ROTHAMSTED RESEARCH

Report for 1981 - Part 1

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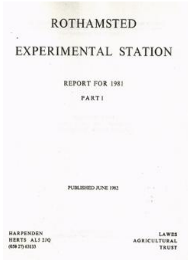
ROTHAMSTED
EXPERIMENTAL STATION
REPORT FOR 1981
PART I

Broom's Barn Experimental Station

R. K. Scott

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Introduction

The year 1981 and the growth of the crop. In many areas rainfall in March was much greater than average (e.g. 99 mm at Broom's Barn, 58 mm above average) and there were only 2 days without rain. This delayed the start of fertiliser application and sowing on

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many farms. Fertiliser spreading began during a short drier spell in the third week of the month but heavy rain followed and continued during April. It was feared that nitrogen fertiliser applied before the rain would be leached out of the soil because there was a long period when land drains ran continuously. Therefore, at the beginning of May nitrogen measurements were made on the top metre of soil in five experiments to which zero or 125 kg ha^{-1} of nitrogen fertiliser had been applied. These showed that part of the fertiliser that was applied during the third week of March had been leached out of the plough layer. However, most of it remained in the subsoil and losses from the top metre of soil varied from zero in loamy soils to 20% on a sand. Experiments were started to determine whether a nitrogen top dressing, in addition to the seedbed application, was necessary to make up for these losses from the plough layer. Nitrogen fertiliser applied in the seedbed increased sugar yield on all the fields but none of the crops responded to a top dressing applied in May.

The frequent rain in late March delayed drilling of most of the crop until April, but 48% was then sown by 11 April and 84% by 18 April. Since the years 1974–76 when yields were low because of drought and virus yellows, sowing has invariably been later than the optimum. In 1964–76 on average 50% of the national crop was sown by 3 April while in 1977–81 the average sowing date for 50% was 12 April, and it was never earlier than 6 April. This is one of the reasons why, despite the use of monogerm varieties which have the potential to yield about 10% more than the best multigerms of the late 1960s, there has been no return to the long-term trend of increasing yields that was checked by the revolution in techniques of establishing the crop in the 1960s and early 1970s.

Sowing during early April 1981 into relatively warm, moist soil favoured rapid germination whereas germination was slower from sowings made about 10 days later when soil temperatures were lower. During the week starting 21 April, rainfall was up to seven times greater than the long-term average, causing flooding or waterlogging on many fields. Previous experiments have shown that the pre-germination growth stages are particularly sensitive to waterlogging; although they often germinate after exposure to wet cold conditions their vigour is impaired so that a greater proportion than usual do not grow into seedlings. Thus, while many seeds in crops sown during the first part of April had probably passed the sensitive growth stage before being waterlogged, later-sown crops were particularly vulnerable. This was shown in one set of experiments at a series of sites where sowings in early April gave better establishment than sowings during the second and third weeks in April. In the time of sowing experiment at Broom's Barn the effects were less pronounced; the first sowing on 7 April gave 84% establishment, sowing on 15 April gave 83% and sowing on 24 April, immediately before the heavy rain, gave 71% establishment.

Detailed measurements in 56 fields in 1981 confirmed the previous observations that most seeds capable of germinating in the standard laboratory test also did so in the field but about 14% (range 2–42%) of those which germinated failed to grow much more. Post-emergence losses, caused mainly by birds grazing, mice or soil pests, occurred in all but two fields and averaged 5% with 22% of plants lost in the worst case. These losses were less severe than in 1980. Post-emergence damage tended to be less when emergence was rapid and greater when emergence was prolonged. We estimate that overall establishment, both in the dry conditions of 1980 and the wet soils of 1981, was about 5% greater than the average achieved during the 1970s. This probably reflects improved seed quality and increased attention to detail in checking and maintaining drills.

The populations of wood mice before sowing, estimated by trapping in early March at 18 sites throughout the beet-growing areas, were the highest in the 3 years of the survey, i.e. 3·9 ha^{-1} compared with 3·3 in 1980 and 1·7 in 1979. As previously, mice were caught in all fields and the risk of crop damage was thought greater than before.

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However, the index of crop damage recorded nationally in the 3 years was 0·43, 3·8 and 0·1 respectively (index based on the area of crop reported destroyed or damaged slightly, moderately or severely). It seems likely that the threatened damage was avoided because of rapid germination of the earliest sowings which are most at risk, and perhaps also deeper sowing following the recent publicity given by Broom's Barn and British Sugar to this means of limiting mouse damage.

The wet weather at the end of April and throughout May stimulated activity of the ecto-parasitic nematodes which cause Docking disorder and by the end of July, 4574 ha of the beet crop were reported affected, mainly in the Bury St Edmunds, York and King's Lynn factory areas, resulting in an estimated yield loss of over 20 000 t roots. Over 40% of the beet area is now treated with granular pesticides which help to control nematode damage, but when heavy rainfall immediately follows drilling their efficiency is decreased because of leaching, emphasising the need for slow-release formulations. Observations suggest, however, that considerable protection is usually given by the currently used formulations and that in the absence of any prophylactic treatment damage to many crops would be more severe and yield losses far greater.

Mean temperatures during the period between drilling at Broom's Barn on 9 April and the end of May were 11°C in both 1980 and 1981. In 1981 the period immediately following drilling was colder, but temperatures increased more rapidly during the second half of May and there was always adequate moisture for growth. Throughout June and early July mean air temperatures in 1981 were about 1°C higher than 1980, which helps to explain why by mid-July the leaf area index (LAI) was 3·2 in 1981 compared with only 2·5 in 1980 for crops of similar density. Analysis of leaf area growth (Milford, Botany Department, p. 62) suggests that temperature differences do not account for all the difference in LAI, and that the very dry period during May 1980 may also have slowed leaf growth.

Although leaf area increased faster and consequently a greater proportion of incident radiation was intercepted, there was little difference between years in dry weight of the crop in mid-July. This was because radiation received during May and June was 1082 MJ m^{-2} in 1980 compared with only 945 MJ m^{-2} in 1981. Subsequently, 1981 was brighter than 1980, with 1447 MJ m^{-2} radiation received from July to October compared with 1339 MJ m^{-2} in 1980. Most of this radiation was intercepted in both years and the increased potential was equivalent to an increase in dry matter production of about 2 t ha^{-1}; by the end of October 1981 the crop was 2·45 t ha^{-1} heavier than an equivalent crop in 1980. The summer and autumn of 1981 were drier than 1980 (only 112 mm of rain fell in June, July and August compared with 192 mm in 1980). There were no long dry periods and rain fell in all but two of the weeks, so that the soil water deficit increased gradually to reach 140 mm at the beginning of September. Irrigation applied to prevent the deficit from exceeding 50 mm did not significantly affect yield.

Following the mild winter it was concluded at the end of March that the beet crop would be more at risk from virus yellows than for the previous four years, when yellows incidence was exceptionally low. However, the use of seed-furrow-applied granular pesticides to control aphids and virus was not recommended because the risk was not thought to be great enough to justify their high cost. Although 43% of the crop was so treated, only 6% was treated primarily against aphids, most of this in East Anglia. May was very wet, but in the third week unusually large numbers of green aphids were found in the Felsted and Kidderminster factory areas, where spray warnings were therefore issued at the end of the month. However, because most beet seedlings were too small for foliar spraying at this time and because of the danger of encouraging insecticide-resistant aphids, growers were advised not to spray if in doubt.

Large populations of green aphids developed later in some fields in the south of the

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beet-growing area and 76% of the crop was sprayed with aphicides. In addition, 16% of the crop was sprayed against black aphids, the attack of which was moderately severe although there had been few overwintering eggs on spindle. There was marked field to field variation both in numbers of the green aphids and in the incidence of virus yellows, which reached 8% on average at the end of August; near the prediction of 6% infection.

Although powdery mildew was first found in parts of Essex and Suffolk at the end of July, the disease did not begin to spread generally in crops in East Anglia until late August or September and it built up more slowly than in the 2 preceding years. Because of the great interest amongst farmers following the yield increases obtained with sulphur sprays in 1979 and 1980, over 40% of the sugar-beet crop in East Anglia was treated with sulphur despite the slow build-up of the disease. In trials a single sulphur spray increased yield by up to 10% and, on average, treatment was again profitable in 1981.

Downy mildew was widespread in most sugar-beet growing areas and the average of 0·3% plants infected at the end of August in British Sugar's specific field survey was the highest since 1967 when 1·1% infection was recorded. The disease was most prevalent in the Peterborough and Spalding sugar factory areas where 4% of crops surveyed had over 10% of plants infected. Virus yellows was also prevalent in these areas in 1981 and the two diseases may have had a common source which, because of the short distance over which downy mildew usually spreads, would have been local.

Plant establishment

Fungicides to control *Phoma betae*. Field screening of a limited range of potential fungicides has failed to find a non-mercurial seed treatment that controls *Phoma betae* as effectively as the currently used ethylmercury phosphate (EMP) steep (*Rothamsted Report for 1978*, Part 1, 63). To test a more extensive selection of chemicals, an *in vitro* screen for activity against *P. betae* has been introduced.

In the first tests, 26 fungicides were included, representing a range of the chemical groups available, with emphasis on those expected to be active against *Ascomycetes*. The candidate fungicides were incorporated in potato dextrose agar at concentrations from 0·16 to 500 ppm and compared with EMP, phenylmercury acetate (PMA) and thiram as controls. The fungicide concentration needed to completely inhibit growth of *P. betae* inoculated on to the plates was estimated by plotting growth of the fungus against log concentration of the fungicide.

EMP was by far the most active material tested, inhibiting growth of *P. betae* at 0·5 ppm. PMA required 4 ppm and the most active non-mercurial fungicides TCMTB and iprodione required 5·6 and 7 ppm respectively. These and most other relatively active non-mercurial fungicides are almost insoluble in water, making their use in a water-steep treatment difficult; work on methods of application will continue.

The possibility that isolates of *P. betae* might differ in their sensitivity to fungicides was tested using isolates of the fungus from different seed lots. Small but consistent morphological differences were found in the colonies of isolates of the fungus in culture, but they did not differ in pathogenicity to seedlings or to root slices. Six isolates were tested against thiram and seven were tested against EMP; there were no differences in sensitivity to either fungicide. (Payne and Byford)

***Phytophthora* sp., causing blackleg of sugar-beet seedlings.** When seedlings with blackleg from an establishment study experiment at Broom's Barn were incubated in sterile water for 24–48 h, five produced zoosporangia of *Phytophthora* sp. Subsequently seedlings with unusual blackleg symptoms were found in a seed treatment trial on a peat soil at

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Wissington, Norfolk, where *Aphanomyces cochlioides* is common. At the four-leaf stage apparently healthy plants were wilting and when lifted showed necrosis and a strangling effect below soil level. When incubated in sterile water *Phytophthora* sp. was found on 80% of affected plants but it was often associated with *Pythium*.

Seed was sown in silver sand mixed with infected seedling roots, incubated at room temperatures (±18°C) and kept moist with sterile tap water. The first symptoms of blackleg appeared after 6 weeks as a scorching effect and after 7 weeks all 20 seedlings grown with infected roots had damped-off. All damped-off seedlings produced zoosporangia of *Phytophthora* sp. after 24 h incubation in water, and the fungus was isolated in pure culture.

Phytophthora spp. are known from several countries, including England, as causal agents of a soft-rot of sugar-beet storage roots on heavy soils with poor drainage. On seedlings, attack by *Phytophthora* has only been recorded under experimental conditions in the glasshouse and its occurrence on seedlings from the field is unusual and not previously recorded in Britain. (Jarowaja)

Seedbed physical structure and seedling growth. In experiments at the Norfolk Agricultural Station and elsewhere, where seedbeds of differing aggregate size distribution were compared, the seedbeds containing most fine aggregates produced most seedlings, especially in dry conditions. It is thought that this was because such seedbeds improved seed/soil contact and retained more water. An experiment at Broom's Barn in 1980 compared seedling emergence in seedbeds of differing aggregate size distribution. In all seedbeds seed germination and seedling emergence were greatly affected by periods of intense drying during which the soil water content of the seed zone fell to 5%. Unexpectedly, the seedbed with a wide range of aggregate sizes gave a greater final seedling emergence than one from which the large aggregates had been removed.

A second unexpected result was obtained in 1981 when three cultivation treatments were compared on both a sandy loam and a clay loam soil. The object of the experiment was to determine whether levelling the ploughed surface during the autumn or winter would produce a layer of frost-weathered tilth of more consistent depth and therefore give a better, more uniform seedbed than conventional cultivation techniques. Seedbed preparation began in either autumn, winter or spring and all treatments were also shallowly cultivated just before sowing. Measurements of bulk density and aggregate size distribution and frequent monitoring of temperature and water content at seed depth during the germination and emergence phases failed to detect differences between seedbeds. Nevertheless, 7% more seedlings emerged on the autumn-cultivated sandy loam soil than on the other treatments. Because numerous factors are involved in determining the number of seeds that germinate and seedlings that emerge, unexpected and conflicting results like these are a feature of many cultivation experiments.

An experiment has been started evaluating current tillage practices on clay loam soil and including four cultivation regimes which should produce seedbeds with very different physical characteristics. Some of these seedbeds will be more intensively monitored than any previously for temperature, water content/potential, mechanical impedance, bulk density and aggregate size distribution; germination and seedling emergence will also be recorded. Laboratory experiments will investigate the effects on seedling emergence of changing these parameters, either singly or in combination. (Jaggard, Gummerson, Webb and Bugg)

Seed quality studies. One way to improve plant establishment may be by more rigorous selection of seed prior to sowing. At present, sugar-beet seed producers use results from the standard laboratory germination test when deciding how to blend seed lots from

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individual growers into commercial bulks. Although laboratory germination of bulks released to growers has averaged 92% in 1979 and 1980 (the statutory minimum is 80%) there may be scope for further improvement because under some circumstances the laboratory test does not accurately predict field performance. A cooperative study, involving the British Sugar Beet Seed Producers' Association, British Sugar, the Plant Breeding Institute, the National Institute of Agricultural Botany, the Official Seed Testing Station and Broom's Barn was started in 1981 to determine whether laboratory or glasshouse tests can be devised which identify those seed lots that are satisfactory in laboratory conditions but not consistently so in the field.

The performance of 20 seed lots, giving between 80 and 95% germination in the laboratory test, was assessed in seven field experiments. Mean emergence at six of the sites varied from 29 to 65% and the difference in germination between the best and worst seed lots was remarkably consistent at 27%. At Broom's Barn, where the plots were protected by a cage, mean emergence was 79% and the overall difference between seed lots was 38%. The ranking of the field performance of the 20 seed lots was similar in all the experiments and results from the standard laboratory germination test accounted for about half the variance found in the field counts.

In glasshouse and controlled-environment experiments the ranking of the seed lots was similar to that in the field but under more controlled conditions the difference in emergence between the best and poorest seed lots was greatest when the average emergence was least. While the emergence of the less vigorous seed lots was comparable in the field and growth-room, the more vigorous seed lots gave relatively fewer seedlings in the field. Recent field surveys have indicated that post-emergence losses occur in most crops. In past experiments it has been assumed that such hazards affect all treatments equally. However, detailed monitoring at Broom's Barn and additional measurements in the field experiments in 1981 suggest that the greatest post-emergence losses occur with seed lots giving the most rapid emergence. Thus, although the field experiments ranked the performance of seed lots in the correct order, both the mean emergence at each site and the true magnitude of the differences between seed lots were probably under-estimated. If this is confirmed there are important implications for seed lot and variety testing. (Durrant, with Johnson and Loads)

Environmental and nutritional aspects of crop growth and productivity

Sodium chloride experiments. Previous experiments showed that sodium chloride is necessary on most fields for maximum profit. Many growers, however, still do not use it, although experiments and associated publicity during the late 1960s and early 1970s helped to increase its use nationally from 45% of the crop area in 1973 to 63% in 1979. New work was initiated in 1975 to obtain more information on how much should be used per hectare, when it should be applied, and on which soils, if any, it is not needed.

Thirty-six field experiments from 1975 to 1979 on the main soil types where sugar beet is grown tested 0, 100, 200, 400 or 800 kg NaCl ha^{-1} applied in either autumn or spring. The plots also received an average of 100 kg K_2O ha^{-1}. Plough-layer soil samples were taken from all the experiments to determine whether exchangeable soil sodium concentrations could be used as a basis for fertiliser recommendations. In some experiments soil sodium was also measured to 1 m depth to determine the quantity in the subsoil and the amount of leaching of autumn-applied sodium chloride. In cooperation with ICI staff, soil sodium concentrations were measured in 800 samples of fenland soil in 1976–77 to determine whether these soils have a natural supply of sodium.

Current advice on use of sodium chloride is that it is not needed by sugar beet on peats and silts, but that the crop should receive 375 kg NaCl ha^{-1} in autumn before

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ploughing on all other soils. The results of the above series of experiments confirmed that none is required on the peats and peaty mineral soils because many of these contain enough natural sodium and often much potassium. As a few crops on the silts responded it is suggested that in future these are included with the other mineral soils although some contain much natural sodium. However, the whole profile would need to be sampled to discover which fields contain enough to rule out a response and this would probably be more expensive than the fertiliser it might save.

The benefits of using sodium chloride on the other mineral soils were further substantiated. Although crops on some fields will not respond it is impossible to predict these from soil analysis of the plough-layer. On most mineral soils, the current recommendation of 375 kg NaCl ha^{-1} (costing £11 ha^{-1}) appears sufficient for maximum sugar yield from an autumn application. Some crops on sandy soils may respond to double this amount, perhaps in part because of leaching losses, but if sodium chloride could be spread after ploughing yet well ahead of sowing then 375 kg NaCl ha^{-1} will usually be optimal on sandy soils and about 200 kg ha^{-1} on clays and silts.

The analysis of plough-layer soil samples from the fenland area made by staff of ICI showed that a large proportion contained relatively large amounts of sodium (and potassium). In particular, most of the organic soils probably had enough to obviate the need for fertiliser but there were some silts where the crops might respond to additional sodium. This survey suggested that the frequency of responses measured on the experiments on organic and silt soils were relevant to the fenland as a whole. (Draycott and Durrant)

Chemical regulation of sugar-beet growth. In laboratory tests at Jealott's Hill, the synthetic growth regulator 'PP 333' reduced lamina area and petiole length of sugar beet so that the foliage grew as compact rosettes with almost horizontal leaves. Leaves of treated plants were thicker and darker green than those on untreated plants, and per unit area, had more chlorophyll, and faster rates of net photosynthesis. This suggested that, on a field scale, beet plants treated with 'PP 333' would have a relatively small leaf area index (L) and hence would intercept a smaller proportion of the solar radiation. However, the plants should have a greater efficiency for converting solar energy to dry matter and a better partitioning of this dry matter to the root. The last two characteristics should be beneficial and the response of sugar beet to 'PP 333' in the field was tested at Broom's Barn in 1980.

Plots of the var. Bush Mono G sown on 9 April 1980 and singled to 70 000 plants ha^{-1}, were sprayed with 'PP 333' at 1 kg a.i. ha^{-1} in 220 litres of water ha^{-1} on 17 June when, on average, the 10th leaf on each plant was 2 cm long. Within 2 weeks sprayed plots appeared darker green than unsprayed controls and after 3 weeks all leaves which had appeared since treatment were thicker and smaller than the controls. Frequent measurements throughout summer and autumn showed that L was smaller in the treated plots and less solar radiation was intercepted although treated plants retained their large older leaves longer than did the untreated; by mid-November they had approximately 50% more living leaves than the controls. Contrary to expectation, treated and untreated beet had almost identical efficiencies for converting radiation to dry matter, 1·57 and 1·50 g MJ^{-1} respectively. This may have been because on the treated plants the large, older leaves, which have a lower rate of net photosynthesis, made up a greater proportion of the total leaf area than on control plants. The retention of leaves on the chemically treated plants also influenced the pattern of shoot:root ratio. Throughout the period July to September the growth regulator caused more of the dry matter to be apportioned to the root than was the case in untreated plants. Thereafter, as more leaves were retained on the treated plants the shoot:root ratio was larger than in the control.

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Because 'PP 333' decreased the proportion of radiation intercepted by the foliage and did not increase the conversion efficiency of intercepted radiation to dry matter, treatment reduced sugar yield by 0·8 to 9·15 t ha^{-1}. If the application of the chemical can be timed correctly it might be useful in crops grown at a high plant density. Dense plant populations have the advantage of intercepting more of the incident radiation early in the summer but the disadvantage of apportioning the additional dry matter so produced to top growth (Harris, *Journal of Agricultural Science, Cambridge* (1972), **78,** 289–302). An application of 'PP 333' at the critical stage might suppress top growth later in the season and cause plants grown in dense stands to apportion more of their dry matter to roots and sugar. This will be tested in further experiments at Broom's Barn. (Jaggard)

Tolerance of sugar beet to herbicides. The two major post-emergence herbicides, metamitron ('Goltix') and phenmedipham ('Betanal E') can check early growth of sugar beet, especially if applied in sequence with a pre-emergence herbicide. The severity of damage varies greatly from season to season and several factors can influence the activity of these herbicides. The aims of field and glasshouse studies were first, to quantify the extent and duration of damage by making detailed measurements of early development and growth and, second, to identify which conditions affecting the uptake and metabolism of the herbicide are responsible for the damage.

In 1979 and 1980 field experiments were made on three different soil types, peaty loam at Arthur Rickwood EHF, sandy clay loam at Broom's Barn and sandy loam at Norfolk Agricultural Station. Pre-emergence herbicides were applied at one or two dose rates to investigate the extent to which they pre-disposed the crop to damage by the post-emergence herbicides. Plots were sprayed post-emergence with metamitron or phenmedipham at the recommended rate; an adjuvant oil, 'Actipron', was added in some treatments to increase contact activity. Untreated control plots and herbicide treated plots were kept weed-free throughout the season. Weather conditions around post-emergence spraying were closely monitored and weekly measurements made of early crop growth and development.

All combinations of pre- and post-emergence herbicides used decreased the dry weight and leaf area of plants; the effects were most marked about 3 weeks after spraying. A propham/chlorpropham/fenuron (PCF) mixture pre-emergence combined with phenmedipham + oil applied post-emergence caused the most severe check to growth at all sites. In both years the proportional decrease in leaf area was similar to that of dry weight; in 1980 this was entirely because leaves were smaller but in 1979 treated plants also had 25% fewer leaves than the control.

Herbicide-treated crops soon began to recover from these initial checks and for a time both dry weight and leaf area increased faster than the untreated crops. At Norfolk Agricultural Station differences in crop dry weight could no longer be detected 7 weeks after the post-emergence application in 1980. In 1979, when the crop was at an earlier stage of development at spraying, the check persisted for a further 4 weeks. By final harvest no significant difference could be detected in sugar yield between treatments at any of the sites. Differences in final yield resulting from herbicide treatment have been observed in previous experiments (*Rothamsted Report for 1977*, Part 2, 57) but then both plant size and plant population were affected.

In the glasshouse it was possible to study in detail the effects of the more potent pre-emergence herbicides on seedling emergence and to test how they pre-dispose plants to post-emergence herbicide damage. The pre-emergence herbicide PCF delayed seedling emergence by 2 days and at high rates plant dry weights were 60% less when the post-emergence herbicide was applied. However, this pre-treatment did not affect

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the retention of a herbicide: dye mixture on the leaves or the penetration of radiolabelled phenmedipham applied post-emergence.

It has proved difficult both in the field and the glasshouse environment to relate the severity of damage to individual weather factors. Further work is being carried out in controlled environment facilities at the Weed Research Organisation, Oxford. (Preston and Biscoe)

Comparison of sown and transplanted crops. There is renewed interest in transplanting as a technique for establishing sugar beet because large yield increases were obtained in trials by ADAS in Humberside in 1980. In 1981 we collaborated with three Experimental Husbandry Farms to examine the system of transplanting that was developed in Japan, where plants are raised in open-ended 13×2 cm paper pots arranged in a honeycomb. At Broom's Barn the aim was to compare interception of radiation and the efficiency with which it is converted to dry matter and sugar in sown and transplanted crops. The intention is to be able to predict the yields of drilled and transplanted crops sown at various times. Previous experiments have shown that transplants can be more affected by water stress so all treatments at Broom's Barn were irrigated to prevent the soil moisture deficit from exceeding 50 mm. Planting was by hand and bird damage was prevented, so establishment of pot-raised seedlings was almost complete.

Sowings were made on 28 January and 10 February in a warm (target temperature 15°C) glasshouse where they were kept until emergence was finished, then hardened off at 5–10°C and moved outside approximately 6 weeks prior to planting in early April. The variety Nomo was chosen for these experiments because of its resistance to bolting but many bolters developed, 45 and 25% in the first and second sowing respectively. For this reason sugar yields from these treatments hardly exceeded the 12·3 t ha^{-1} from the earliest field sowing in the experiment made on 7 April, which was one of the heaviest yields ever at Broom's Barn. However, beet sown under glass in early March and transplanted in early April produced 14·4 t ha^{-1}. (Webb and Jaggard)

Effect of sowing date on winter wheat. In recent years, in order to maximise yields, there has been a move towards winter- rather than spring-sown cereals and a trend towards sowing wheat earlier in the autumn. Currently, half the sugar-beet area is followed by winter wheat which often suffers because late drilling leads to lower yields. The aims of this research programme, sponsored by ICI, are to determine how the growth and development of winter wheat are influenced by sowing date and to examine different ways of minimising the adverse effects of late sowing, expecially by varying the amount and time of application of nitrogen fertiliser.

During the first year Avalon winter wheat was sown at two sites; on sandy loam at Broom's Barn on 26 September (B_1), 3 November 1980 (B_2) and 2 February 1981 (B_3), and on heavy boulder clay at Ropsley, Lincolnshire, on 25 September (R_1), 3 November (R_2) and 12 December 1980 (R_3). At both, wheat sown at different times during the autumn gave similar yields of dried grain; 7·7 and 7·4 t ha^{-1} for B_1 and B_2, and 7·2, 6·6 and 6·6 t ha^{-1} for R_1, R_2 and R_3 respectively. However, the February sown crop at Broom's Barn yielded only 6·2 t ha^{-1}. At Broom's Barn wheat sown on all three dates converted intercepted solar radiation to dry matter with similar efficiency; the mean of 2·09 g MJ^{-1} is comparable to that of high yielding sugar-beet crops (*Rothamsted Report for 1980*, Part 1, 71). B_3 produced the same total dry matter as B_1 but had a smaller ratio of grain yield to total yield—0·4 compared with 0·45. There were fewer established plants and fewer ear-bearing stems at harvest in B_1 than B_3; 247 and 300 plants m^{-2} and 398 and 414 ears m^{-2} respectively, but tillering patterns were very different. In B_1 tillers reached a maximum of 2·73 per plant on 12 January 1981 and these

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remained until 5 May when tillers started dying, indicated by the yellowing of the youngest leaf, and numbers decreased rapidly to 0·61 tiller per plant at anthesis on 22 June. At harvest 62% of the ears were from main stems, 30% from tiller 1 (the tiller that extends from the sheath of the first leaf) and only 8% from tiller 2. In B_3 tillers reached a maximum of 2·55 per plant on 11 May, and tiller death began almost immediately, leaving 0·38 tiller per plant at anthesis on 6 July. However, only 20% of the B_3 plants produced a tiller 1 and none survived, so that at harvest 72% of the ears were from the main stem, 15% from tiller 2 and 12% from tiller 3.

Ears on lower order (i.e. late formed) tillers are smaller and have smaller grains than ears on the main stem and first formed tillers. Tiller 1 ears on B_1 had 40 grains per ear each weighing, on average, 43·9 mg compared with only 34 grains in tiller 2 ears of B_3 weighing 40·8 mg. In addition, main stem ears from B_1 had 49·9 grains weighing 46·8 mg per grain compared with 47·1 grains weighing 41·4 mg from B_3. Thus, the lower yield of Avalon winter wheat when sown in spring was expressed through a combination of a lower ratio of grain yield to total yield, a higher proportion of ears from lower order tillers and smaller main stem ears with lighter grains. (Willington and Biscoe)

Diseases and pests

Use of enzyme-linked immunosorbent assay (ELISA) in the study of beet yellowing viruses. Although the two viruses causing yellowing of beet, beet mild yellowing virus (BMYV) and beet yellows virus (BYV), are very different in their properties, transmission, host-range and effect on yield, they are not readily distinguishable by field symptoms. A quick and sensitive method of determining which virus is present in an infected plant is therefore essential for studies of the behaviour of the viruses and the epidemiology of the disease. Such a technique is an asset also in field studies on the effects of the viruses on growth and yield because it is possible to check for unwanted infections, and to identify symptomless infected plants. The ELISA technique has been adapted for this purpose using antisera to both viruses prepared by D. Govier, Plant Pathology Department (p. 189).

Field inoculations. Plants in the field were inoculated with either BYV or BMYV at the two to three leaf stage (2 June). They were then destructively sampled at intervals through the season and absorbance readings at 405 nm (A_{405}) were obtained for each leaf. BYV could be detected in all leaves above (i.e. younger than) the inoculated leaf, including those showing no symptoms, 2 weeks after inoculation, but BMYV was not detected in leaves other than the inoculated leaf until 4 weeks after inoculation. For both viruses the highest A_{405} values were obtained from leaves showing symptoms. The A_{405} values decreased from the end of August onwards, but it was still possible to detect virus in leaves showing symptoms at the end of September.

TABLE 1

Maximum A_{405} values for leaves showing symptoms

	Number of weeks after inoculation						
	2	3	4	5	6	10	17
BYV	0·55	0·17	0·78	1·30	1·62	1·50	0·24
Uninoculated	0·01	0·02	0·01	0·01	0·03	0·01	0·03
BMYV	0·15*	0·10*	0·28	1·02	0·40	0·23	0·20
Uninoculated	0·05	0·05	0·03	0·03	—	0·04	0·02

* Inoculated leaves

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Field survey. The first appearance and distribution of BYV and BMYV were monitored in 64 fields in East Anglia and the West Midlands in which regular disease counts were being made by sugar factory fieldmen. Samples of leaves from plants, with and without symptoms, were sent to Broom's Barn at the end of June, July, August and September. In all, leaves from 1584 plants showing yellowing symptoms were tested throughout the season; 60% contained BMYV, 8% BYV and 6% a mixture of both viruses. Of the 202 leaves tested from plants showing no symptoms 14% were found to contain BMYV. Both viruses occurred at random throughout the sampling regions in June and July and by the end of September some plants in all 64 fields had BMYV; plants with BYV were found in 53 fields.

Virus in aphids. In studies of the epidemiology of virus yellows it would be useful to know if aphids entering beet crops are carrying BYV or BMYV. Since the proportion of viruliferous aphids is likely to vary each year, ability to monitor this variation has potential for improving the Spray Warning Scheme. In a preliminary experiment adult apterous *Myzus persicae* were fed for 7 days on sugar beet and *Claytonia perfoliata* plants infected with BMYV, and then tested using ELISA. A_{405} readings in the range 0·042–0·717 were obtained for single viruliferous aphids compared with readings of 0–0·002 for non-viruliferous aphids. It seems possible therefore that ELISA can be used for this purpose. (Smith)

Comparison of aphicides used against virus yellows. Following the first proof of insecticide resistance in *M. persicae*, field trials in the virus yellows epidemic years 1974–76 showed that many of the insecticides 'approved' by the Ministry of Agriculture, Fisheries and Food for control of aphids and virus yellows in sugar beet were ineffective (*Rothamsted Report for 1976*, Part 1, 56). In 1977 the only insecticides recommended by Broom's Barn and British Sugar were demephion, demeton-S-methyl and pirimicarb.

In 1977–81, field trials in collaboration with British Sugar tested the recommended insecticides at commercial rates, and various new ones, partly for their direct control of aphids but principally for their ability to decrease virus yellows incidence. During this period field populations of *M. persicae* were tested at Rothamsted for insecticide resistance and it was found that at the beginning most of the aphids from south-east England were moderately resistant (R_1). However, from 1979 onwards highly resistant (R_2) aphids were found in some samples.

In seven trials in 1977 demephion, demeton-S-methyl and pirimicarb were compared with acephate, ethiofencarb, permethrin, nitrilacarb and 'Hoe 25682'. Although all the insecticides decreased the numbers of wingless green aphids at the three infested sites, the ranking order was inconsistent and only acephate (450 g a.i. ha^{-1}) gave satisfactory control in all three trials. Virus yellows was only prevalent at Witham (Essex) where it developed late but rapidly; in mid-September plots treated with pirimicarb, demephion, permethrin (100 g) and nitrilacarb (500 g) contained significantly fewer infected plants than untreated plots.

In 1978 demephion, demeton-S-methyl and pirimicarb were compared with acephate, ethiofencarb and 'Hoe 25682' at four sites. At Saxham (Suffolk) all the insecticides decreased the number of aphids but they acted slowly. At Maldon (Essex) aphids were fewer but control was better. Virus yellows incidence was very low in all the trials.

In all five field trials in 1979 there were too few *M. persicae* and plants infected with virus yellows for comparisons to be made. In 1980 acephate, demephion, demeton-S-methyl, ethiofencarb, pirimicarb, carbosulfan and deltamethrin were compared at Loddon (Norfolk) in a crop where the grower had reported poor control of *M. persicae* when it was sprayed earlier with demeton-S-methyl. Aphids from the field were checked

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for insecticide resistance at Rothamsted; some were R_1 but none were R_2. On the fifth and eleventh day after treatment pirimicarb had decreased the number of aphids by 87 and 90% respectively; the other treatments were less effective and often slower acting. Yellows incidence was slight in the whole experiment. Three other trials in 1980 compared demeton-S-methyl, pirimicarb and deltamethrin (25 g). At Broom's Barn there were few aphids and none of the treatments significantly affected the very low incidence of virus yellows. At Maldon (Essex) there were 1·1 wingless green aphids per plant on the untreated plots 6 days after treatment; all treatments decreased the number of aphids but did not affect the low incidence of virus yellows. At East Harling (Norfolk) there were 7·9 wingless green aphids per plant on untreated plots 6 days after spraying and all treatments decreased the number of aphids but again there was little virus yellows.

In 1981 two trials compared demeton-S-methyl, pirimicarb and the synthetic pyrethroids deltamethrin (12·5 g) and fenvalerate (25 g) applied in mid-June when there were 1·7 and 3·2 green aphids per plant, and deltamethrin applied at two rates (12·5 and 25 g) at the end of May as a possible repellent. There were few *M. persicae*, and treatments did not affect the populations; however, at one site, at the only count made post-spraying (9 July), the number of *A. fabae* was greater following deltamethrin treatment than on the control. The incidence of virus yellows was low at both sites and was masked at one by severe wilting in August. It was decreased by deltamethrin at the lower, but not the higher rate on both application dates, and by fenvalerate applied in mid-June.

The inconclusive results of these 22 trials, despite quite large populations of *M. persicae* at some sites, stem from the low incidence of virus yellows; they highlight the problems of trying, in these conditions, to determine the best field spray treatments for epidemic years. In 1981 an attempt was made to introduce virus yellows artificially into the plots and this technique will be developed further. Although the efficiency of the two pyrethroids in the 1981 trial offers promise, the inefficiency of the double rate of deltamethrin may be a reflection of its adverse effect on beneficial insects, paralleling the increase of *A. fabae* population following spraying in one trial, a result previously recorded for permethrin (*Rothamsted Report for 1974*, Part 1, 56).

Since this series started acephate and ethiofencarb were added to the Broom's Barn/BSC list of recommended aphicides but more recently, and for commercial reasons, acephate, demephion and ethiofencarb have been withdrawn from the market. Currently the grower only has the choice of demeton-S-methyl (organophosphate) or pirimicarb (carbamate). (Winder and Dunning)

Broom's Barn Farm

The new fertiliser policy of applying phosphate and potash only twice in the 5-year rotation, once before beet and once before winter wheat, in the sequence sugar beet, spring barley, winter oats, winter wheat and winter barley, was started in autumn 1980. For the first time subsoiling was done after spring barley, its new place in the rotation and the first convenient opportunity to carry out the operation after sugar-beet harvest which, when weather is wet, is the operation most likely to damage soil structure. Farmyard manure is still spread 18 months before sowing sugar beet and the pH is checked 18 and 6 months before beet, with lime applied as necessary.

Cereals. On most fields seedbeds were prepared with shallow cultivations and ploughed only where crop residues or FYM made the operation necessary. Most of the winter cereals were drilled by mid-October 1980 and were sprayed with residual herbicide immediately after drilling. Part of the nitrogen top dressing was applied in the third week of March and the remainder in the last week of April or the first week of May

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giving the wheat a total of 180 kg N ha^{-1}, the barley 140 kg ha^{-1} and the oats 110 kg ha^{-1}. Spring barley was sown on Marl Pit on 27 February and on White Patch on 6 April after a period of prolonged rain; both followed sugar beet and looked weak and undernourished through the dull, cold spring and early summer. Self-sown cereals from the previous crops, oats in the wheat and wheat in the winter barley, were a major problem in 1981. There were no volunteers in fields that had been ploughed so all the winter cereal fields were ploughed in the autumn of 1981 to prevent a recurrence of the problem. Yields were: winter wheat (Brigand) 7·4–8·0 t ha^{-1}; winter barley (Igri) 6·4–6·8 t ha^{-1}; winter oats (Peniarth) 5·9–6·2 ha^{-1}; spring barley (Triumph) 3·4–5·3 t ha^{-1}.

Sugar beet. All the crop was sown with pelleted monogerm seed, and 80% was spaced at 18 cm or wider. Sixty-five per cent was treated with a granular insecticide at drilling, mainly to minimise the risk of early virus infection. Most of the crop was band sprayed at drilling with 'Pyramin' (chloridazon), followed by a half-rate, high pressure application of 'Betanal E' (phenmedipham) during late May and a further overall application of half-rate 'Goltix/Actipron' (metamitron) mixture at high pressure in mid-June. Weed control was good except for many perennial weeds—docks, thistles and campions—which had established over winter and were not killed during seedbed preparation; these were controlled by tractor and hand hoeing. Much of the crop was sprayed three times with aphicides, the first (second week in June) and second sprays to control green aphids, and the third mainly against black aphids. Sulphur was applied to most areas with the last aphicide spray to ensure protection against powdery mildew. Although the soil water deficit approached the limiting values on a number of occasions rain was sufficiently frequent for large-scale watering not to be necessary.

Harvest started on 14 October in difficult, wet conditions following above average rainfall in September and October. Most of the crop was lifted during a dry spell in November and finished on 10 December before the Arctic conditions set in, except for 0·5 ha, which was finished on 5 January 1982. Yields were the best for many years and averaged 41·2 t clean roots ha^{-1} at an average sugar content of 17·2%, ranging from 15·8 to 18·7%. Mean dirt and top tares were 11 and 7%. National yields averaged 35·7 t ha^{-1} at 16·5% sugar content.

Livestock. In October and November 1980, 71 cross-bred heifers and 30 cross-bred steers were bought and fattened in the yards on a ration of one-third brewers grains and two-thirds pressed beet pulp. This was fed *ad lib* with added minerals and fresh straw was always available. Some rolled barley was added to the ration in the finishing stages. The cattle were sold between mid-February and mid-May and the yards re-stocked in autumn 1981 with 50 Friesian steers and 53 cross-bred and Friesian heifers. (Golding)

Staff and visitors

During the year R. J. Gummerson was appointed to a new post as soil physicist, initially to work on seedbed conditions, and Kay F. Brown was appointed to study the growth and activity of the fibrous root system. M. J. Durrant was awarded the Ph.D. degree by Nottingham University.

Members of Broom's Barn staff took an active part in the work of the International Organisation for Biological Control and the International Institute for Sugar Beet Research, where they made major contributions to a session on Seedling Establishment at the Winter Congress in Brussels in February, to a meeting in June of the Spring Mechanisation Sub-Group in England, and to meetings in September of the Pests and Diseases Study Group in Denmark and the Genetics and Breeding Group in Holland.

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R. K. Scott and G. L. Maughan attended the IIRB Summer Tour in Austria. P. V. Biscoe contributed to a meeting of the European Weed Research Society in Ghent, Belgium, in April, to a symposium on the Growth of Leaves in Sydney, Australia, and to the XIII International Botanical Congress in Sydney in August. Before and after the Congress he visited research stations and universities at Adelaide, Canberra, Sydney, Tasmania and at Christchurch, New Zealand. R. K. Scott opened a Conference on 'Opportunities for Manipulation of Cereal Productivity' organised by the British Plant Growth Regulator Group at Wye College in September, and P. V. Biscoe and K. W. Jaggard contributed to the 33rd Easter School in Agricultural Science at Nottingham University.

A 3-day course on sugar-beet problems and practice for British Sugar fieldmen was held in September and 1 day training courses were given to Ministry of Agriculture beet cyst-nematode surveyors and Union Carbide technical representatives. Four scientific meetings were held during the year. The station contributed exhibits of current research to the Spring and Autumn Sugar Beet Demonstrations at Barton Bendish, Norfolk.

Dr N. Jarowaja of the Sugar Beet Research Institute, Warsaw, worked on seedling diseases with the Plant Establishment Study Group from April to July. Parties of visitors during the year included students from Denmark and Holland, and staff of Delaplanque et Cie from France.

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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