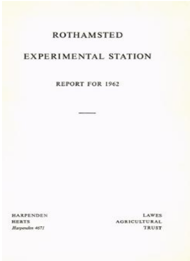
ROTHAMSTED RESEARCH

Report for 1962


ROTHAMSTED
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Botany

Rothamsted Research

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BOTANY DEPARTMENT

D. J. WATSON

G. J. Leach, holder of a scholarship from the Ministry of Agriculture, Fisheries and Food, was awarded a Ph.D. degree of the University of Reading. He left in May to take a post at the Waite Agricultural Research Institute, Adelaide. Audrey F. Evans was awarded the B.Sc. degree of the University of London. P. W. Dyson, one of the first group of Potato Marketing Board scholars, arrived in October to work on the nutrition of the potato plant. Two overseas visitors arrived in November—Mr. Ken-ichi Hayashi, from the National Institute of Agricultural Science, Japan, and Mr. J. C. S. Allison, from the University College of Rhodesia and Nyasaland.

D. J. Watson was invited by the Australian Academy of Science to contribute to the international symposium on Environmental Control of Plant Growth held in Canberra in August, on the occasion of the official opening of the phytotron CERES, in the Division of Plant Industry of the Commonwealth Scientific and Industrial Research Organisation. He also visited other research centres in Australia, Ceylon and New Zealand.

At long last the three controlled-environment rooms in the West Building were completed, and the first plants were grown in them in November. The rooms will be used to study effects of climatic factors on growth in dry weight of crop plants, to help in interpreting experiments on growth in field conditions.

Physiology of Growth and Yield

Competition between rows of a wheat crop. When winter wheat was sown in rows spaced 21 in. apart, in comparison with the normal 7-in. spacing (*Rep. Rothamst. exp. Sta.* for 1960, p. 94), the dry weights of grain per metre of widely spaced and closely spaced rows, and of edge-rows with a wide spacing on one side and a narrow spacing on the other, were closely related to their leaf area durations per metre of row after ear emergence (*D*). There was no significant effect of spacing on the grain leaf ratio (grain dry weight/*D*). This ratio is taken as a measure of the photosynthetic efficiency of the leaves after ear emergence (5.8), although its interpretation in this sense is complicated by photosynthesis in the ears. The results therefore suggest that in the period after ear emergence when the grains are filling there is little, if any, competition for light between normally spaced rows of wheat, i.e., there is then not enough mutual shading between rows to affect the rate of photosynthesis of the green parts, presumably because at this stage they consist mainly of the flag leaf and its sheath, the peduncle and the ear, all of which are well exposed at the top of the shoot. If this is correct grain yield might be increased by closer spacing of rows, provided this could be accomplished without a compensating decrease of *D*.

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Competition between rows after ear emergence was further studied in an experiment in 1961, in which spring wheat sown in rows 7 in. apart received uniform treatment until ears began to emerge, and then the row spacing was varied on different plots by leaving the crop intact, or removing alternate rows to give 14-in. spacing, or two out of every three rows to give 21-in. spacing. Half the plots were harvested after 2 weeks, and the rest after 8 weeks when the crop was ripe.

The first harvest was intended to be made before the variations in spacing could affect leaf area, so that any differences found in dry weight would directly indicate differences in photosynthetic rate. However, differences in leaf area had already developed, because on unthinned plots leaf area decreased throughout the post-emergence period, while on the thinned plots there was initially a small increase; more nitrogen per metre of row was absorbed on the thinned than on the unthinned plots, and this probably explains the delayed senescence of the leaves. Subsequently, for reasons that are not understood, leaf area per metre of row of the widest spacing decreased more rapidly than those of the other spacings. As a result of these changes, D per metre of row between emergence and final harvest was most for the 14-in. spacing, and least for the 21-in. spacing. The yield of grain per metre was correspondingly largest for the 14-in. spacing, but it was a little greater for 21-in. than 7-in. spacing, and there was a significant increase in grain leaf ratio with increase in row spacing. The results show that in the period after ear emergence there was some competition for light between rows spaced at 7 in., but its effect on the rate of photosynthesis was relatively much less than was found in the vegetative phase in the 1960 experiment.

Closer spacing of rows, with corresponding increase in nutrient and water supply to maintain post-emergence leaf area per row, might therefore give increased grain yield, by increasing the size of the photosynthetic system (leaf area index and the amount of photosynthetic tissue in ears) with little decrease in its efficiency (grain leaf ratio). However, the more severe mutual shading that occurs in the vegetative phase may restrict shoot growth, and so set a limit to increase in leaf area index by closer row spacing.

The effect of still closer row spacing (3 in. compared with 6 in.) on grain yield of wheat, and its interactions with time and rate of nitrogen supply, was studied on the Garden Plots, but severe damage by birds, in spite of precautions that had prevented damage in previous years, greatly complicated the analysis of the results. (Watson, Thorne and French)

Growth of sugar beet on different soils. The comparative study of growth and yield of the sugar-beet crop on widely contrasting soils (*Rep. Rothamst. exp. Sta.* for 1961, p. 91) was continued for a third season at the same six centres as in 1961. Three of the centres were common to all three seasons. The differences in total dry matter yield between sites and years, and the effects of nitrogenous fertiliser, were closely associated with differences in leaf area index (L), and net assimilation rate (E) was inversely related to yield and L. E decreased more rapidly with increase in L in 1961 than in

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1960, or in previous Rothamsted experiments, implying that optimal L was smaller in 1961.

In 1961, but not in 1960, the ratio of root: total dry weight varied between sites and was increased by nitrogenous fertiliser. In both seasons plants at high-yielding centres had a larger ratio of water to dry weight than at low-yielding centres; this probably reflects differences in water availability, though it may be attributable partly to nitrogen supply.

Analyses of the mineral nutrient content of the 1960 and 1961 samples show that nitrogen uptake was closely correlated with total dry weight yield, and at the high-yielding centres the ratio of nitrogen to dry matter was usually more than elsewhere. In 1960 nitrogen was lost from the plants in late October; at Stamford on a limestone soil the leaves, and at Rothamsted the roots and crowns also, contained less nitrogen in November than earlier in the year. There was no such loss in 1961. In both seasons potassium and sodium were lost from the plants in October, except on the silt soil at Holbeach, suggesting that these elements were more abundant in the silt than in the other soils, or that for some other reason senescence was delayed on this soil. In 1961 at Stamford and Rothamsted, where nitrogen was limiting, nitrogenous fertiliser increased uptake of potassium and sodium and decreased uptake of phosphorus. (Goodman)

Effects of soil-water deficit on plant growth. Owen (*New Phytol.* (1958), **57**, 318–325) found that repeatedly withholding water for short periods from sugar beet growing in pots had little or no effect on dry weight or leaf area. Other workers with different species have found much larger effects. Owen's pots were watered until they drained, and the drainings were collected and returned to the pots at the next watering time, which gave a larger maximum soil-water content than the more usual practice of watering a closed container to a weight corresponding to field capacity. These different techniques were compared in an experiment on sugar beet grown in Mitscherlich pots containing a mixture of soil, sand and peat with a water content at field capacity of about 30% of dry weight, and at the permanent wilting point of about 11%. The plants were subjected to repeated drought cycles, defined by the minimum and maximum soil-water contents. The pots were weighed daily, and watered when 5, 60 or 95% of the available water (between field capacity and permanent wilting percentage) had been transpired, or after the plants had wilted for 2 days. Watering was done by (1) adding enough water to give free drainage, repeated three times with intervals for drainage, (2) as (1) but with only one application of water, or (3) by adding water to raise the water content to 30%, or (4) to 25%. With treatments (3) and (4) drainage was prevented. The maximum soil-moisture content for (1), 41%, was consistently greater and more uniform than for (2), 38%, and both were above field capacity.

Leaf growth was measured during 3 weeks of treatment. The effects of differences in method of rewatering were small, and there were no interactions with severity of drought. Treatment (1) gave nearly twice as much leaf area as (4), but only a little more than (2) or (3). Watering after loss of 5 or 60% of available water gave the same leaf areas; after repeated loss of 95% available water the leaf area was decreased only to 83% of that of

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control plants watered after 5% loss, but wilting for 2 days decreased it to 56% of the controls. The difference between Owen's results and those of other workers evidently cannot be explained by the difference in method of watering; it probably means that sugar-beet plants are relatively insensitive to water stress provided they do not wilt.

The effect of varying the duration of drought cycles between the same maximum and minimum soil-water contents was investigated by growing sugar-beet plants in controlled environments with a 12-hour day and the same temperature régime (25° day, 15° night) but with different atmospheric humidities during the day (55 and 95% R.H.). The soil-water content fell from about 30 to 11% before rewatering. At 55% R.H. the rate of transpiration was about double that at 95% R.H., and the length of the drought period was halved to 16 instead of 35 days. Control plants were watered daily to maintain soil-water content close to field capacity.

As the soil-water content diminished during the drought cycle, the transpiration rate decreased and the leaves grew more slowly. Rewatering the plants restored the original transpiration rate and made the leaves grow faster than the controls, although not enough to catch up with them in total area. Although leaf growth was initially slower at 55% R.H., the difference was not maintained, and when the experiment ended after 4 weeks leaf area was the same at both humidities. The longer exposure to moisture stress with the lower transpiration rate may have been balanced by the greater stress produced with the higher transpiration rate. Two rates of potassium supply were compared; contrary to common belief, potassium supply did not affect the response to drought.

Experiments in the Dutch-light glasshouse tested whether recovery from drought by increase in relative leaf growth rate (R_L), and sometimes in net assimilation rate (E), above those of continuously irrigated plants depends on light intensity. Illumination was varied during the recovery period by covering part of each plot with a white cotton-cloth shade.

In 1961 the leaf area index (L) at the end of the drought period was about 2·5 on dry plots and 3·0 on irrigated plots. E was unaffected by drought, but R_L was less during drought and more after watering than in the continuously watered controls; the increase was less under shade. In 1962 L was varied by varying the spacing of plants and the time of planting; at the end of the drought period it was <2 on irrigated plots and <1 on dry plots. R_L was not increased during recovery from drought, but there was some evidence that E was increased on plots with close spacing, and that the increase was less under the shades. The results are inconclusive, but suggest that recovery depends on light intensity only when L is large enough to affect illumination within the crop by mutual shading of leaves. (Orchard)

Dependence of photosynthesis on growth.

Comparison of sugar beet and spinach beet. Sugar beet and spinach beet grown in pots in 1961 (*Rep. Rothamst. exp. Sta.* for 1961, p. 90) had nearly the same leaf areas, but sugar beet had more total dry weight and root dry weight than spinach beet, implying that sugar beet had the higher net assimilation rate (E). Possible explanations are either that the

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rate of photosynthesis of the leaves depends on the size of the sink for photosynthetic products, i.e., the storage root, or that sugar-beet leaves inherently have greater photosynthetic efficiency, and this determines the greater root growth. To distinguish between these alternatives, grafts were made between tops and roots of seedlings of sugar beet (Sharpe's Klein E) and spinach beet in all the four possible combinations, and the grafted plants were compared with intact sugar-beet and spinach-beet plants.

As in 1961, root dry weight and E of intact plants were greater for sugar beet than spinach beet, but spinach beet had more leaf area and top dry weight and only slightly less total dry weight than sugar beet. Self-grafts, of sugar-beet tops on sugar-beet roots or of spinach-beet tops on spinach-beet roots, behaved similarly to intact plants. Grafted plants with sugar-beet roots had greater E and root dry weight, slightly greater total dry weight, but less leaf area and dry weight of tops, than those with spinach-beet roots, irrespective of the type of top. Grafted plants with sugar-beet tops had greater E, total dry weight and root dry weight, but smaller leaf area, than those with spinach-beet tops. Thus, sugar-beet roots increased the rate of photosynthesis of both sugar-beet and spinach-beet leaves, but decreased top growth, presumably by providing a larger sink for photosynthetic products than spinach-beet roots. Also, sugar-beet leaves photosynthesised more than spinach-beet leaves, whichever sort of root they were supplying.

Sugar-beet tops or roots each increased E by about 25% compared with spinach-beet tops or roots, and when the more efficient tops and roots were combined, in intact plants or self-grafts of sugar beet, E was 60–75% greater than for comparable spinach-beet plants. (Thorne)

Photosynthesis of detached leaves. The net assimilation rate of detached primary leaves of dwarf French bean increases with increased growth of adventitious roots from the petioles (*Rep. Rothamst. exp. Sta.* for 1961, p. 90). To confirm this effect on the rate of photosynthesis, and to follow the change with time in more detail, CO_2 uptake by the lamina of rooted leaves in light was measured with an infra-red gas analyser. The rate of CO_2 absorption by successive samples taken at intervals from a group of comparable rooted leaves was measured for 1 or 2 days, and the dry weight of roots was then determined. The rate of photosynthesis increased with increase in root dry weight. Continuous measurements on rooted leaves showed that the rate of photosynthesis increased with time, but reached a steady value after a week or more, when the volume of culture solution restricted root growth. Removing the roots immediately slowed photosynthesis, but it increased again when new roots were formed.

In another experiment one of the pair of fully expanded primary leaves on a bean plant was removed and the petiole put in dilute culture solution to form roots, while the other leaf remained attached to the plant. At first detached leaves photosynthesised at less than half the rate of attached leaves, but the rate increased steadily as roots formed, while that of the comparable attached leaves decreased. Consequently, the rate of photosynthesis of detached and attached leaves became equal after about 7 days, and afterwards was faster for the detached leaves. Rooted, detached leaves

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have previously been shown to survive longer and become senescent more slowly than comparable attached leaves (*Rep. Rothamst. exp. Sta.* for 1960, p. 102). These results support the conclusion from previous work (5.2) that the rate of photosynthesis depends on use of the photosynthetic products by growing organs. (Humphries and Thorne)

Photosynthesis of ears of wheat. In a field experiment (*Rep. Rothamst. exp. Sta.* for 1961, p. 86) Jufy I spring wheat produced 45% more grain than Atle, although the two varieties had similar leaf area durations after ear emergence. The additional yield of Jufy I was therefore attributed to more photosynthesis by its ears, and not by its leaves. This explanation was tested in 1962 by measuring directly the rates of apparent photosynthesis of ears and of shoots (i.e., flag-leaf lamina and sheath, and peduncle) selected at random on small plots of the two varieties growing on a garden soil near the laboratory. Ears or shoots were enclosed separately in glass tubes, through which air was aspirated, and the change in CO_2 concentration in the air stream was measured with an infra-red gas analyser.

In these conditions Jufy I gave only 6% more grain yield than Atle, and the rates of photosynthesis of the two varieties were not significantly different, so the experiment did not confirm the interpretation of the 1961 results. Moreover, the rates differed greatly from those in a similar experiment on barley (*Rep. Rothamst. exp. Sta.* for 1961, p. 88). Immediately after anthesis, wheat ears absorbed less than 0·1 mg CO_2/hour during the day, compared with about 1 mg/hour for barley ears, and later there was a net output of CO_2 in daylight as well as at night. Apparent photosynthesis of the shoots, about 3·5 mg/hour at anthesis decreasing to zero at maturity, was faster than for the smaller shoots of barley (about 1 mg/hour at anthesis), but the rates per cm^2 of leaf area were similar for the two species.

If the rate of photosynthesis of wheat ears were always as small as in this experiment differences in ear photosynthesis could not cause appreciable differences in grain yield. Evidently further work is necessary to determine the cause of the difference in yield between Atle and Jufy I. (Thorne)

Effects of various growth regulators

CCC. The compound 2-chloroethyltrimethylammonium chloride (chlorocholine chloride, CCC) was first described as a growth retardant. Some of its effects on growth are opposite to those of gibberellic acid, e.g. it decreases stem extension, but in some conditions it has growth-promoting properties. Thus, CCC applied to mustard plants growing in the glasshouse increased their total leaf area, by increasing the number of leaves on lateral branches (*Rep. Rothamst. exp. Sta.* for 1961, p. 94). In experiments on mustard plants grown in a controlled environment lit by fluorescent tubes the total leaf area was still increased, although lateral branches were few, by increasing the size of leaves on the main stem. Although mustard is a long-day plant, its leaf area was greater in 8-hour than in 16-hour days. The larger leaf areas induced by CCC or by short days were both associated with decreased stem elongation. As before, CCC decreased net assimilation rate of the mustard plants.

The effect of CCC on the composition of plants was also studied.

https://doi.org/10.23637/ERADOC-1-95

Tobacco plants were grown in nutrient solution without CCC, or with CCC present continuously or in alternate fortnights. Continuous application nearly doubled the nitrogen per cent of dry matter in stems, and increased that of leaves by one-third. Nitrogen per leaf was increased, but the total nitrogen content of the plant was not; CCC did not increase nitrogen uptake, but altered its distribution in the plant. It also increased chlorophyll content and dry weight per unit area of leaf lamina estimated in the 15th leaf.

A 10^{-2} *M* solution of CCC applied to soil containing germinated sunflower seeds increased the area of leaves at the first three nodes, and shortened the internodes. It also increased the dry matter, total nitrogen and protein contents of the leaves; the protein content was increased by 20%. Thus stem shortening by CCC is accompanied by increased dry weight and growth of main stem leaves or lateral shoots, presumably because the distribution of assimilate between the different plant parts is changed, and with less used in stem growth there is more for other organs.

CCC also increases tillering of wheat, and an experiment was done to find what effect this has on grain yield. Wheat (var. Koga II) was grown in pots, and at the two-leaf stage, 18 days after sowing, CCC was applied to the soil at four rates, repeated on half the treated pots after 17 days. The largest rate (200 ml of 10^{-2} *M*) increased the maximum number of shoots per plant from 9 to 11, and the number of ripe ears from 7·7 to 8·9, but this was more than offset by effects on ear size and grains per ear, and the yield of grain per pot was decreased from 29·4 to 12·9. The length and weight of straw was also decreased by CCC, and ear emergence was delayed by about a week. (Humphries)

Benzyl adenine. Benzyl adenine is a synthetic kinin that is said to retard protein breakdown in detached leaves in the same way as the chemically related kinetin. Cereal grain yield depends on leaf-area duration after ear emergence, so delaying leaf senescence with benzyl adenine might increase yield. This possibility was tested by spraying the leaves of Koga II wheat, grown in soil in pots, with a solution of 10 mg benzyl adenine per litre either four or eight times on alternate days after the first ears emerged. Benzyl adenine did not prolong the life of attached wheat leaves or affect the yield of grain. (Humphries)

Betaine. The possibility was studied that betaine, which occurs in sugar-beet tissues and is closely related to CCC, may act as a growth regulator. Dilute solutions of betaine stimulate growth of sections of wheat coleoptiles, but more concentrated solutions are inhibitory. Also, sugar-beet seed balls, and aqueous extracts of them, inhibit germination and growth of other seeds.

Aqueous extracts of sugar-beet seed balls, leaves or roots were partitioned with ethyl acetate. Chromatograms of the aqueous fractions of extracts were treated with iodine vapour and a region with the same Rf as betaine produced a red-brown spot, similar to that given by betaine. This region decreased the growth of disks cut from primary leaves of etiolated dwarf French bean plants; it also promoted growth of wheat coleoptile sections and cress hypocotyls when the chromatograms were

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made with small amounts of the aqueous fraction, but large amounts of extract inhibited growth of these tissues. These effects resemble those of betaine solutions. Ethyl acetate fractions of the same extracts had no effect on growth of bean-leaf disks or cress seedlings, but inhibited germination of cress seeds, whereas betaine solutions did not. Thus, the germination inhibitor in sugar-beet tissue is not betaine but an ethyl-acetate soluble substance. Aqueous extracts contain another substance, presumably betaine, that stimulates or inhibits growth of coleoptile sections or hypocotyls, depending on its concentration, and decreases leaf expansion. Leaf expansion was similarly inhibited by aqueous fractions of extracts of dwarf French bean leaves. (Wheeler)

Endogenous growth substances in leaves and cotyledons. Bioassay of leaf extracts estimates their total content of free growth-substances when they are extracted, some of which may be transported to the stem and other leaves and influence their growth. Methods were sought to assay growth-substance moving from primary leaves of French bean. Exudates from petioles dipping into water or sucrose solution did not influence the growth of leaf disks floating on the solution, nor did leaves grafted on to epicotyls of pea seedlings influence internode extension. However, grafting young, still expanding, leaves on to hypocotyls of dwarf French bean seedlings increased the growth of the primary leaves of the stock plants, but grafting older leaves diminished it. The maximum increase in leaf size of the stock plants, indicating maximum transportable growth-substance content of the grafted leaves, occurred contemporaneously with the maximum gibberellin content of the primary leaves reported earlier (*Rep. Rothamst. exp. Sta.* for 1959, p. 74; Wheeler, A. W. (1960) *J. exp. Bot.* **11**, 217–226).

Early removal of the cotyledons from dwarf French bean seedlings checks growth of the primary leaves (*Rep. Rothamst. exp. Sta.* for 1960, p. 100), presumably because the cotyledons supply growth substances and nutrients to the leaves. The nature of these substances was investigated by treating plants from which cotyledons had been removed with solutions, either in cotton-wool surrounding the cotyledonary node or injected into the hypocotyl by a hypodermic syringe. Gibberellic acid, indolyl-3-acetic acid, sucrose, ascorbic acid, aqueous extracts of ungerminated seeds and of cotyledons of seedlings and young expanding primary leaves grafted on to the hypocotyl, all failed to increase growth of the primary leaves of the stock. Concentrated solutions of ascorbic acid checked primary leaf growth. However, the shortening of internodes by excision of cotyledons was counteracted by gibberellic acid. (Wheeler)

Measurement of leaf area. Two new optical planimeters were constructed. Both have a uniformly illuminated window on which the leaves are placed, and measure leaf area from the amount of light the leaves intercept. In the first the light beam is collimated by a parabolic mirror of 18 in. diameter, and is focused on a photocell by a similar mirror. Light that penetrates the leaf is scattered and does not reach the photocell, and the system is also very insensitive to stray light, so that the window need not be screened during measurements. The second is a portable instrument

https://doi.org/10.23637/ERADOC-1-95

intended for measurements on intact plants. It also uses a collimated light beam from a lens system. The incident beam, 1 in. square, is dissected by a stepped mirror system to illuminate a window 4½ in. square. The transmitted light is collected by a similar mirror system and is focused on a photocell. An optical path of nearly 3 ft is accommodated in a box only 9½ in. × 7½ in. × 5 in. Discrimination against stray light is good, of the order of several hundred times. (Orchard)

Weed Studies

Wild oats. Chitted seeds of wild oats from Australia, Iraq and Israel planted in pots on 23 January in 1960 and 1961 flowered earlier than British specimens (*Rep. Rothamst. exp. Sta.* for 1961, p. 81). To test whether these differences depend on the date of sowing, chitted seeds of *Avena fatua*, type fA, and *A. ludoviciana*, type 1A, from Australia, Iraq and Britain, and two sorts of *A. sterilis* from Israel were sown in pots in a cool glasshouse in December 1961, or February or April 1962. With all sowing dates, the two British sorts were the last to flower. The date of 50% panicle emergence was consistently later with later sowing, but late sowing shortened the period between sowing and flowering; sowing 4 months later delayed flowering of each sort of seed by only about 1 month. The interval between dates of 50% panicle emergence of the British and of the foreign fA was 3–4 weeks for December and April sowings, but only 1–2 weeks for the February sowing. The intervals between flowering of British and foreign 1A, and between flowering of the British sorts and *A. sterilis*, were similar for the three sowing dates.

The earliest sowing produced the tallest plants with most seeds; the plants had fewer panicles, but with more seeds in each, than those from later sowings. Plants from the December sowing of fA and 1A from Australia and Iraq had three or four shoots and were taller than 60 cm when their first panicles emerged in early May, whereas in corresponding plants of the April sowing the first panicles emerged when the plants had only one or two shoots and were shorter than 30 cm; emergence continued as tillers were produced, suggesting that flowering was induced in the long days of late May almost regardless of the amount of vegetative growth. These results would be expected if flowering is determined by the seasonal cycle in photoperiod and temperature, and if morphologically similar types from different countries differ in their relations to the external factors that determine flowering. Full analysis of these relations would require experiments in controlled environments.

Further work was done on effects of storage conditions on germination of *A. fatua*, to extend the results obtained in the international experiment already reported (*Rep. Rothamst. exp. Sta.* for 1961, p. 82). Seeds of *A. fatua* from a batch collected in July 1961, of which 97% were viable and 87% dormant, were stored dry in incubators at 4°, 7°, 16° and 21° for 5 months, and then either placed out of doors on the surface of the soil for varying periods up to 4 months, in January–April 1962, or held in the incubators.

Dry storage for 5 months at 16° decreased the dormancy of seeds to 50%; higher or lower temperatures had less effect. After 1 month outdoors differences in dormancy resulting from different previous storage tempera-

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tures had disappeared, and 70–75% of seeds of all treatments were then dormant. After 2 or 3 months more outdoors dormant seeds were only 30%, but the proportion increased in the next month as the temperature rose, except of seeds previously stored at 16°, whose proportion of dormant ones continued to decrease. After 4 months outdoors the percentage of dormant seeds was less than in samples stored dry for 9 months. These results apply only to one batch of seeds, and may not be true of others, but they show that the sequence of temperature and humidity during storage can profoundly affect dormancy. (Thurston)

Black grass (*Alopecurus myosuroides*). The behaviour of *Alopecurus myosuroides* on Broadbalk in 1961 (*Rep. Rothamst. exp. Sta.* for 1961, p. 83) suggested that germination was inhibited by the very wet soil during autumn 1960. The effect of waterlogged soil on germination was tested in a pot experiment. Maintaining a water-table at or above the level of *Alopecurus* seeds sown 1 in. deep in Rothamsted soil induced dormancy. After 3 months of this treatment free drainage alone scarcely increased germination, but when combined with cultivation of the soil to just below the level of the seeds as many seeds germinated as had done previously in pots with free drainage from the start. A water-table 3 in. below the seeds did not induce dormancy, but fewer seedlings reached the surface of the soil than in the free-drainage pots. Conditions in this experiment were unfavourable to emergence of seedlings, as the maximum was 11%, compared with 80% viability in a laboratory test. Seedlings from small seeds, like those of black grass, possibly have difficulty in penetrating 1 in. of wet clay soil. (Thurston)

Broadbalk weeds. Counts of viable weed seeds in soil samples from Section Ia, where herbicides have been used annually since 1957, showed that no species has yet been eliminated. The herbicides used hitherto are effective only against dicotyledons; perennial grasses, chiefly *Agrostis stolonifera* (creeping bent grass) and *Poa trivialis* (rough-stalked meadow grass), are increasing slowly, as they are no longer restrained by the fallow cycle used on the rest of the field.

Soil samples for enumerating the weed-seed population were taken from selected plots of Section V, half of which will, in future, be treated with herbicides without fallow, like Section Ia. Weeds are more prevalent on Section V than elsewhere, so this change should provide a useful test of the possibility of weed control in continuous wheat by herbicides.

The visual scoring of weed infestation used on Broadbalk since 1930 was calibrated by determining numbers and dry weight per unit area of different species on areas previously scored in different grades. As found with visual rating of other size attributes, the logarithms of plant number per unit area were linearly related to the grading; unit increase in grade represented a 2½ to 3-fold increase in plant number. The relation between grade and dry weight per unit area was more complex, possibly because, with dense infestations, competition between individuals of the same species decreases the weight per plant, and this effect may not be correctly assessed in visual scoring.

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In drilling Broadbalk and other cereal experiments, occasional drill rows are omitted, giving wide spacings to guide the combine at harvest. Samples taken in July from unlodged plots showed more and larger plants of most weed species per unit area in the wide than the normal row spacings. *Odontites verna* (red Bartsia), a semi-parasite of wheat, was an exception; there were 30% fewer plants of this species per unit area in wide row-spacings than in normal ones, presumably because it is favoured by proximity to wheat plants. (Thurston)

Effect of sowing date on competition of weeds with a crop. If the spring flush of weed germination is determined primarily by the season and is independent of the time of early cultivations, as it appears to be, earlier sowing should favour crops in competition with weeds by increasing the interval between emergence of crop and weeds. To test this, kale was sown on 23 March, 24 April or 14 May on a weedy site on the Garden Plots, where each sowing was preceded by a shallow cultivation. Three treatments were applied to each plot—no weeding, hoeing between rows or clean weeding. All sowings were eventually thinned to 4-in. spacing, in rows 18 in. apart. At harvest at the end of September total fresh and dry weight yields of kale and of weeds were recorded.

The mean fresh weight of kale on weed-free subplots (22·7 tons/acre) was unaffected by sowing date. Weeds remaining in the rows, on plots weeded only between the rows, decreased the fresh weight of crop by 21, 15 and 7% for the first, second and third sowings respectively, and those on the unweeded plots did so by 60, 32 and 40%. Dry weight yields gave a similar picture. These results, almost the opposite of what the hypothesis predicted, were probably determined by the fact that the cultivations before the second or third sowings killed about 80% of the seedlings of *Atriplex patula* (orache) and 65% of *Chenopodium album* (fat hen), which were the chief weeds. Another contributory factor was a cold period after the first sowing, which prevented the kale growing rapidly before the weeds emerged at about the time of the second sowing. (Welbank and Witts)

Relation of crop yield to density of weed infestation. Attempts to relate crop yield to the numbers of each weed species present when the crops were sprayed with herbicides had limited success (*Rep. Rothamst. exp. Sta.* for 1959, p. 83; for 1960, p. 104; for 1961, p. 83). An experiment was therefore done to see whether more useful information could be obtained by estimating weights of weeds per unit area at spraying time instead of numbers of seedlings. It seemed possible that the total dry weight of weeds might be a suitable measure of the combined competitive effects of all weed species present, and also allow for differences in development of the weeds at different sites.

Forty small plots were marked out at sites differing widely in weed density in a field of barley. One half of each plot was covered by a plastic sheet while the field was sprayed with herbicide (MCPA/dichlorprop) and one subplot in each half was hand-weeded. The weight of weeds removed was taken as an estimate of the quantity on the unweeded subplot. Weeds were sorted into species, counted, dried and weighed. The principal

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species were *Atriplex patula* (orache), *Polygonum aviculare* agg. (knotgrass) and *P. convolvulus* (black bindweed), with *Stellaria media* (chickweed) and *Matricaria* sp. (mayweed) less frequent. The crop was cut by hand when ripe, and grain and straw dry weights recorded.

Unfortunately, the crop became very patchy in June, possibly because of uneven fertiliser distribution. This patchiness persisted until harvest and grossly increased experimental errors, by introducing more variability that was independent of weed infestation. Preliminary examination of the results suggested that the grain yield was inversely related to dry weights per plot of *Atriplex* and perhaps of *Polygonum* spp., but a regression analysis did not substantiate this.

On hand-weeded plots the mean effect of herbicide spray was to decrease grain yield by about 9%, and on unsprayed plots hand-weeding increased grain yield by 7%; both effects were highly significant. Consequently, there was no gain from applying herbicide to unweeded plots. (Welbank and Witts)

Competition for light and nitrogen from weeds of different habit. A species that produces deep shade may have less effect on a competitor by restricting its nitrogen supply than one that produces little shade, because the nitrogen requirement of the competitor may be decreased by shading. If so, the effect on a competitor of a species producing deep shade should depend less on nitrogen supply than that of a species producing little shade. This idea was tested in an experiment on the competitive effects of *Atriplex patula* (orache) and *Chenopodium album* (fat hen) on thousand-headed kale, with three levels of nitrogen supply and in two light intensities. The weeds were chosen because they differ in mature habit, but are nearly related taxonomically and have seeds and seedlings of similar size.

Kale plants 5 weeks old were transplanted into pots of soil in which *Atriplex* or *Chenopodium* had been planted 10 weeks before and into similar pots without weeds. The different amounts of N, with uniform P and K, were applied at transplanting, and light intensity was varied by placing pots either in the open or under perforated zinc screens passing 40% of the incident light. There were also pots with weeds and no kale. Some kale and weed plants were harvested at the time of transplanting, and the rest 2 weeks later. The dry weights of the plant parts and the leaf area of kale were measured. Periodic measurements showed that *Chenopodium* decreased the light intensity at the level of the kale leaves by 30–40% and *Atriplex* by 5–10%; a greater difference than this had been hoped for. Soil temperature in pots under the screens was about 1° higher on overcast days, and 5° higher after several hours of bright sunshine, than in pots in the open. The effect of this complication is difficult to assess.

So far only data on dry weight and leaf area have been examined. Leaf area of kale was hardly affected by nitrogen in absence of weeds, but was decreased by both weeds, and the decreases were greater the smaller the N supply. Differences between the effects of the species and the effect of shading were not significant. However, total dry weight of kale was decreased by shading, and it was decreased more by *Chenopodium* than by *Atriplex* with the largest amount of N. There was no evidence that the

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competitive effect of *Chenopodium* was greater than that of *Atriplex* at the lower light intensity, nor that increase in N supply from the smallest to the intermediate rate diminished the competitive effect of *Chenopodium* less than that of *Atriplex*. The results may depend on the rather slight shading by *Chenopodium*, and the hypothesis might have been tested more effectively had the difference in shading between the species been enhanced by giving the plants more nitrogen at the time of sowing, to produce larger tops. (Welbank)

Competitive effects of *Agropyron repens* and *Agrostis gigantea*. In the 1961 experiment to compare the competitive effects on spring wheat of the two rhizomatous grass weeds *Agropyron repens* (couch grass) and *Agrostis gigantea* (common bent) (*Rep. Rothamst. exp. Sta.* for 1961, p. 85) the net assimilation rate (E) of *Agrostis* grown alone was consistently less than that of *Agropyron*, possibly because the more prostrate habit of *Agrostis* caused more mutual shading of its leaves. E of wheat was decreased by competition with *Agropyron*, but not with *Agrostis*. This also may reflect the difference in growth habit between the grasses; the more erect shoots of *Agropyron* probably caused more severe shading of wheat leaves.

Agrostis absorbed more nitrogen from soil without nitrogenous fertiliser than *Agropyron* did, and in these conditions the dry weight and grain yield of wheat was decreased more by competition with *Agrostis* than with *Agropyron*. When nitrogen was supplied at the time of sowing the two grasses took up similar amounts; nitrogen absorption by *Agropyron* was initially faster, but continued longer in *Agrostis*. Consequently, with this early nitrogen application the dry weight of wheat was at first decreased more by competition with *Agropyron* than with *Agrostis*, but the two grasses eventually had similar effects on yield of wheat grain. They also had similar effects on grain yield when nitrogen was applied 5 weeks after sowing, but the effects were greater than when nitrogen was given early.

The ability of *Agrostis* to absorb more nitrogen than *Agropyron* from nitrogen-deficient soils may partly account for its association with light soils. (Witts and Welbank)

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