Report for 1978 - Part 1

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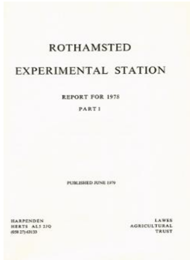

Broom's Barn Experimental Station

R. K. Scott

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Introduction

The year 1978 and the growth of our crop. After a better crop in 1977 than for the previous 3 years a slightly greater area was sown with sugar beet in 1978. In many respects the weather in 1977 and 1978 was similar. Temperatures from April until July were again lower than the long-term average. With only one exception rain fell in every week from April until late August, whereas July had been virtually rain-free in the previous year. The late summer and autumn were predominantly dry.

In general, plant establishment and final populations were again satisfactory. However, there were exceptions. At Broom's Barn frost damaged and killed approximately 40% of

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seedlings which emerged during the first half of April from early March sowings. Overall plant establishment from sowings made on 10 March, 5 April and 24 April was 47, 81 and 67% respectively. In the slow growing conditions, soil pests, especially symphylids and millipedes, caused damage on some farms. On chalkland, in experiments aimed at control of spiral nematodes, fumigation and high rates of aldicarb and carbofuran improved establishment.

With frequent rainfall after sowing, fertiliser applied at sowing did not adversely affect establishment. A notable feature of experiments in which seed was pre-treated to improve establishment and accelerate early growth was that increases in plant dry weight at singling of 50% resulted in 0·4 t ha^{-1} or 6% more sugar yield (worth about £50 ha^{-1}) at harvest compared with untreated seed.

Heavy rainfall at the beginning of May in many sugar-beet growing areas caused leaching of granular pesticides (aldicarb, carbofuran and oxamyl). This decreased their efficiency on many fields where the ectoparasitic nematodes which cause Docking disorder (*Longidorus* spp, *Trichodorus* spp and *Paratrichodorus* spp) were numerous and some damage was reported to treated crops. Despite this the area of Docking disorder reported was much less than would have occurred without the use of pesticides, because weather early in the season favoured nematode activity. In June, 1448 ha were reported affected (including 478 from York, 348 from Bury St. Edmunds, 233 from Wissington, 130 from Allscott, 110 from Newark and 100 from the King's Lynn factory areas), compared with 7800 ha in 1969 when May rainfall was similar.

A feature of many samples arriving at the plant clinic was a stunted and otherwise generally unhealthy root system. There were many reports of plants showing typical magnesium deficiency symptoms but in many fields examined the soil contained sufficient available magnesium for normal growth, indicating that poor root systems prevented the plant taking up enough of the element. There is a great urgency to obtain a better understanding of the form and function of the healthy root system throughout the life of the beet plant so that the importance of root disease, or other problems impairing root growth, as a yield limiting factor, can be defined and overcome.

With the low spring temperatures the leaf canopy was slow to close and it was clear by late July that weedy crops were particularly widespread. In some, weeds were so prolific that hand-pulling or a pass with a weed cutter was required. The reasons were that frequent rain early in the season encouraged more weeds to emerge, and over a longer period, than in recent years. Most pre-emergence herbicides appeared to work well, but the activity of the more soluble ones was cut short because of leaching in wet soils. Any grower who had not used pre-emergence herbicides had to consider making applications of post-emergence herbicides, e.g. phenmedipham, as 'Betanal E' very early in May, but changeable weather and saturated soils prevented timely spraying. In most crops a second application of phenmedipham or mixtures was needed in late May/early June when there was a spell of hot, bright weather. Because the bright weather augured a danger of severe herbicide checks to beet growth, some growers delayed spraying giving weeds a further opportunity to evade control. At Broom's Barn phenmedipham applied at the recommended dose in bright but cool conditions on 26 May caused yellow blotches to appear on the leaves of beet plants. However, 4 weeks after spraying plant dry weight had only been decreased by 13% and, unlike 1977, there was no reduction in yield at final harvest. Finally, in late June and early July, when a last side-hoeing was needed, wet soil which was ideal for the germination of late weeds (particularly *Chenopodium album*) prevented tractors getting onto the land.

In 1977 the sugar-beet crop was remarkably free from virus yellows and in 1978 even fewer plants were infected nationally; only about 0·5% of plants showed symptoms at the end of August. This low incidence was partly due to the small number of infected beet,

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groundkeepers, mangolds and weeds which overwintered. There were more frosts during January to March than in recent years and April was cold and wet. The aphids which overwintered were therefore slow to multiply and migration to the beet crop was small and exceptionally late. No 'spray warning' cards were sent to growers and only about 3% of the national crop was sprayed against green aphids. Black aphids were also slow to multiply and few crops suffered damage from them. Powdery mildew was generally at a low level and the only noteworthy foliar diseases were sporadic outbreaks of rust and *Ramularia* leaf spot which showed up clearly on the otherwise green foliage late in the season.

Free from disease and water stress, both the national crop and our own at Broom's Barn responded to the brighter conditions in the latter part of August and at the end of the month sugar yields were greater than in 1977. Despite the driest autumn recorded at Broom's Barn (60 mm of rain from September to November compared with an average of 165 mm) there was no response to 50 mm of irrigation applied at the end of August. Soil moisture measurements showed that the deep root system was able to provide all the water necessary for transpiration during September to December. Because of the above average rainfall during the previous winter it was expected that the crop would be more than usually responsive to nitrogen. This proved to be so and the optimum dressing was 125 kg N ha^{-1} which increased sugar yields by 50%. As in 1977, the freedom from disease and the dry late summer and autumn favoured high sugar concentration. For the second year running extraction rates at the factories were at very high levels until Christmas.

In last year's report reference was made to the possibility that, after late ripening of the 1977 seed crop and partial vernalisation of seed while on the straw, bolting might again be a feature of the 1978 crop. Bush Mono G and Nomo sown on 10 March had produced 18·1 and 5·8% bolters respectively by the end of the season; less than 0·5% bolters were recorded in Bush Mono G sown on 5 April. Usually there is little increase in the number of bolters after August but this year bolters continued to appear late into the autumn. By the end of September nearly all bolters from the earlier sowings had set some viable seeds. During the summer a great effort was made to alert growers to the possibility of a weed beet infestation if bolters were allowed to set seed. After cereal harvest sugar-beet plants were widely distributed in the cereal stubbles at Broom's Barn. Most were groundkeepers, both whole roots and crowns, but a few had very small apparently complete roots which could have grown from seed germinated this year. Although some showed signs of flowering, none had reached the stage of bearing seeds before ploughing.

A major activity at Broom's Barn during 1978 has been the preparation of the future long-term programme of work requested and now approved by the Sugar Beet Research & Education Committee after the change in Head of Department. The objective was to review the background to current problems facing the industry and the scientific principles involved to provide a basis for future annual programmes. Multi-disciplinary groups were set up to tackle four major topics of concern to the industry, on which Broom's Barn has the expertise to make progress. The format of this report relates to the thinking and activity of each of the groups.

During the year we have begun to up-grade the glasshouse facilities and associated laboratories and to make plans for continuous recording of weather data, together with automating recordings from balances and other equipment in the tarehouse and field laboratories. We have also embarked on a programme of insulating the buildings and changes to the heating system, intended to improve the working environment and the efficiency of energy use.

Plant establishment

'Drilling-to-a-stand', with seeds spaced 12·5 cm or more apart, entered commercial use

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in the mid-1960s and, in 1978, some 75% of the national crop was grown by this method. In rows 50 cm apart, normal in England, 75 000 plants ha^{-1} reasonably evenly distributed are needed for a full yield of sugar and to obtain this population 70% or more of seeds sown at 18 cm spacing need to establish a plant. However, in over 200 trials made by British Sugar staff between 1970 and 1977, on average, only 56% of seeds established a plant; mean annual averages varied from 49–62% and, within years, the site-to-site range was from 16 to 89%. On 86% of the fields, the establishment was below the target 70%. It is estimated that, overall, 10% of potential sugar yield is lost by poor plant establishment. Another problem with 'drilling-to-a-stand' is that emergence takes place over a prolonged period, commonly 40–50 and occasionally 80 days. For reasons which are unknown, seedlings are still emerging when quite large established seedlings are present and this makes it impossible to apply post-emergence herbicides at the optimum development stage of all plants; it also contributes to variation in plant size which makes for difficulties at harvest. Our aims will therefore be to make emergence quicker and more uniform and to increase the number and vigour of seedlings which emerge and become established.

An alternative way of overcoming the establishment problem is to develop different ways of growing the crop which are less dependent on good emergence, e.g. high plant-population on narrower rows, or bed systems. Although some attention will be given to these, the main effort of this group will be to improve establishment.

The primary objective must be to understand why, when everything is done during seedbed preparation and drilling to the best of available knowledge and ability, seeds which laboratory tests show have the potential to grow do not all produce seedlings. Particular attention will be given to individual seeds to define the conditions both of the soil and of the seed which either allow them to germinate and then produce a seedling or cause them to fail at some stage. Having defined the conditions, it should be possible to determine the causes, fix treatments for subsidiary experiments to confirm these, and then suggest approaches and methods to overcome the adverse effects.

Seedling establishment observations at Broom's Barn in 1978. Two areas of sugar beet (var. Bush Mono G) were sown on contrasting soil types, the clay loam of Bull Rush and the sandy loam of Brome Pin fields, for an interdisciplinary study of factors affecting seedling establishment. Seedbeds were prepared with a powered and rotary harrows. On Bull Rush two passes of the harrow gave a firm but not very fine seedbed and pelleted beet seed was sown on 13 April. On Brome Pin a single pass of the harrow gave a good fine seedbed and beet was sown on 19 April.

Within 24 h the pellets were found to be fully supplied with water and remained so. Frequent rain ensured that the top soil never dried for more than a day or two until the third week of May. Between 19 April and 5 June, Bull Rush soil at approximately seed depth (2·4 cm) contained 15·0% water and Brome Pin 13·7%. The amount of water fluctuated more in the top 5 cm than deeper; water content of the 5–20 cm horizon remained relatively constant until late May. There was a gradual decrease in pH from 7·85 to 7·55 and in conductivity during this period.

Soil aggregate size distribution was measured on Bull Rush on 17 April, 24 April and 20 June. The soil covering the seeds contained a higher proportion of large aggregates than was present in the seedbed at drilling. This has been observed before, and is thought to be caused by the operation of the coverer on the Stanhay drill. A surface soil cap developed around 9 May at the time when the rate of emergence was decreasing. Subsequent weakening of the cap by rain did not affect emergence rate. Emergence on both sites was 74%. Few seedlings were lost after emergence, most from slugs, birds and *Pythium*.

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On 20 June when emergence was judged completed, soil samples from around seedlings and vacant seed stations on Bull Rush were collected. The only consistent difference between the successful and failed seed stations was that more large stones were found around the latter. At the same time a sample of seed positions were carefully excavated on Brome Pin. Of these 70% had emerged seedlings, 4% contained no pellets, 10% had produced seedlings with long hypocotyls that were no nearer than 1 cm to the soil surface, 2% germinated but produced only short radicles, 3% had pellets containing empty fruits, 2% had pellets with no fruits, 3% had failed to germinate in the field but subsequently germinated in the laboratory and 3% had pellets containing non-viable seed. (Byford, Draycott, Dunning, Durrant, Jaggard, Longden, Scott and Webb, with Bugg, Cooper, Johnson, Thornhill and Sanderson)

Manganese deficiency and seed pelleting. Manganese deficiency still restricts yields, particularly on organic soils, because current control measures ($MnSO_4$ spraying) are not very effective in the seedling stage. Experimental work continued on improving the manganese content of seedlings by incorporating MnO in the seed pellet on a 50% w/w basis with the pelleting clay. Four field experiments, two on peats where deficiency was expected and two on sandy loams where deficiency was unlikely, compared normal pellets with those containing MnO, or $MnSO_4$ which had supplied maganese to seedlings most effectively in glasshouse tests. All pellet treatments were compared with and without a $MnSO_4$ spray in the latter half of June.

On the most deficient crop MnO in the seed pellet increased the manganese concentration in seedlings from 10 ppm to 17 ppm and increased sugar yield by 10%. However, a foliar spray in addion to the MnO in the pellet increased yield further, showing that maganese in the pellet only supplied the plant in the seedling stage. Manganese sulphate in the pellet supplied seedlings in the field with manganese more effectively than MnO but decreased emergence on mineral soils, whereas MnO was never harmful.

In 1978, for the first time, a small quantity of pellets of two varieties containing 50% w/w MnO were available commercially. These were sown in strips in 64 fields, mostly on peaty or sandy soils, and compared with untreated pellets. Manganese did not affect seedling emergence but marked improvements in growth and colour of the treated plants was recorded. Fourteen of the most deficient fields were examined in detail and seedling weight was significantly increased. (Farley)

Method of nitrogen application. Experiments are in progress to determine when and how to apply nitrogen fertiliser so that leaching is prevented as far as possible and toxic effects on germinating seeds avoided. However, it is also important that fertiliser is available to seedlings because their weight and early growth is greatly increased by nitrogen.

A machine has been developed at Broom's Barn which applies the nitrogen to the soil surface between the rows at sowing. Applied in this way, the fertiliser does not decrease the number of seedlings which establish, whereas broadcasting normally decreases establishment by 5–10% but there is insufficient evidence that seedlings absorb nitrogen effectively when it is applied between the rows. Thus the method appears satisfactory in terms of both establishment and plant growth, but it is more difficult to assess whether it should become a standard component of commercial sugar-beet growing. Experiments are in progress with prototype machines to confirm that the crop always benefits from nitrogen applied in this way and to determine whether the improvement in plant establishment, compared with broadcasting immediately before or after drilling, is worthwhile. (Draycott, Last and Webb)

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Wood mice taking seed. Extensive trapping from 1974 to 1978 showed that almost all sugar-beet fields in eastern England held populations of wood mice, *Apodemus sylvaticus*, during March–April. Despite the wide distribution of the pest, severe losses of seed between sowing and emergence caused by mice digging up and eating seeds were sporadic. Thus any rational damage-control strategy would require not only an effective means of reducing damage but also an ability to recognise in advance fields and seasons of high risk (*Rothamsted Report for 1976*, Part 1, 54). Wood mouse populations on sugar-beet fields can be rapidly reduced by anticoagulant poisoning (*Rothamsted Report for 1977*, Part 1, 64), and trials in 1978 showed that seed taking could be stopped within a few days by poisoning. Hence, since an effective control exists, the remaining problem is to evolve a means of identifying when crops would benefit from treatment.

Differences in mouse population density between years and fields may contribute to variations in damage severity. An intensive live-trapping study of wood mice on arable farmland showed that there were permanent field-living populations which did not require immigration from woodlands or hedgerows to maintain their numbers. It was concluded that fields close to woods or hedges were not at special risk and this was confirmed by surveys mapping actual losses of seed. The overwinter survival rate was the most important factor affecting spring population density since breeding does not begin until April. Winter survival was very variable from one winter to the next and may depend on the availability of food supplies. Much of the winter diet of farmland wood mice consists of soil arthropods and earthworms whose abundance in the surface layers of the soil is affected by temperature and moisture. Thus weather may influence spring population densities via winter food supplies, accounting for the tendency for year to year fluctuations in spring mouse density to be in phase over large areas. The population densities of wood mice on fields of newly sown sugar-beet seed would therefore be expected to be greatest in years when mild, wet weather had permitted large numbers to survive and, since numbers fall continuously from autumn to late spring, early sown fields would have larger populations of mice than those sown later.

The abundance of wood mice is clearly not the only factor affecting the severity of seed losses. On some fields with many mice no losses of seed occurred, and on damaged fields losses were usually restricted to discrete patches, even where mice were found over the whole field. These observations suggest that the inclusion of sugar-beet seed in the diet may involve individual learning and be affected by the abundance of other foods. Therefore it would be expected that for fields with a given density of mice, seed losses should be greatest where seed is particularly easy to detect and where alternative food sources are restricted. In fact, losses were most common on fields where some seed was inadequately covered with soil at drilling. Furthermore, damage was most widespread in dry springs when soil invertebrates, which form over half the spring diet of wood mice, were scarce near the soil surface.

The risks of severe losses of sugar-beet seed in newly-sown fields are probably highest when mice are numerous, the soil is dry, sowing is early and where some seeds have been inadequately covered with soil. The possibility of using surveys of mouse populations in late winter, and weather forecasts to predict damage levels and alert growers to the need to inspect fields regularly for damage, is being investigated. (Green)

Birds grazing seedlings. The extent of grazing damage by skylarks (*Alauda arvensis*) and red-legged partridges (*Alectoria rufa*) to a field of sugar beet in the cotyledon stage depends on the density of these birds, the length of time the plants are exposed, and the extent to which the birds include sugar-beet cotyledons in their diet. Studies on a sample of sugar-beet fields in East Anglia in which birds were counted, their diet determined by

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faecal analysis and the abundance of their food supplies determined, were completed in 1978.

Skylarks and partridges graze both weed and beet seedlings and, in addition, skylarks take weed seeds and beetles from the soil surface. Most of the diet of both species was found to be weed seedlings and it was shown that the density of the birds on the field increased with the abundance of palatable seedlings. Although birds were most numerous on fields with high densities of weed seeds and weed seedlings, the most important grazing species, the skylark, was less likely to graze seedlings when weed seeds were numerous. On these fields the birds caused much less damage to sugar-beet seedlings than would have been expected from their numbers.

Seedlings of different weed species were not equally preferred by grazing birds. *Veronica* and *Matricaria* spp. seedlings were not commonly taken while *Polygonum aviculare* and *Atriplex patula* were usually heavily grazed. Sugar beet was also a preferred species. The birds' feeding preference was strongly positively correlated with the nitrogen and phosphorus content of the seedling cotyledons.

Where sugar-beet seedlings had been treated with aldicarb at drilling, they were grazed little relative to the other species. Aldicarb had reduced the incidence of grazing damage in an extensive sample of fields surveyed in 1976 (*Rothamsted Report for 1976*, Part 1, 54), and in trials with captive skylarks in 1978 untreated seedlings were more heavily grazed than those treated with aldicarb. It appears that, through its systemic action, aldicarb reduces the palatability of sugar-beet cotyledons. Treatment with aldicarb to protect sugar beet from bird damage is undesirable on both economic and environmental grounds, but the possibility of using systemic agents to modify the palatability of seedlings deserves further investigation. (Green)

Seed treatment fungicides. Seed produced in the UK is frequently heavily infected by *Phoma betae*, which causes seedling blackleg, and must therefore be treated with the most effective available fungicide. Since 1961 all seed has been EMP steeped (20 min steep at ambient temperatures in a 40 ppm solution of ethyl mercury phosphate). Because the material is poisonous and the process expensive many alternatives to steeping have been tested, but results of field experiments from 1973 to 1977 suggested that if the best of these replaced EMP steep, average establishment would fall from 56 to 53%.

The future of EMP steep is at present in doubt due to political pressures to stop the use of organomercury (particularly alkylmercury) fungicides, and to some uncertainty on the long-term availability of a toxic fungicide with such restricted usage. The need to find a satisfactory replacement is urgent and trials with pelleted seed in collaboration with the British Sugar Corporation continued to test the most promising alternative treatments.

Fungicide seed treatments were compared on eight seed lots with different levels of *P. betae* infection of which three were grown at each of 15 sites. Emergence varied greatly between sites; from 25 to 71% for EMP steeped seed but, because the seed lots were distributed at random between sites, it was not possible to correlate improvements in emergence produced by treatments with the proportion of seeds infected by *P. betae*. On average (45 comparisons), seedling emergence was 31% from untreated seed, 52% with EMP steep, 51% with phenylmercury acetate (PMA) (80 ppm) steep, 54% with thiram (0·2%) steep, 46% with TCMTB (40 ppm) steep and 49% with maneb (1%) applied at pelleting. Thus thiram steep appears slightly superior to EMP steep but because it requires a steep of 24 h at 30°C the possibility of using it commercially on sugar beet is doubtful. PMA at a higher concentration than used for EMP may be of value as a stop-gap treatment if EMP cannot be used; its effectiveness and safety will be tested further. (Byford)

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Environmental and nutritional aspects of crop growth and productivity

In the past much of the research on the productivity of sugar beet (and most other crops) has been based on results obtained from factorial or multi-factorial experiments, and the interpretation of the results has relied heavily on final yield data. This approach has provided very little information on the processes that can restrain growth. The group intends to overcome this problem by integrating the knowledge and experience of agronomists, nutritionalists and crop physiologists. The aim is to combine and concentrate their efforts on a limited number of experiments where comprehensive measurements on the crop and the environment will be made at frequent intervals from emergence to harvest. This will provide a detailed description of crop growth and enable physical and physiological analyses to be made of the processes governing total dry matter production and the accumulation of sugar in the storage root. (Biscoe, Draycott, Jaggard and Scott with Milford, Botany Department)

Radiation interception and sugar production. Studies with other crop species have shown that dry matter accumulation can be related to the quantity of solar radiation intercepted by the leaf canopy. During 1978 the group started a study of this relationship by examining the growth and development of three crops sown on 7 April, 24 April and 18 May; mean dates of seedling emergence were 2, 16 and 29 May respectively. The crop sown in early April grew slowly at first, but by the middle of July had reached a leaf area index (LAI) of 2·4. The rate of leaf area growth of the second sowing was similar to that of the first, so that by mid-July its LAI was 2·0. The LAI of both crops was 3·3 in early August. Leaf area growth of the crop sown on 18 May was much slower and by mid-July was only 0·5. However, between mid-July and mid-August the leaf area of the late sown plants expanded very rapidly, and from then until October all crops maintained a LAI of more than 3. The production, expansion and persistence of individual leaves was measured at weekly intervals in the three crops and the relationships with temperature and leaf nutrient status are being examined (see below). Measurements of leaf growth and radiation interception (made with tube solarimeters) were used to produce a relationship between LAI and the proportion of incident radiation intercepted by the crop sown on 18 May. If the assumption is made that all three crops had the same relationship then all converted radiation to dry matter with a similar efficiency, 1·9 g MJ^{-1}, comparable to values measured in healthy, unstressed cereal crops. Between seedling emergence and harvest the three crops, in order of sowing date, intercepted 1170, 1110 and 930 MJ^{-2} of solar radiation respectively. On 23 October their sugar yields were 857, 806 and 620 g m^{-2}. In the two April-sown crops 46% of the total dry matter was sugar in the root, but this proportion was only 43% for the crop sown on 18 May. Thus, while the difference in sugar yield between the two April sown crops is consistent with the small difference in intercepted radiation early in the season, the poor yield of the May-sown crop was due to the reduction in radiation intercepted before mid-August and an unfavourable distribution of dry matter. (Biscoe, Jaggard, Farley and Messem)

Temperatures and leaf area production. The area of successive leaves on a sugar beet plant increases usually until about leaf 12, and thereafter decreases with subsequent leaves. However, the rate of leaf production and the ultimate size of individual leaves can be modified by temperature. This study aimed to discover how fluctuating temperatures in the field affected leaf area production using crops sown on three dates.

The rates of appearance and expansion of individual leaves were measured weekly throughout the season on the same groups of plants. There were considerable variations in the weekly mean temperatures early in the season, which allowed the growth of leaves

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produced at similar positions on the plant to be compared when they had been initiated or were expanding at different temperatures. The weekly rate of leaf production was mainly determined by the weekly mean temperature. During the early weeks of growth it was also influenced by the time of sowing; the rate of production was faster the later the crop was sown. By mid-July plants of the two earliest-sown crops had 21 and 23 leaves respectively and plants of the last sown crop 19 leaves. Thereafter, leaves appeared at a similar rate in all three crops. When harvested in the third week of October, plants from the early, middle and late-sown crops had on average produced 48, 49 and 44 leaves respectively.

The patterns of growth of individual leaves are currently being examined mathematically (p. 46). Preliminary results indicate that the temperatures early in a particular leaf's development (between initiation and unrolling) had an overriding effect on its subsequent development. They not only determined the final area of the leaf – as found earlier in growth room experiments (*Rothamsted Report for 1971*, Part 1, 101) – but to some extent pre-determined leaf growth rate during the 3–4 weeks of expansion, with current temperatures having a minor influence. The weekly mean temperature during leaf expansion had its greatest effect on the time needed to complete expansion. (Milford, Botany Department)

The effect of nitrogen on leaf persistence. An understanding of the uptake and movement of nitrogen by individual leaves is necessary because, first, nitrogen fertilisation increases the area of individual leaves and second, both decreasing photosynthesis and the senescence of the leaf are associated with the movement of nitrogen from leaves.

At the beginning of July many plants were selected at random in the crop sown in 24 April and the 15th leaf on each was marked. Three of these plants were harvested every week until the end of October and divided into crown, root and groups of five leaves, i.e. leaves 1–5, 6–10 etc. The leaves were divided into laminae and petioles and the dry weight and nitrogen concentration of all plant parts was measured. The concentration of nitrogen was highest in the youngest leaf group and progressively decreased as the leaves aged. After the beginning of August leaves 11–15 were the heaviest and their dry weights remained relatively constant until the end of October. The nitrogen concentration decreased consistently from July until October although the maximum leaf dry weight and area were not reached until the middle of August. Total nitrogen increased as the leaves increased in size, reaching a maximum at maximum dry weight and thereafter decreasing. The loss of nitrogen from the leaves was associated with a change in their visual appearance. When the nitrogen concentration reached about 2·5%, which in leaves 11–15 occurred approximately 5 weeks after reaching maximum size, the leaves began to show some yellowing and when they were dead the concentration had reached about 1%. Because leaf dry weight remained relatively constant the decrease in nitrogen concentration must have been associated with the translocation of nitrogen from the leaves to other parts of the plant. If this loss of nitrogen could be prevented, particularly in the large leaves, would this improve leaf persistence with a corresponding increase in radiation interception and dry matter production? (Bürcky and Biscoe)

Nitrogen. Mineral nitrogen in soil, whether given in fresh fertiliser or provided by residues of previous crops and fertilisers, greatly influences growth and yield of sugar beet. Profitability relies on providing the crop with sufficient nitrogen for maximum root yield but without excess, otherwise fertiliser is wasted and the sugar percentage which affects payment for the roots is decreased and the processing quality of the crop is lowered. Thus it would be in the interest of both growers and processors if the amount of nitrogen applied could be modified to take account of that present in the soil.

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Analysis of sugar-beet crops over several years on various soil types showed that residues in the soil provided at least half the crop's need and in about 20% of fields there was sufficient for maximum yield without fresh fertiliser. The soil's ability to supply such a large quantity of nitrogen shows that it is essential to take this into account if the amount of fertiliser applied is to be optimised. At present, the amount of nitrogen applied to beet in the UK is based on average optima from field experiments, with slight modifications for previous crop and soil type.

In co-operation with the British Sugar Corporation, a new study was begun monitoring soil mineral nitrogen on five fields, one in each of the main sugar-beet growing regions. Soil samples were taken during autumn, winter and spring prior to the 1978 crop and rainfall measurements were made at each site. The results provided information on the quantity of nitrogen present in the soil profile to 1 m deep before sowing and an indication of the degree of leaching of nitrogen. Measurements of leaching were also made in small lysimeters of each soil. Results of both field and lysimeter measurements indicated that in 1978 much nitrogen was leached before sugar beet was sown. Comparing the results with previous information, a large response to fresh fertiliser was expected and a tentative forecast was issued to the British Sugar Corporation that a need of 80–100 kg N ha^{-1} was expected in all five regions. Field experiments testing five amounts of nitrogen fertiliser on each of the fields subsequently showed that response was very large and 90 kg N ha^{-1} was needed on average. As this approach seems to give results which might be useful commercially, it will be continued in 1979. (Last and Messem)

Sodium. The area of sugar beet in the UK which receives sodium chloride fertilisers continues to increase. In the past, it was regarded simply as an inexpensive substitute for potassium which it partly replaces. However experiments have shown that in spring and early summer sodium stimulates early leaf growth and increases dry matter production more than potassium, whilst in autumn, sodium increases the proportion of total dry matter partitioned to the roots and increases sugar percentage. In addition, there is evidence that sodium increases the crop's tolerance to drought because it increases the efficiency of the leaves during short periods of water stress (*Rothamsted Report for 1977*, Part 1, 61).

The overall effect of these improvements in growth are reflected in sugar yield and a recent review of field experiments made over many years showed that, on mineral soils, sodium fertiliser increased yield by about 10% although the response was halved where potassium fertiliser was also given. Response to both elements differs greatly between fields and experiments have been made to determine whether this is due to differences in the amount of sodium in the soil. If so, it should be possible to improve use of sodium fertilisers by taking into account the amount of soil sodium.

Sandy soils and light loams were found to contain least exchangeable sodium, usually between 5 and 20 mg kg^{-1} and yield of sugar beet on these fields was greatly increased by sodium fertiliser. Organic soils contained most sodium, often in excess of 100 mg kg^{-1} and under these conditions the crop did not respond to this fertiliser. On clay loams which usually contained 20–100 mg kg^{-1}, responses to sodium were small. Thus, there appears to be three broad ranges of response, 0–20 mg kg^{-1} where the increase in yield is likely to be large, 20–100 mg kg^{-1} where it is marginal and over 100 mg kg^{-1} where sodium fertiliser is unlikely to improve yield. (Allen and Cormack)

Magnesium. Recent surveys of fertiliser applied for sugar beet show that 17% of the area was treated with magnesium-containing fertiliser which, on average, supplied 70 kg Mg ha^{-1}. A further 15% received kainit at 575 kg ha^{-1} which contains a variable amount of magnesium but, on average, probably supplies about 25 kg Mg ha^{-1}. In-

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creasingly, soil analysis is being used to determine where and how much magnesium is needed.

Research continued on different forms of magnesium fertiliser, particularly magnesium oxide, and the factors which affect the availability to plants of the magnesium it contains. Most forms of the oxide so far studied have been produced from magnesium carbonate, a mineral known as magnesite. As mined, this is unreactive in soil so it is converted to oxide by calcination, a process of heat treatment which removes carbon dioxide. Apart from increasing magnesium concentration, calcination increases the chemical activity of the product. Evolution of carbon dioxide results in the development of an extensive internal surface area, the calcined magnesite being essentially microporous. This increase in reactivity is revealed in such properties as enhanced rate of reaction of the solid with liquid reagents, an increased rate of dissolution in solvents and a marked absorptive capacity of gases. Increasing the temperature or prolonging the time of calcination causes the oxide to sinter and reactivity is decreased because the magnesium oxide crystals grow and weld together, with reduced surface area.

Experiments have been made to establish whether this variation in the internal surface area of the oxide affects the rate of release of magnesium from calcined magnesite in the soil. In co-operation with G. Brown of the Soils and Plant Nutrition Department, X-ray measurements showed that as the temperature of calcination increased so the size of the magnesium oxide crystal increased from 14 nm at 650°C to 150 nm at 750°C. Field and pot experiments are in progress to determine the effects of calcining conditions on the availability of magnesium for sugar beet (*Rothamsted Report for 1976*, Part 1, 68). Results so far suggest that quite large differences in chemical characteristics are difficult to detect in terms of plant uptake of magnesium or differences in yield in field experiments. It is clear, however, that the temperature of calcining must be above 700°C so that all the carbonate is converted to oxide, but below 900°C to prevent excessive growth of oxide crystals with resultant loss of reactivity. This work is continuing and for the first time this year initial tests were made to determine whether an oxide produced from magnesium obtained from sea water could be suitable for use as a fertiliser for sugar beet. (Hutchison)

Diseases and pests

Although following the epidemic of 1957–61 virus yellows was relatively scarce for most of the 12 years 1962–73, there was considerable expenditure on control measures. In 1974, the disease increased abruptly to cause severe crop losses, as it had done in 1957, and then remained important although less devastating in 1975 and 1976. In 1977 and 1978 the disease was at a low level but it is safe to assume that it will return, causing heavy yield losses unless control measures are improved.

It was against this background that current knowledge of the disease, including the losses caused and the costs incurred in attempting control, was thoroughly reviewed in order to seek means of improving control measures. The control measures used are only partially effective and the appearance of insecticide resistance in the main vector of the viruses (the aphid *Myzus persicae*) from 1973 onwards has made the situation worse.

A research programme has been planned in which research objectives, generally divided into specific projects, can be related to potential improvements in advice to the industry on the control of virus yellows. These have been divided between the stages in growing the crop at which decisions must be made that might affect yellows incidence.

First, pre-drilling decisions on control measures; scope is limited, but improvements are required in our forecasting of the probable level of yellows incidence. Second, preventing the disease from entering beet crops; the current spray warning scheme allows aphids which may be carrying yellows to enter beet crops but seeks to prevent them from

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multiplying and spreading the disease within crops. This approach cannot control yellows in years like 1957 and 1974 when large numbers of viruliferous winged aphids enter the crop.

Thirdly, preventing spread of the disease within the crop; this is the main current method of control but survey data over many years show that sizeable losses can still occur in spite of considerable expenditure on control measures and the problem is made more acute by the frequency of occurrence of insecticide-resistant strains of *M. persicae* (Insecticide and Fungicide report, p. 130). Finally, the possibility of minimising the effects on the plant of infection with virus yellows will be investigated.

Two field research projects that will be continued for a series of years were started in 1978. In spring and summer the occurrence of winged and wingless aphids and the natural appearance and spread of yellows in the absence of insecticides was monitored on a 0·5 ha area of sugar beet at Broom's Barn. This study will be linked to work on aphid predators also in progress. This year there was a moderate infestation of *A. fabae* in late July and early August but only three winged *M. persicae* were found and the maximum mean population of wingless was 0·1 per plant on 7 July. The potato aphid *Macrosiphon euphorbiae*, was more abundant than *M. persicae*, with a maximum of 1·2 wingless per plant on 27 June. In mid-September only 1·7% of plants in the study area had virus yellows.

In the autumn an overwintering area was established where populations of aphids and their enemies will be followed on aphid and virus host plants; beet stecklings, rape, cabbage and weeds. In November *M. persicae* was well established in the area with the largest populations on cabbage. (Byford, Dunning, Heathcote and Scott, with Helen Smith and Thornhill)

Rotational aspects of sugar-beet growing

This group examines those biological, chemical, physical and economic factors which influence and are influenced by the choice of rotation. Sugar beet is considered in relation to other crops and its value as a break crop is assessed, the emphasis being to study the productivity and profitability of the rotation as a whole. The problems caused by harvesting beet under difficult conditions are examples of the way in which it influences succeeding crops; likewise previous cropping and cultivations affect soil properties which directly influence the yield of sugar beet.

Fertiliser regimes should be planned for the rotation to ensure that each crop has the correct amount of nutrients, that application costs are minimised and that the timing of application does not conflict with other farming operations. Rotation experiments at Broom's Barn have demonstrated the importance for maximum profitability of maintaining a correct nutrient balance in the soil, and have shown that under such conditions high sugar yields can be maintained in rotations containing frequent or continuous sugar beet until biological problems appear. The whole programme of both long-term experiments at Broom's Barn and the farm rotation are currently being reviewed by the group.

Two biological problems associated with crop rotation have been considered; beet cyst-nematode and weed beet. The revoking of the legislation which enforced crop rotation in the scheduled area of the Fens and on all fields known to be infested with beet cyst-nematode, and the appearance of large populations of this pest in a long-term experiment at Broom's Barn, necessitated a review of the research programme on this subject. Weed beet is already a serious problem and may soon threaten a large proportion of the beet crop unless effective control methods are developed. (Cooke, Draycott, Dunning, Golding, Jaggard, Longden, Scott and Webb)

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Beet cyst-nematode (*Heterodera schachtii*). Two aspects of the present situation will be considered.

(a) In the old scheduled area, on which about 20 000 ha of beet are grown annually and where most fields are believed to be infested, the relaxation of statutory rotational control (*Rothamsted Report for 1977*, Part 1, 54) may result in more frequent cropping with hosts of beet cyst-nematode. It is necessary to be able to predict how populations are influenced by cropping on these soils and at what population levels yield will be decreased. If possible, economical alternatives to crop rotation will be developed to control damage; soil fumigants are often rendered relatively ineffective in peat soils because they are adsorbed on to the organic matter – systemic compounds may be preferable. Much information is available from previous experiments but further work needs to be done.

(b) On mineral soils outside the old scheduled area, a clause in the beet grower's contract prevents beet from being grown more frequently than 1 year in 3, even on the most suitable fields. In other countries, rotation restrictions are less stringent and pests are controlled, where necessary, by chemical means. Surveys in England have revealed detectable populations of beet cyst-nematode in only 1–2% of randomly selected sugar-beet fields on mineral soils although it is certain that populations undetectable by current techniques are present in far more fields. Possible changes in the rotation policy allowing more frequent cropping on some fields will be assessed to determine whether they would improve the economics of sugar-beet growing in the UK without jeopardising the long-term prospects of the crop. In order to do this it is necessary to know how populations are influenced by cropping and at what population levels yields will be decreased; the development of large populations of beet cyst-nematode in a long-term experiment at Broom's Barn has given the opportunity to do much of this work here.

The only alternatives to crop rotation for controlling damage on mineral soils currently available are the use of fumigant or systemic nematicides. Experiments will be made to determine the most effective materials and methods of application, and their effect not only on beet cyst-nematode and sugar beet but also on other pests, diseases, weeds (including weed beet) and other crops in the rotation. Although soil fumigation is an expensive way of controlling cyst-nematodes (costing around £210 ha^{-1}) it is widely used in some other European countries, especially when it is known to improve the yields of other crops in the rotation (e.g. by controlling potato cyst-nematodes). Systemic compounds may be cheaper but give protection for only one season and often leave large post-crop cyst populations.

Research on non-chemical control measures which do not involve crop rotation (resistant or tolerant varieties, biological control agents, etc.), is still at a very early stage but co-operation with other workers will be continued in these areas. (Cooke, Chwarszczynska and Cooper)

Weed beet. Annual forms of beet (*Rothamsted Report for 1975*, Part 1, 65) have appeared on an increasing proportion of sugar-beet land in recent years. Surveys have shown that from 1·4% of the 1975 crop, the area of the crop infested had risen to 15% in 1977 and 19% in 1978. Heavy infestations (more than 75 plants ha^{-1}) were most common in the Allscott, Cantley, King's Lynn, Nottingham and Wissington sugar factory areas. Allowing for other land in the rotation also being infested it is probable that 170 000 ha of arable land in England are now affected to some degree by annual beet. Clearly the way to control this problem is to prevent seed production by beets which bolt in their first year of growth. Early experiments simply compared pulling with cutting or chemical application with a rogueing glove. Less than half the growers with the problem have responded to advice to control bolters, despite considerable efforts to get the message across, so annual

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beets will probably be with us for a long time to come, and may become as serious a weed as the wild oat. Therefore, our research programme has been consolidated and all aspects of the weed's biology will be investigated.

Work planned will examine the development of viable seeds as influenced by their position on the mother plant and the time of flowering; studies of the effect of the germination time of the parent plant and of plant density should help determine what characterises the early development of many viable seeds. A second phase of the work is to examine in the field how rotation and different cultivations before and after the sugar-beet crop influence the population dynamics of weed beet. Experiments have already started in collaboration with the Weed Research Organisation and British Sugar staff. A modelling approach will also be tested here. It is envisaged that the weed beet work will be a major commitment for several years. (Longden and Johnson)

Broom's Barn Farm

Ploughing was completed by mid-January. Following a cold and wet winter, spring work did not start until mid-March. The grass ley and most of the winter wheat established well. With the dull summer, cereals ripened late and combining did not start until late August. White Patch, Hackthorn and New Piece were subsoiled at 55 cm deep with 90 cm between tines in both directions, and FYM was applied to White Patch.

Cereals. Only the second year wheats on New Piece and Hackthorn had nitrogen in the seedbed. They were sprayed with carbendazim on 26 May to control eyespot.

Spring barley sowing started on 10 March but wet weather delayed completion until 5 April. All was Ark Royal with ethirimol seed treatment, the only fungicide used this year. Wet and windy weather delayed herbicide spraying; as crops were becoming too advanced for safe use of the usual herbicides alternative products had to be used. On one field of winter wheat application of a reduced rate of terbutryne gave satisfactory control of broad-leaved weeds. No aphicide was necessary. Following the wet summer, the undersown grass on Dunholme had grown through the barley by harvest and considerably reduced yield.

The first of the cereals, Hobbit winter wheat, was harvested on 21 August. The harvest continued slowly as some crops ripened late and the weather was unfavourable. It finished on 18 September. Moisture content of the grain ranged from 15–23%.

TABLE 1

Cereal crops on Broom's Barn Farm and their yield

	ha		Yield ($t\ ha^{-1}$ at 85% DM)
Hackthorn	3·93	Hobbit wheat (2nd)	6·27
New Piece	5·22	Hobbit wheat (2nd)	5·80
Marl Pit			
West end	1·72	Maris Huntsman wheat (1st)	5·53
East end	1·72	Maris Huntsman wheat (3rd)	4·76
Little Lane	8·78	Maris Huntsman wheat (1st)	6·19
The Holt	4·24	Maris Huntsman wheat (1st)	5·43
Flint Ridge	8·82	Ark Royal barley	4·86
Dunholme	8·97	Ark Royal barley (undersown)	3·55
Windbreak	2·20	Ark Royal barley	4·98

Fodder crops. The ryegrass ley on White Patch was given compound fertiliser in two spring applications and cut for silage during the first week of June. It was immediately top-dressed with N and irrigated. Hay was made in mid-July.

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Sugar beet. All the fertiliser except nitrogen, which was broadcast between the rows at drilling, was ploughed down in autumn 1977. Seedbeds were easy to prepare and the first sowing was made on 10 March; very wet conditions delayed further sowings until April. Apart from small areas intended for late sowing trials, the remainder was drilled by the end of April. All except the variety trials was sown with pelleted monogerm seed; 80% spaced at 16 cm or more. Most of the crop was band sprayed with chloridazon (formerly pyrazone). Experiments with non-standard row widths were sprayed overall. Subsequent weed control was partly by hoeing and partly by post-emergence sprays. A granular insecticide was applied to 75% of the crop at drilling and, other than on virus and time of spraying trials, no additional aphicide was used. No irrigation was applied.

Due to late opening of the factory harvesting did not start until 16 October. Initially conditions were dry but gradually improved allowing the heavier land and part of the light land to be cleared by mid-November. Snow and frost delayed further harvesting until the first week of December, when rain stopped work for a further week. Lifting was completed by 21 December but deliveries to the factory continued beyond the end of the year. Yields averaged 38·75 t clean roots ha^{-1} at an average sugar content of 17·42% ranging from 15·9–19·3%. Mean dirt and top tares were 10 and 5%. Nationally yields averaged 34·72 t ha^{-1} at 16·75% sugar content.

Livestock. During October 1977, 85 cross-bred heifers were bought and fattened in the yards on *ad lib* silage and a restricted concentrate rate of 50% rolled barley and 50% pulp nuts. They were sold between late March and mid-June. The yards were restocked with 71 cross-bred heifers in November. (Golding)

Staff and Visitors

During the year Susan M. Allen, W. F. Cormack and R. E. Green resigned; P. V. Biscoe, Mrs. Helen G. Smith, Patricia E. Preston and A. W. Glauert (ARC Research Student) were appointed. R. E. Green was awarded the Ph.D. degree by Cambridge University and R. F. Farley was awarded the M.Phil. degree by the University of East Anglia. D. Drane and E. G. Harrod retired from the farm staff in December.

A. P. Draycott and R. K. Scott contributed to the 41st Winter Congress of the Institut International de Recherches Betteravières (IIRB) in Brussels in February. The meeting was also attended by R. A. Dunning (Chairman of the Pests and Diseases Study Group) and G. L. Maughan (Chairman of the Spring Mechanisation Study Sub-group) who presented reports on the work of their groups. R. A. Dunning also attended meetings of the IIRB Scientific Advisory Committee in Brussels in February, May and October. R. K. Scott and K. W. Jaggard attended the IIRB Summer Tour in Holland and extended their visit to see research groups in Wageningen and Lelystad. In September R. K. Scott visited the Swedish Sugar Co., and Weibull Seed Co. P. C. Longden attended the IIRB Genetics and Breeding Study Group meeting in Sweden and also studied beet seed growing in the Beauce region of France at the invitation of Delaplanque et Cie. G. D. Heathcote contributed to the 3rd International Congress of Plant Pathology in Munich, which was also attended by W. J. Byford. D. A. Cooke contributed to the 14th Symposium of The European Society of Nematologists held as a section of the Congress and to a meeting of sugar-beet nematologists held immediately after the Congress chaired by R. A. Dunning. A. P. Draycott (in October) and B. J. Hutchison (in January) visited Madrid to discuss magnesium fertiliser problems with Magnesitas de Rubian. R. A. Dunning spent 10 days in September in Zaragoza lecturing on sugar-beet pests on a course organised by the OECD.

Four scientific meetings were held at Broom's Barn in 1978 and a 2-day training course

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in pests, diseases, fertilisers and agronomy for sugar factory fieldmen was held in September. During the autumn six British Sugar trainee fieldmen spent 2-week periods at Broom's Barn getting experience of methods of field experimentation. At the end of February Broom's Barn provided the venue and many of the speakers for a 2-day course on sugar beet organised by ADAS. Broom's Barn was also the venue for the Sugar Beet Research & Education Committee (SBREC) 'Open' and 'Closed' meetings held in July. The Station contributed exhibits of current research to the Spring and Autumn Sugar-Beet Demonstrations at Eye and the Open Days of the Arthur Rickwood E.H.F. W. J. Byford, A. P. Draycott, R. A. Dunning, K. W. Jaggard and G. L. Maughan joined a Working Party with the British Sugar Corporation which reviewed the Corporation's programme of crop reporting and field surveys, some of which are made in collaboration with Broom's Barn, and prepared and introduced new procedures integrating into a single scheme a number of surveys that had previously been conducted separately; A. P. Draycott acted as Technical Secretary to the Working Party. P. C. Longden became Technical Co-ordinator of the SBREC weed beet work and also organised a tour for research workers and advisers of fields badly infested with weed beet.

Dr. K. Bürcky of the Institut für Zuckerrübenforschung, Göttingen, Germany, worked with the Crop Productivity Group during July and August and again in October, and Dr. M. Montanari of the Istituto di Agronomia, University of Bologna, worked for 10 weeks on seed production. Parties who visited us during the year included east European Plant Protection specialists; French sugar-beet seed producers; farmers from the Côte d'Or of France and the King's Lynn sugar factory area; members of the Association of Applied Biologists; and students from Holland and the Universities of Newcastle, East Anglia and Wales (Bangor).

W. J. Byford assisted in compiling this report.

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