicopter study was extended to include transects across the major beet-growing areas of England, enabling data to be collected from over 300 fields on each of the four flights.

The second area of investigation was to study how crop husbandry and health might affect the yield/reflectance relationship. Regular reflectance measurements using hand-held radiometers have been made over experimental plots set up for trials on nitrogen fertilizers, virus yellows and powdery mildew. Changes in foliage condition, i.e. a combination of leaf colour and leaf area, between different treatments were easily detectable using reflectance measurements, and the implications of these variations, particularly the marked differences in colour, are currently being analysed in relation to the efficiency of the crop in converting sunlight to dry matter and sugar yield.

The third area of investigation was into the suitability of satellite remote sensing systems for crop monitoring in Britain. A preliminary study of a Landsat Multispectral Scanner (MSS) image of East Anglia from August 1982 revealed the problems of dealing with imagery at low spatial resolution. In many cases it was impossible to distinguish individual fields, and for those fields where reflectance data could be obtained, the values showed no correlation with crop yield. In addition to the problem of low spatial resolution, which is partially overcome by the Landsat Thematic Mapper (TM), there is the problem of obtaining regular cloud-free imagery. Although Landsat, which carries both MSS and TM, passes along the same path every 16 days, most images of Britain are obscured by cloud, and it is rare to obtain more than one or two suitable images per growing season. Since the new French satellite, System Probatoire d'Observation de la Terre (SPOT), became operational in February 1986, further opportunities have developed for crop monitoring. The sensors carried by SPOT have improved spatial resolution and the option of off-nadir viewing from the satellite makes it possible to obtain data for one location more frequently–approximately 11 times in 26 days. A study was carried out to see whether the SPOT system can provide sufficient low cloud-cover images to enable crop monitoring in Britain. Daily cloud cover records, 1964-85, from Broom's Barn were examined at various satellite return intervals to estimate from the historical record the likely frequency of obtaining useful imagery (i.e. <25% of the sky covered by cloud). Results showed that using SPOT's off-nadir capability it was possible, in 20 years out of 21, to get at least four images separated by ten or more days during the period of particular interest for beet growth (1 June–30 September). This suggests that SPOT could obtain enough suitable images for crop monitoring. However, the use of off-nadir imagery introduces new problems. Reflectance measurements are highly dependent on the angular relationship between the target, the sun and the sensor, and the non-Lambertian response of sugar-beet canopies further complicates this. Conventionally, measurements are made from a vertical position above the crop (nadir) as close to midday as possible. Imagery obtained in SPOT's off-nadir mode would need to be corrected before being used in conjunction with nadir measurements for yield prediction. To investigate the variation in reflectance associated with viewing geometry, a series of experiments was carried out on the ground and imagery suitable for

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investigating the effect of view-angle was obtained using the Natural Environment Research Council's airborne thematic mapper. So far, analysis has shown that reflectance changes depend strongly upon whether the sensor is looking towards or away from the sun. In comparison with this variation, row orientation effects are small.

Remote sensing can play an important role in the future monitoring of the beet crop. At the moment reflectance data collected during the helicopter surveys provide a valuable addition to ground-based observations. If the problems related to reflectance variation with view angle can be overcome, SPOT imagery could be used to provide data for a much greater proportion of the national crop. (Trigg and Jaggard)

Diseases and pests

***Polymyxa* studies.** *Polymyxa betae*, the fungal vector of beet necrotic yellow vein virus which causes rhizomania disease, is common in soils from the sugar-beet-growing regions of England (*Rothamsted Report for 1985*, 51-52). Preliminary experiments suggested that the proportion of infected sugar-beet seedlings in the field was highly correlated with accumulated soil temperature in day degrees (*ibid*). The temperature relations of the fungus were therefore examined using controlled environment facilities and naturally infested soil.

In a preliminary experiment at 20°C, it was possible, by harvesting 20 seedlings at weekly intervals from sowing, to quantify the rate at which successive stages in the life cycle of the parasite developed in roots. The first lateral root to be produced on each plant was examined. After two weeks, sporangia, which produce secondary zoospores, were present on 75% of the plants whereas plasmodia, which give rise to cystosori, were detected in only 35%. Some plant roots (5%) already contained cystosori. Subsequently there was a decline in the incidence of zoosporangia and a corresponding increase in cystosorus production in these roots, so that, at six weeks only 25% of plants still contained the former whereas all roots contained mature cystosori.

Infection at constant temperatures of 10, 15, 20, 25 and 30°C was examined using naturally infested soil as inoculum and taking daily samples of five plants. Both the incidence and severity of infection of the first four lateral roots on each plant was assessed. The earliest infections were detected four days after sowing pre-germinated sugar-beet seed at 25°C, five days at 30°C and at seven days at 20°C. At 15°C infection was first seen after 21 days whereas, at 10°C no infection was observed over the ten weeks of the experiment. Fitted linear regressions were used to estimate rates of increase in severity of infection at different temperatures. There was a clear optimum at 25°C, the rate at this temperature being 2, 6 and 11 times the rate at 20, 15 and 30°C, respectively. Thus the time to initial infection of roots is less sensitive to temperature (over the range 20-30°C) than is the progress of infection thereafter. We will investigate the possibility that the temperature requirements for the release of zoospores from cystosori in soils are different from those influencing parasitic development on roots.

The development of *P. betae* infection in small plots at Broom's Barn was again examined in 1986 (cf. *Rothamsted Report for 1985*, 51-52). Seed was sown on 11 April and samples of 50 plants were taken on five occasions at 14 day intervals beginning on 27 May. Soil temperature at 5 cm depth was recorded automatically at hourly intervals throughout this period. The progress of infection was extremely slow, with less than 20% of plants infected by 8 July, and there was no clear relationship with accumulated soil temperature, in contrast to the previous year. However during this period there was very little rain and the soil moisture deficit in the top 10 cm reached 12 mm (28 mm in the upper 30 cm). Following 44 mm of rain between 2 July and 8 July, infected plants increased to 60% of the population by 22 July. Soil moisture may have been limiting fungal development. Further work is planned to determine more precisely the influence of soil moisture on fungal activity so that this factor

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may be incorporated, along with soil temperature, into a forecasting scheme for predicting the annual severity of rhizomania. (Blunt and Asher)

Primary colonization of sugar beet and subsequent virus transmission by alate *Myzus persicae*. Primary infection of sugar-beet crops by beet mild yellowing virus (BMYV) and beet yellows virus (BYV) is caused by the immigration of viruliferous alate *Myzus persicae*. Investigations were made to quantify the factors affecting primary infection, as distinct from secondary dispersal via the wingless progeny of alatae, by using aphid-proof cages (2 × 2 × 2 m) at times of low natural aphid infestation. The enzyme-linked immunosorbent assay (ELISA) technique was used to detect BYV and BMYV in plants as soon as possible after infection, when the plants were still symptomless. This enabled accurate assessments to be made of the numbers of plants infected with each virus by known numbers of viruliferous, winged aphids released in the cages for set periods. Plots were treated with insecticides after each trial to minimize subsequent natural colonization and spread of virus until after ELISA tests had been carried out.

Experiments to examine the effects of sowing date and/or plant density on colonization by winged aphids and subsequent virus transmission showed no difference in the number of plants infected initially with either virus, indicating that alate aphids had no preference for plant age or population density. However, subsequent spread (after ELISA tests had been done) was greater in late-sown plants suggesting that offspring of the later-arriving aphids multiply more rapidly on the younger, perhaps more nutritious plants.

The granular pesticides aldicarb, thiofanox and carbofuran will kill aphids, but in recent years they have seldom been used specifically for this purpose. The efficacy and persistence of these pesticides in reducing virus transmission by susceptible (S) and moderately resistant (R1) alates was monitored over several weeks. The pesticides could not completely prevent transmission of the semi-persistent virus, BYV, or the persistent virus, BMYV, because the aphicidal action was too slow. However, all three materials reduced virus infection compared with untreated plots, and this persisted throughout the growing season. The increase in infection, via wingless aphids, six or more weeks after application was similar in both treated and control plots, due to the limited persistence of the pesticides. The value of applying these pesticides as a prophylactic treatment against virus yellows is questionable, except when an early migration of viruliferous winged aphids is anticipated.

Insecticides, such as pirimicarb, demeton-S-methyl (DSM) and the synthetic pyrethroid, PP321, can limit the secondary spread of virus by killing the aphids present at the time of spraying. In these tests all three insecticides had short persistence on rapidly-growing plants and did not prevent virus transmission by resistant alates. One day after spraying, transmission of BYV by susceptible alates was reduced by DSM and PP321, but not by pirimicarb, but transmission of BMYV was not affected by any of the insecticides tested. Seven days after spraying there was no control of either virus by any of the treatments. This suggests that DSM and PP321 repelled aphids for one or two days but did not kill them, since the semi-persistent BYV but not the persistent BMYV was controlled. Pirimicarb was the most effective at killing resistant aphids when exposed to the insecticides in clip cages, though it acted too slowly to stop transmission of virus. It appears that, with the increase in proportion of resistant aphids, conventional insecticides are unable to stop primary virus infection and secondary spread will only be minimized by reducing the resident population by subsequent spraying. If the primary infestation is heavy, insecticide application, even at the time of migration, cannot prevent virus infection and will only add to the selection pressure for greater resistance.

It is important that the role played by the alates causing primary virus infection is seen as distinct from that of the apterae that are mainly responsible for secondary spread. With

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a better understanding of the extent of primary infection and the factors which influence the behaviour of alate *Myzus persicae*, it is hoped that control measures can be more precise. (Akers and Dewar)

Seed crops and virus yellows. Sugar-beet seed crops can be major sources of beet yellows virus (BYV) and beet mild yellowing virus (BMYV) for root crops, and are therefore subject to strict control measures which are administered under the Seed Certification Scheme. In spite of the contribution of these measures to decreasing the incidence of virus yellows, infection is commonplace on root crops in most years in East Suffolk and Essex, and recent surveys have shown that BMYV occurs commonly throughout the whole of the root crop area. Sugar-beet seed crops have been sampled to reassess their importance as potential sources of yellowing viruses. The possibility that seed crops of red beet and fodder beet in Essex, which are not subject to the Seed Certification Scheme, are acting as sources of infection has also been examined.

In spring 1983, 21 sugar-beet seed crops in Essex, Bedfordshire, Lincolnshire and Northamptonshire were sampled by taking leaves from 100 randomly-selected plants at each site, and using ELISA to detect BYV and BMYV. The licenced crop inspectors' reports of the previous autumn, based on visual symptoms, had indicated very low levels of infection (0.1%) in these crops. Using the ELISA test, BYV was detected in five seed crops in 1-3% of the sampled plants and BMYV was found in 19 crops, in 1-13% of sampled plants.

In spring 1987, 14 sugar-beet seed crops, none of which had symptoms of virus yellows, and three fodder-beet seed crops in Lincolnshire were sampled by taking leaves from 20 randomly-selected plants at each site, and screening them for BYV and BMYV using ELISA. BMYV was detected in seven of the sugar-beet seed crops, in 20-40% of the sampled plants: none contained BYV. One fodder-beet seed crop had both viruses in 20% of the sampled plants. The results imply that much greater proportions of seed-crop plants are infected than are indicated by assessments of visual symptoms.

In spring 1986, leaves were collected from 40 randomly-selected plants in each of three red-beet seed crops and one fodder-beet seed crop in Essex, and screened for BYV and BMYV. No BYV was detected, but BMYV was found at each site, in 10-25% of the sampled plants. In the following year most of the Essex red-beet seed crops did not survive the winter, but a seed crop of spinach beet was sampled in spring 1987 and found to have more than 50% of plants infected with a mixture of BYV and BMYV. These results show that there are sources of BYV and BMYV in Essex which had not been recognised previously. (Smith)

Resistant aphids. Recent surveys of *Myzus persicae* collected from insecticide-free crops including winter greens, potatoes and sugar beet, have suggested that the proportion of the species resistant to insecticides has increased in the last two years. In addition, an epidemic of virus yellows in sugar beet in 1986 in the Spalding and Royston areas was thought to be due to lack of control of these resistant aphids with existing insecticides.

To establish which of the insecticides approved for use in sugar beet is best able to control resistant aphids, potted sugar-beet plants inoculated with two resistant lines of aphids (R1 and R2) obtained from Rothamsted's Insecticides and Fungicides Department, were sprayed with pirimicarb (140 g a.i. ha^{-1}), demeton-S-methyl (DSM) (420 ml a.i. ha^{-1}), cypermethrin (6.3 g a.i. ha^{-1}), and a formulated mixture of deltamethrin plus heptenophos (D+H) (7.5 g a.i. + 120 g a.i. ha^{-1}, respectively) at the four-leaf stage. Two trials were carried out: the first ran from 29 May to mid-June, and the second from 23 June to early July.

Treatments were applied using an Oxford Precision Sprayer with a 3 m boom fitted with T 8002 jets delivering 217 l ha^{-1} at 2 bar pressure. In Trial 1 treatments were only applied once, but in Trial 2 a second application was made seven days after the first. Sprayed and

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unsprayed plants were kept outdoors at spacings comparable to field crops (17 cm within rows, 50 cm between rows), but under cages to exclude naturally occurring aphids and to minimize predation by ladybirds, lacewings and other aphid-specific predators. Predation by ground-dwelling predators could not be prevented.

Aphid numbers were assessed at intervals up to two weeks after spraying and adult or large instar survivors were typed for resistance using the immunoassay technique at the Insecticides and Fungicides Department at Rothamsted.

In Trial 1, at the time of spraying there were just over 20 aphids per plant. Aphid populations in the untreated plots reached a peak of 48 per plant before declining to 34 per plant at the end of the experiment. This decline may have been the effect of cold, wet weather. All the insecticides significantly reduced aphid numbers three and seven days after treatment, but only pirimicarb, DSM and D+H did so after 14 days. Pirimicarb gave the best kill in the first week, closely followed by D+H, but DSM was best after two weeks.

In the untreated plots the proportions of R1 and R2 aphids remained close to the initial 50% throughout the experiment, suggesting that there were no differences in reproductive potential between the two clones. All insecticide treatments reduced the proportion of R1 aphids, but pirimicarb had the greatest effect. Numbers of R2 aphids were highest on the DSM and cypermethrin treated plants and least on the D+H treated plants.

Warmer weather during the second trial stimulated a rapid increase in aphid numbers in the untreated plots from 36 aphids per plant to over 200 by the end of the experiment. Pirimicarb, DSM and D+H significantly reduced the aphid population two days after spraying, but only pirimicarb and DSM had a significant effect seven days after spraying. Cypermethrin had no significant effect. After the second spray, pirimicarb had very little effect on aphid numbers, while populations increased gradually on plants treated with DSM but rapidly on plants treated with cypermethrin and D+H.

The proportion of R1 to R2 aphids remained close to the initial frequency of 75% to 25% throughout the trial period in the unsprayed plots, again suggesting that the clones had similar fecundity. Susceptible aphids were again present in small numbers. The effects of pirimicarb and DSM on both clones of aphids were similar to those in Trial 1. Pirimicarb killed the R1 aphids very well, but was not so effective against R2s. DSM performed less well against either clone. The increases in populations after second treatments of DSM, cypermethrin and D+H were attributable mostly to increases in numbers of R2 aphids.

The results of the second trial suggest that the two pyrethroid treatments were stimulating aphid populations, either by enhancing fecundity, or by killing or repelling those predators which penetrated the cages. The latter seems the most likely, since there was no increase in the pirimicarb plots and this chemical is reported to preserve predators. The effect of DSM was intermediate between the pirimicarb and pyrethroid treatments, and this may indicate less contact activity against aphids. D+H was more effective than cypermethrin in the earlier stages of the experiment, perhaps due to the systemic activity of its organophosphorus component, heptenophos. The activity of heptenophos is short-lived however, and the subsequent effect of the mixture on aphid populations was more typical of, and probably attributable to, the pyrethroid component, deltamethrin.

The effect of pyrethroids to increase the aphid population was not noted in Trial 1, which may have been due to the lack of predators when the trial was done in early June, and the adverse effect of the cold, wet weather. (Dewar with Devonshire and ffrench-Constant, Insecticides and Fungicides)

Broom's Barn Farm

Cereals. Weather conditions meant that the 1987 cereal year was not an easy one. The dry spell during September and early October 1986 made some seedbeds difficult to prepare.

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Rain for the remainder of 1986 and above average rainfall in 1987 made it difficult to time crop operations correctly.

All the land for winter cereals was ploughed and furrow pressed (following subsoiling on the spring barley stubble). Wheat (cv. Mercia) was sown on Little Lane and Marl Pit; the seedbed on the heavier field (Little Lane) was difficult to prepare because large dry clods were present after ploughing, but the lighter field required only minimal preparation. Barley (cv. Igri) was drilled directly on the ploughed and pressed land on Brome Pin and after one cultivation on Bullrush. Oats (cv. Penna) were sown on Hackthorn and White Patch, the latter on 17 October after some rain as it had been impossible to break the clods before this. All winter cereal crops eventually established well. It was only possible to spray two of the winter cereal fields in the wet autumn (using the herbicide chlortoluron and the insecticide cypermethrin) and the remaining fields were treated with herbicide (using a mecoprop/ioxynil/bromoxynil mixture) in the spring. The autumn-applied chlortoluron on Marl Pit controlled wild and volunteer oats well, as did the flamprop-M-isopropyl applied to part of Little Lane in early June; rain prevented the completion of this treatment, and many oats were present on the untreated area.

Spring barley (cv. Triumph) was drilled on 12 and 16 May on good seedbeds which had benefited from severe winter frosts. The first nitrogen dose was applied during the second week of March. The winter wheat had three applications totalling 250 kg N ha^{-1}, the winter barley and winter oats had two applications totalling 140 kg N ha^{-1} and 120 kg N ha^{-1}, respectively, and the spring barley 100 kg N ha^{-1} in a single dose.

The first fungicides were applied in late April to the winter wheat (with the growth regulator) and winter barley to control eyespot and mildew; the winter barley growth regulator was applied later. The barley required no further fungicide but the wheat was treated again in mid-June to control mildew and Septoria and a third time in mid-July to control further Septoria and aphids. The winter oats received a growth regulator in mid-May, but remained surprisingly free of mildew; only the headlands were treated with a fungicide. The spring barley was treated once in mid-June to control mildew.

Harvest started very late on 3 August with the winter barley, which yielded better than expected after the poor summer. The lighter field gave 7.5 t ha^{-1} and the heavier one 6.7 t ha^{-1}. The yield difference was partly due to the absence of water stress on the lighter field and the presence of trial plots, some fallow, on the heavier field. One oat field was then cut and yielded 5.8 t ha^{-1} but the second was not ripe and was left while the spring barley and winter wheat were harvested. The cutting of the second oat field was completed on 12 September and yielded 5.2 t ha^{-1}; both fields yielded less than the long-term average for this farm. The spring barley yields were about average at 4.9 t ha^{-1} and 5.5 t ha^{-1} but the wheat yields were the lowest since 1980 at 6.5 t ha^{-1} and 6.4 t ha^{-1}. Although the wheat was a hard cultivar (Mercia) it did not reach the required standard for bread making and was sold as feed.

Sugar beet. March and early April were showery; there were 19 days with rain in March and 15 in April. The soil temperature at 5 cm was 2°C lower than average for March, but the good spell of weather in mid to late April brought that month's figure 2.5°C higher than average. A small area of beet was drilled by hand on 16 March, but the main beet drilling at Broom's Barn could not be started until 16 April. The dry spell lasted well and 25% of the crop was sown in two days and 75% by 24 April, leaving only the areas intended for late sowing; the last sugar beet was drilled on 13 July.

A granular pesticide (aldicarb) was applied in the seed furrow on 70% of the crop to decrease the risk of early virus infection, but not where it would interfere with experimental treatments. We are at greater risk than most local farms because research on virus yellows continues throughout the winter

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A pre-emergence dose of chloridazon was sprayed overall immediately after drilling. When the beet emerged they showed symptoms of herbicide damage which was probably caused by a combination of chlorsulfuron applied in the autumn of 1984 and chloridazon. We decided not to apply any further herbicide and all subsequent weed control was by tractor and hand hoes. The soil was wet almost continuously and the standard of weed control was not as good as we would have liked; fat hen was being pulled right up to the start of the cereal harvest. Mayweeds were a cause of concern in the long term experiments, where it is difficult to spray safely, and these areas will receive particular attention next year.

'Fubol' 58 WP (metalaxyl + mancozeb) was again used this year to control downy mildew, which was found over most of the crop but particularly in the late-sown areas. An aphicide was applied in early July to most of the crop and throughout the season to specific trials. Aphid control was satisfactory with virus symptoms only showing on the artificially infected plots. Sulphur was only used in and around a powdery mildew experiment to prevent infection spreading to the remainder of the crop, most of which stayed healthy.

There was a dry period in early July when the soil moisture deficit approached the value at which growth is limited, and eight experiments on Flint Ridge field received 20 mm of irrigation in the middle of the month. The subsequent rain makes it doubtful whether this was of any value.

At the start of harvest, 27 September, the crop had little mildew or virus and no water stress, resulting in a large, healthy leaf canopy intercepting more than 90% of available light. However, early growth had been slow and the weather was dull during the most important months for radiation interception, July and August. As a consequence we expected a crop of only average yield with, as a result of the wet autumn, a much lower sugar content than in recent years. After a good start, harvesting conditions deteriorated rapidly with heavy rain early in October. However the remainder of the month was drier, November rainfall was slightly below average and early December was also dry, enabling most of the harvest to be carried out in reasonable conditions. The last beet were lifted on 18 December and deliveries to the factory were finished before Christmas. The final root yield was 44.4 t ha^{-1} with sugar percentages ranging from 15.4% to 18.2% and averaging 17.1%; tares averaged 10% dirt and 4% tops. National yields averaged 40.4 t ha^{-1} at 16.7% sugar.

Livestock. During October and November 1986, 100 Friesian steers were bought and fed to appetite on a basic diet of one-third brewer's grains and two-thirds pressed beet pulp. In addition, rolled barley was fed at 1 kg per head per day at the start and increased gradually to 3 kg per head per day at the finish of the fattening period. Minerals were added, some hay was fed while settling in and either fresh oat or barley straw was always available. 'Compudose' implants were used to obtain a high rate of live weight gain. All the cattle were sold during spring 1987. A decision has been made to discontinue this enterprise and no cattle were bought in autumn 1987. The cattle building is being modified to provide a corn and general store. This will release space in the old black barn, which will be demolished as it is past economic repair. (Golding)

Staff and visitors

We were saddened by the death in March of Bill Bray, who had held the position of Broom's Barn/British Sugar Coordinating Officer since 1984. His working life was devoted to sugar-beet research and he will be greatly missed by colleagues at Broom's Barn and throughout the sugar industry.

R.K. Scott left at the end of August to take up the Chair of Agriculture at Nottingham University after ten years as Head of Broom's Barn. K.W. Jaggard was appointed Acting Head

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of Station. R.J. Gummerson left to join Germains (UK) Ltd. and J.M. Cooper left to manage a tropical butterfly house. P.D. Tiley and A.J. Mallett also resigned. M.F. Allison was appointed as a soil chemist and Audrey Riley as Station Administrative Officer.

Several members of Broom's Barn staff contributed to the work of the International Institute for Sugar Beet Research (IIRB). R.K. Scott attended Scientific Advisory Committee meetings in Brussels, Hanover and Paris. R.K. Scott, K.W.Jaggard, M.J.C. Asher, A.M. Dewar and S.J. Blunt attended the Winter Congress in Brussels. Members of staff also contributed to study group meetings on breeding and genetics (P.C. Longden), pests and diseases (A.M. Dewar) and spring mechanization (R.J. Gummerson).

A.M. Dewar and H.G. Smith visited Hilleshog Seed Company, Sweden, in September and A.M. Dewar visited field trials in France and Belgium in June as a guest of ICI. M.J.C. Asher made a study tour in September of research institutes and rhizomania field trials in France.

In July an AFRC Visiting Group interviewed senior members of staff and inspected the farm, glasshouse and laboratory facilities. Programmes of talks and demonstrations were provided for student groups from Shuttleworth and Silsoe Colleges, Newcastle, Nottingham and East Anglia Universities, the Agricultural School of Hertogenbosch (the Netherlands) and the Embry-Rittle Aeronautical University, Florida. Visiting farmers included parties of sugar-beet growers from Finland and France. Other visitors included a group from Hilleshog Seed Company and individual scientists from Germany, Denmark, Yugoslavia, Morocco and the USA.

Demonstrations were provided at the National Sugar Beet Spring Demonstration in June and the Norfolk Show in July. Training courses were arranged for British Sugar Northern Group fieldstaff, British Sugar Southern Group fieldstaff, British Sugar trainees, ADAS staff and Ciba-Geigy technical advisers. A pest and disease recognition course was organised for British Sugar fieldstaff and a cyst nematode day for MAFF surveyors. Several British and overseas scientists contributed to the SBREC open day meeting on rhizomania held at Broom's Barn in July.

Winter meetings were held at Broom's Barn on 'Sugar-beet varieties - the way ahead' (Dr A.J. Macefield), 'Sugar beet on an irrigated arable farm' (R.J. Upton), and 'Aspects of sugar-beet research and development in the USA' (R.K. Scott and C.W. Peck).

The work of Broom's Barn is undertaken for the Sugar Beet Research and Education Committee.

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