Report for 1960

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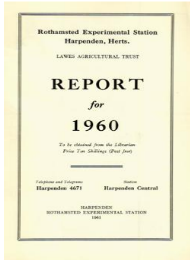
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Botany Department

D. J. Watson

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BOTANY DEPARTMENT

D. J. WATSON

P. J. Goodman was appointed to work on the physiology of the sugar-beet plant, with a grant provided by the Sugar Beet Research and Education Committee; he joined us in September. Mr. Jamaludin bin Lamin, of the Department of Agriculture, Malaya, came in August to spend a year here.

Joan M. Thurston and P. J. Welbank contributed to the second Symposium of the International Research Group for Weed Control, held at Oxford in April.

PHYSIOLOGY OF GROWTH

Competition within a wheat crop

The results of the experiment done in 1959 (*Rep. Rothamst. exp. Sta.* for 1959, p. 80) to compare the growth of winter wheat in normally spaced rows (7 inches), widely spaced rows (21 inches) and edge rows (normal spacing on one side, and wide on the other) were analysed. In April plants in the wide and edge rows had a higher nitrogen content and began to tiller more, and during May they developed a larger leaf area and dry weight, than those in normal rows. Up to the time when ears emerged, wide rows had no more leaf area than edge rows, but they produced more dry weight. The greater dry weight per metre of edge rows than of normal rows at the time of ear emergence was attributable mainly to greater leaf area, and partly to slightly higher net assimilation rate (E), but the greater dry weight per metre of wide rows than of edge rows was caused wholly by higher E. After ear emergence, leaf area per metre of wide rows decreased less rapidly than that of edge rows. The grain yield per metre of wide rows was about twice that of normal rows, and that of edge rows was about 60% more than of normal rows, so the additional yield did not compensate for wider spacing. The differences in grain yield between wide, edge and normal rows could be accounted for wholly by the differences between them in leaf area in the period between ear emergence and harvest, and there was no evidence that at this stage variation in spacing affected the photosynthetic efficiency of leaves or ears.

Our interpretation of these results is that, during vegetative growth, competition between rows was mainly for nutrients, particularly nitrogen, but also for light, especially at the wider spacings. The relation between E and leaf area per unit area of land (leaf area index, L) for the different spacings was similar to that previously found for barley when L was varied by differential thinning (*Rep. Rothamst. exp. Sta.* for 1957, p. 90), which supports the assumption that the differences in E were caused by differences in mutual shading, i.e., competition for light. The fall of E with increase in L implies that the rate of dry matter production during the vegetative phase would be maximal with L about 6, which is probably within the current range for wheat crops. The highest value of L in this experiment was just over 5.

After ear emergence there was apparently no competition for light, presumably because at this stage the photosynthetic tissue consists mainly of flag leaf and sheath, peduncle and ear, which are so fully exposed at the top of the plant that closer packing in narrow than in wide spacings does not much increase mutual shading. The absence of shading effects indicates that mutual shading may not limit grain yield until leaf area duration after ear emergence has much higher values than in this experiment.

Mature straws in wide and edge rows had a slightly greater mean diameter than in normal rows, and large straws from wide and edge rows required a greater force to bend and buckle them in the first or second internode than did straws of the same diameter from normal rows. These two effects may together account for the frequently observed tendency for edge rows of cereal plots to remain standing when the inner rows are lodged; in this experiment there was no lodging. (Watson and French.)

Effects of drought on plant growth

When sugar-beet crops were watered after a prolonged drought they temporarily grew faster than plants that were never subjected to water stress (*Rep. Rothamst. exp. Sta.* for 1959, p. 77). An experiment was done in 1960 to test whether barley responds like sugar beet to watering after drought, and, more generally, to study the effects of soil water deficit on the barley crop.

Proctor barley was grown in the Dutch-light glasshouse, with or without nitrogenous fertiliser applied at sowing. During the period of vegetative growth the following treatments were compared: (*a*) *minimal water stress* maintained by frequent watering, (*b*) *short drought*: no watering for 3 weeks after the three-leaf stage, (*c*) *long drought*: no watering for 5 weeks after the three-leaf stage. After the drought periods the crops were watered as for (*a*) until ear emergence. Each of these treatments was followed by a comparison of watering (*d*) with no watering (*e*) from ear emergence to maturity. On the plots that received nitrogenous fertiliser the plants tended to lodge, and the amount of water applied in treatment (*d*) had therefore to be restricted, so there was a water deficit at the end of the period and the difference between treatments (*d*) and (*e*) was smaller than was intended. Treatment (*c*) produced short, stiff, dark-green shoots that did not lodge.

During the drought periods of treatments (*b*) and (*c*), growth in dry weight and in shoot number was less than in the watered plants of treatment (*a*). The effect on dry matter accumulation was caused by decreased leaf growth; net assimilation rate was unaffected. When the drought was broken many new shoots were produced, some of which persisted to harvest. Thus, treatments (*b*) and (*c*) increased the total number of ears, although the proportion of fertile shoots was decreased; they also hastened ear emergence.

When watered after drought, plants of treatments (*b*) and (*c*) had higher relative growth rates than those of treatment (*a*), but, in contrast to the results for sugar beet, the spurt of growth was

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apparently caused wholly by delayed senescence of leaves increasing leaf area, as net assimilation rate was not increased.

The decrease in total dry weight caused by drought persisted until the ears were nearly ripe, and slightly depressed ear dry weight, but there were no significant effects on final yield. Treatments (*b*) and (*c*) delayed ripening of the ears, and their longer growth period may have helped to offset the effects of drought. Treatment (*e*) hastened ripening of the ears. Drought had more severe effects on the plants that received nitrogenous fertiliser, but they recovered more rapidly when watered.

An attempt was made to induce water stress in plants growing in culture solutions, by adding an inert solute to the solutions, to produce effects of drought with better control than is possible in soil cultures. The solutes usually employed, sucrose and mannitol, are readily decomposed by bacteria and can be absorbed by the plant, so they are useless for experiments lasting more than a few hours. Polyethylene glycol (PEG) was studied as a possible alternative. It exists in a range of molecular weights, is microbiologically stable and apparently does not penetrate potato slices. The response of dwarf French bean plants to PEG added to the culture solution depended on the molecular weights of PEG, the age of the plant and the environment, as well as on the concentration of PEG. An osmotic strength of 7 atmospheres usually caused wilting, followed by recovery of turgor that was slower with the larger molecules. Leaf growth rate and relative turgor were permanently decreased, and often leaves were scorched or became chlorotic. The recovery from wilting implies either that PEG entered the plant or that the plants became adapted to the increased water stress by metabolic changes. (Orchard.)

Growth on different soils

Hitherto, our studies by growth analysis of the physiological causes of variation in crop yield have been confined to Rothamsted farm, but the appointment of P. J. Goodman provided the opportunity to investigate variation in yield between different soils. Some preliminary work was done in 1960 to gain experience of the problems involved in doing growth analysis at widely separated places. Samples were taken at intervals from June to October from sugar-beet crops grown with or without nitrogenous fertiliser at four centres, including Rothamsted. At three of the four centres the yields were similar when nitrogenous fertiliser was applied, but they were more variable without nitrogen, suggesting that the main variable factor between the soils was nitrogen supply. Presumably there was no lack of water at any centre. The fourth centre yielded less, probably because of the small and irregular plant population. Variation in yield of dry matter between soils was closely correlated with leaf-area duration. Net assimilation rate was lower on the higher-yielding soils, presumably because it decreased with increase in leaf area through increased mutual shading of leaves. Apart from this there was no evidence of variation in photosynthetic rate between soils. The partition of dry matter between leaves and roots was similar at all the centres. (Goodman, Thorne and Watson.)

Photosynthesis at different heights in crops

The net assimilation rate (E) of sugar beet decreases much less rapidly than E of kale with increase in leaf area index (L), and this has been attributed to more uniform illumination of the foliage of sugar beet than of kale, associated with a different spatial arrangement of the leaves. If this explanation is correct, the rate of photosynthesis should change less with height in a sugar-beet crop than in a kale crop. An attempt to demonstrate this by comparing short-period increases in dry weight of crops from which varying fractions of the leaf area had been removed was inconclusive, because estimates of dry-matter increments of large plants are subject to relatively high errors (*Rep. Rothamst. exp. Sta.* for 1959, p. 81). A less laborious method of estimating the rate of photosynthesis at different heights in a crop, which should be more precise and adaptable and avoids confusing height variation with variation from differences in age of leaves, has therefore been developed. It depends on estimating the net assimilation rate of small plants (phytometers) placed within the crop. Sugar-beet seedlings proved the most suitable of several species tested, because their stems do not elongate. They are grown in solution culture, and for the field measurements are transferred to glass vessels provided with a reservoir of nutrient solution to last 1 week, and designed to minimise shading. The initial and final leaf area and dry weight of each phytometer are estimated or determined directly, and from these measurements net assimilation rate and other growth parameters can be calculated. Phytometer growth was measured at various times in crops of barley, kale, potatoes and sugar beet at various heights from 20 cm. above ground level to just above the crop, with eight replicates at each height. Calculations of E on the electronic computer are not yet complete. The vertical distribution of leaf area in the crop was also measured. In the later stages of growth of barley, kale and sugar beet there was very little leaf area within 20 cm. from the ground, but the potato crop had a large fraction of its leaf area in this zone throughout the growth period. So, except in the potato crop, the growth of the phytometers at 20 cm. from the ground can be used as an estimate of the interception of light by the foliage of the crop. It was least in barley; growth of phytometers at 20 cm. in barley in June and July was three-quarters of that above the crop; for kale at the end of June it was a half and in early August a quarter; for sugar beet in August it was a half. These results show that photosynthesis was still possible at the bottom of the crop profile until late in the growing season. (Leach.)

Photosynthesis by ears of Proctor and Plumage Archer barleys

Field crops of Proctor barley consistently yield more than Plumage Archer, and the difference has been attributed to more photosynthesis by the ears of Proctor than of Plumage Archer. Previous experiments to test this by measuring the effect on yield of shading ears to prevent them photosynthesising were done on plants grown in pots, but in these conditions the two varieties gave similar yields; the experiments were therefore repeated on field crops.

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Newly emerged ears of the two varieties were selected at random, covered with opaque nylon or cotton fabric shades, and their yields compared with those of unshaded shoots. Shading decreased grain yield per ear by 39% for Proctor and by only 15% for Plumage Archer. It decreased the 1,000-grain weights of both varieties by about 18%. The number of grains per ear of Proctor but not Plumage Archer was decreased by shading, although both varieties were covered when the ears were almost fully emerged; previously, shading at this stage had negligible effects on grain number. Even if there were no effect on grain number, and photosynthesis per ear were similar for the two varieties, the contribution of ear photosynthesis to grain yield per acre would still be greater for Proctor, because it had 70% more ears per acre than Plumage Archer.

Previous experiments showed that ear : shoot weight ratio was greater for Plumage Archer at ear emergence, but at maturity it was greater for Proctor, and this reversal occurred in both shaded and unshaded shoots (*Rep. Rothamst. exp. Sta.* for 1959, p. 79). In a pot experiment in 1960 the reversal of the varietal difference in ear : shoot dry-weight ratio between ear emergence and maturity depended mainly on the greater relative growth rate of Proctor ears, especially when shaded, but also the decrease in dry weight of shoot was slightly greater for Proctor than for Plumage Archer. As in 1959, leaves of Proctor survived longer than those of Plumage Archer and, when the ears were shaded, appeared to be more efficient in producing dry matter. Shading ears had similar effects in both varieties: it decreased ear weight by 33%, and stem weight by 8%, and increased leaf-area duration between emergence and maturity by 8%.

The CO_2 uptake by photosynthesis and loss by respiration of shoots similar to those of the ear-shading experiment were measured directly with an infra-red gas analyser. The rates per ear of apparent photosynthesis during the day and of respiration at night never differed significantly between Proctor and Plumage Archer. They changed little between 10 and 24 days after ear emergence, but fell considerably after 35 days, when some green colour still remained in the awns. The rate of apparent photosynthesis per shoot of the flag leaf and sheath and peduncle, the parts of the shoot that supply assimilate to the ear, was similar to that of the ear 10 days after emergence, 60% of the ear rate at 24 days and negligible at 35 days. It was similar for the two varieties at 10 days, but later was slightly greater for Proctor, probably because the leaves yellowed more slowly than those of Plumage Archer. The respiration rates of the flag leaf and peduncle did not differ between varieties, and fell with age. Calculations from hourly rates of photosynthesis and respiration showed that photosynthesis by the ear contributed 30% of its final dry weight, made up of an increase of 45% from photosynthesis and a loss of 15% from respiration. Of the final ear weight 15% was present at emergence and 55% came from the shoot. Shoot photosynthesis provided more material for the grain than ear photosynthesis until 10 days after ear emergence, but by 24 days the relative importance of shoot and ear was reversed.

The rate of photosynthesis of the ear remained constant for most of the period between ear emergence and maturity, but that of the flag leaf and peduncle decreased, both per shoot and per unit area. Independent evidence that the rate of apparent photosynthesis of leaves falls with age was obtained from measurements on the seventh and eighth leaves of Proctor and Plumage Archer shoots made in artificial light during 40 days between full expansion and the start of senescence. The rate fell by 0·36 mg./dm.^{2}/day, 5% of the mean value. The photosynthesis rates of the two varieties were similar but the respiration rate per g. or per dm.^{2} was slightly greater for Proctor than for Plumage Archer. (Thorne.)

Interpretation of ear-shading experiments

Shading ears prevents photosynthesis, but presumably does not decrease respiration. Therefore, according to the direct measurements of photosynthesis, shading ears should decrease ear weight of barley by about 45%, but in numerous experiments the decrease was only 15–30%. Possible causes of this discrepancy are: (1) increased translocation from the shoot into shaded ears—shoots and roots of shaded plants sometimes lost more weight after ear emergence than those of unshaded plants; (2) increased photosynthesis by the leaves when ears are shaded—leaves often stay green longer on shaded than on unshaded shoots; (3) decreased ear respiration—shaded ears may lose less weight by respiration than unshaded ones because they are smaller, but this is unlikely, because respiration rates of unshaded ears at 10 and 24 days after emergence were similar although their weight increased from 0·4 to 0·9 g. Experimental estimates of (1) and (2) rarely accounted for all the differences between observed and expected effects of shading. Estimates of the relative importance of ear photosynthesis in different varieties made by shading ears are valid only if the causes of underestimation of photosynthesis do not vary with variety. There is no evidence that they do between Plumage Archer and Proctor. (Thorne.)

Effect of gibberellic acid on the growth of potato

Experiments in 1958 and 1959 showed that potato plants sprayed with gibberellic acid (GA) solution had larger leaves, and though at first this increased the rate of dry-matter production, the net assimilation rate eventually fell below that of unsprayed plants, and their final yield was not increased (*Rep. Rothamst. exp. Sta.* for 1958, p. 75, and 1959, p. 72). The deterioration in photosynthetic efficiency of sprayed leaves, accompanied by yellowing and earlier senescence and by a decrease in nitrogen content % of dry weight or per unit area, occurred sooner when the initial nitrogen supply was low than when it was high, but addition of ammonium nitrate to the soil or repeated spraying of the leaves with urea solution after treatment with GA did not prevent or delay the onset of chlorosis. Further analysis of the results of the 1959 experiment showed that late N application increased the rate of leaf production on lateral branches and the leaf area per plant but not leaf size. These effects were independent of the spraying with GA. In contrast with nitrogen, GA increased leaf area per plant solely by increasing leaf size. Additional N did not arrest the decrease in N content of the leaves of plants sprayed with GA. The absence of interactions between GA and N treatments does not support the hypothesis that the

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chlorosis, impaired photosynthesis, and more rapid senescence of leaves caused by GA are the result of acute nitrogen deficiency.

In a similar experiment done in 1960, in larger pots holding 16 kg. of soil instead of 10 kg., the increase in dry-matter production by GA was more persistent and the final yield was increased. Also, the effect of GA increased with increase in N supply. In the previous experiments the effect of GA may have been restricted in some way by the amount of soil per pot, but the cause is not yet known. (Humphries and French.)

Leaf-growth substance from dwarf French bean leaves

A leaf-growth substance similar to gibberellic acid (GA) was found in extracts of leaves of dwarf French bean seedlings (5.9). Zones from chromatograms of leaf extracts with R_f similar to GA increased the growth of disks cut from dwarf French bean leaves, when tested either in light or in darkness with disks from plants grown either in light or in darkness, but the assay was more sensitive with disks cut from etiolated plants. An inhibitory zone close to the starting-line appeared on chromatograms assayed in light.

An attempt was made to characterise the substance more precisely by biological tests that are more specific for gibberellins. The substance promoted extension of internodes of Meteor dwarf pea seedlings; this confirms that it is a gibberellin. Extension of the hypocotyls of two-day-old lettuce seedlings was stimulated by as little as 0·01 GA in light, but no activity in this test was found on chromatograms of leaf extracts in zones corresponding to the GA marker spot. This shows that the substance is not GA. Phinney * showed that some dwarf mutants of maize can be made to grow to normal height by supplying gibberellins. Leaf-sheath growth of dwarf mutants d-1, d-3 and d-5 is promoted by GA, but the leaf-growth substance had no effect on d-1, some effect on d-3 and most effect on d-5. Similar activity on d-5 but not on d-1 has been attributed by Phinney to Bean Factor II. Thus, the gibberellin extracted from dwarf French bean primary leaves that promotes leaf expansion is not GA, but has properties similar to Bean Factor II, now known as GA_5.

When apical growing points of dwarf French bean plants were excised the primary leaves grew larger and contained more GA-like growth-substance than leaves of intact plants. The epicotyls were also longer. Removing the cotyledons before the primary leaves unfolded prevented the leaves expanding and GA-like growth-substance accumulating in them. Later removal of cotyledons had less effect. Soaking seed in water for 24 hours caused no detectable loss of seed dry weight but decreased the area of the primary leaves and their content of GA-like growth-substance. This suggests that growth-substance was leached from the cotyledons. However, previous work showed that the sensitivity of etiolated bean leaf disks to GA was not increased by prolonged soaking of the seed or removal of cotyledons. (Wheeler.)

* Phinney, B. O. (1956). *Proc. nat. Acad. Sci., Wash.* **42**, 185–189.

Gibberellins in potato leaves

A growth-substance active in the etiolated-bean-leaf disk test, with R_f similar to GA and to the leaf-growth substance present in leaves of dwarf French bean, was found on chromatograms of extracts of potato leaves. Spraying potato plants with aqueous GA (50 mg./l.) soon after the 15th leaf began to expand increased the content of gibberellin-like growth-substance of that leaf by five times and increased its growth rate. The gibberellin content of sprayed and unsprayed leaves changed little during 23 days after spraying, but had decreased by the 37th day, when leaf expansion had nearly ceased. These results show that an endogenous gibberellin-like leaf-growth substance is present in potato leaves, and affects their growth rate similarly to externally applied GA. (Humphries and Wheeler.)

Effect of light quality on growth and growth-substance content of plants

The increased growth of dwarf French bean plants in artificial light when fluorescent tubes were supplemented by tungsten-filament lamps (*Rep. Rothamst. exp. Sta.* for 1959, p. 74) was further studied, and stems and leaves were analysed to see whether the effects of additional incandescent light were related to the content of growth substances. The main effect of incandescent light, increased length of internodes, occurred consistently in seven varieties of dwarf French bean. Incandescent light made stems elongate more in 16-hour than in 8-hour photoperiods. Plants were exchanged between treatments consisting of fluorescent light with or without incandescent light, when 12 days old, leaving control plants to continue with their previous treatment. When they were harvested after 25 days, stem height was increased only by incandescent light in the later period, and there was no interaction between early and late incandescent light treatments. Dry weight was usually increased by additional incandescent light, perhaps because stem elongation brought the leaves nearer the lamps, and hence into a higher light intensity.

The increased growth of internodes of Canadian Wonder dwarf French bean plants grown with additional incandescent light was associated with more of both gibberellic acid-like and indolylacetic acid-like growth substances. The content of IAA-like growth-substance increased as the plants aged, but that of GA-like growth-substance did not. (Wheeler.)

Boron and adventitious root formation

A remarkable interaction of boron and light on adventitious root formation reported last year (*Rep. Rothamst. exp. Sta.* for 1959, p. 77) was confirmed in 1960. Dwarf French bean plants were grown at 20° in soil in cabinets lit by fluorescent tubes with a 16-hour photoperiod. When the first pair of leaves was fully expanded the hypocotyls were cut and placed in nutrient solution with or without boric acid. In addition to light from fluorescent tubes, some plants received light from incandescent lamps either before or after the hypocotyls were cut, or throughout both periods or during neither period. After 14 days the numbers of roots and root initials on the hypocotyls were counted, and the roots cut off and

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weighed. Incandescent light given before or after the hypocotyls were excised decreased the number and weight of adventitious roots on plants without boron, but had no effect on root formation of plants given boron. Or, in terms of boron action, boron had little effect on plants illuminated with fluorescent light only, but lack of boron decreased root formation by plants that received supplementary incandescent light. The growth in dry weight of the hypocotyls without boron was decreased by incandescent light given before but not after the hypocotyls were cut. (Humphries.)

Growth of rooted detached leaves

The changes that lead to rapid senescence and death of a detached leaf are arrested when roots are formed on the petiole, and the system may then begin to accumulate dry matter. After rooting, a detached leaf increases little in area, but its life may be prolonged far beyond what it would have been had it remained attached to the plant. The behaviour of rooted-leaf cultures is therefore being examined, to find whether they can be used to study the factors that control leaf expansion and longevity, and the dependence of photosynthesis on growth.

When primary leaves of dwarf French bean were cut from the plant and kept in light with their petioles dipping in nutrient solution roots began to appear in 7 days. During this time growth in dry weight was small, but after roots appeared the rate of growth increased. When petioles were treated with indolylacetic acid before they were placed in nutrient solution more roots were formed, and leaves so treated had a higher growth rate and net assimilation rate than leaves rooted in nutrient solution alone. However, the net assimilation rate of rooted leaves, even after treatment with IAA, was much below that of intact seedlings grown in the same conditions. These results indicate that the rate of photosynthesis depends on the rate at which photosynthetic products are used in growth. Adding kinetin to the nutrient solution suppressed root formation but induced a large growth of callus (5.3) and decreased net assimilation rate only slightly below that of rooted leaves, showing that callus affects the rate of photosynthesis in the same way as roots. (Humphries.)

Weed Studies

Wild oats

Survival of seeds under temporary ley. In the fifth and last year of the experiment at Rothamsted (*Rep. Rothamst. exp. Sta.* for 1959, p. 81) on plots ploughed in autumn 1959 after 5 years under ley, the number of seedlings of *Avena fatua* per 10 sq. yd. was 7, compared with 6 in 1959, and 90 before the ley was sown. The residual population of viable dormant seeds is evidently still far from being exhausted.

The experiment on a field in Northamptonshire with a mixed infestation of *A. fatua* and *A. ludoviciana* also ended, because the ley was ploughed in spring 1960. The number of seeds in 14 lb. of dry soil had fallen from 41 ± 7 in 1959 to 23 ± 3 in 1960. Soil samples taken from the field in 1959 and kept watered in the glasshouse have already produced seedlings from 50% of the estimated number of seeds present, proving that the seeds are viable. After 6½ years under ley, this field still had over 2 million wild-oat seeds per acre. (Thurston.)

Wild oats from other countries. Plants of 84 European and 10 Australian selections of wild oats were grown in pots to compare with 8 British sorts. European *A. fatua* and *A. ludoviciana* behaved like their British counterparts, except that their panicles emerged a few days earlier. Australian selections of these species differed greatly from both European and British, their panicles emerged about 3 weeks earlier and were shorter, with fewer seeds in each, and they had nearly twice as many panicles per plant. *Avena barbata* from France and Australia had the same prostrate habit as *A. barbata* from Malta (*Rep. Rothamst. exp. Sta.* for 1958, p. 85). Those from Australia reached 50% panicle emergence about 4 days before the French, showing a tendency to earliness similar to, but smaller than, that found for the other species. Over 90% of the seeds of most of the selections from the plants grown in the glasshouse were dormant when sown in October 1960, except that seeds of British and two European selections of type fM of *A. fatua*, the first seeds of spikelets of *A. ludoviciana*, and seeds of *A. barbata* from France and Australia (unlike those from Malta) were all non-dormant. (Thurston.)

International experiments on A. fatua. We collaborated in two experiments arranged by the International Research Group for Weed Control. Seeds of *A. fatua* were collected in nine countries, and samples of each collection were sent to three laboratories where their susceptibility to new herbicides intended for wild oat control will be tested, and to Rothamsted for botanical analysis and identification.

For the second experiment on the effect of storage conditions on dormancy and viability, ripe seeds were collected when ready to shed, exposed outdoors on the surface of the soil for 1, 2 or 3 months, and then stored for 0–6 months at 10° or 20° in the laboratory. Immediately after collection, and after each period of outdoor exposure and laboratory storage, seeds were set to germinate at 10° or 20° for 3 weeks, to determine how many were non-dormant. The viability of the residue was tested by germination after cutting off the distal ends. At Rothamsted none of the treatments decreased viability or dormancy below 95% during the first 4 months, although in a similar experiment in Sweden in 1960 2 months' dry storage decreased dormancy from 100 to 50%. Results have not yet been obtained from other centres. (Thurston.)

Broadbalk weeds

Alopecurus myosuroides (black grass) and *Avena ludoviciana* (winter wild oat) were much more abundant in 1960 than in recent years because of the early sowing date (19 October 1959), which allowed all the seedlings to survive undisturbed by seedbed cultivations.

The series of soil samples taken from 1955 to 1960 from Section 1a, which has returned to continuous wheat, and Section 1b, which remains in the fallow cycle, show that the use of herbicides on

Section 1b has decreased the numbers of seeds of *Ranunculus arvensis* (corn buttercup) and *Vicia sativa* (common vetch) in the soil. The numbers of *Medicago lupulina* (black medic) and *Alchemilla arvensis* (parsley piert) seeds were also decreased, but they had increased so much in 1956, when no herbicide was used, that they are still above the numbers on Section 1b, which was fallowed in 1956. Seeds of *Papaver* spp. (poppies) were also much decreased by the 1956 fallow on 1b, but by 1959 they were again more numerous than on 1a. *Alopecurus myosuroides*, unaffected by herbicides, increased in the continuous wheat, although late sowing has helped to control it all over Broadbalk. (Thurston.)

Survival of arable weed seeds in Geescroft wilderness

Natural woodland has grown undisturbed on this area since arable cultivation ceased in 1867. Samples were taken from the leaf-litter, surface humus, the formerly ploughed layer of the soil and the subsoil in February 1960, and kept watered in pans in the glasshouse. Seedlings of *Rumex obtusifolius* (broad-leaved dock), *Anagallis arvensis* (scarlet pimpernel) *and Vicia hirsuta* (hairy vetch) have appeared from the ploughed layer, but not from the litter or humus above it, suggesting that these species have survived as dormant seeds for many years. Plants of *R. obtusifolius* were found in 1903, and of the other two species in 1913, but records were infrequent, and how long these species continued to fruit is not known. *A. arvensis* and *V. hirsuta* are not now found growing in the Wilderness, and *R. obtusifolius* grows only at the edges, not near where the samples were taken. Viable seeds of *Urtica dioica* (stinging nettle) and grasses were also found in the ploughed layer, but as they were also present in the layers above, and the species still grow in the wood, long survival of these seeds cannot be assumed. (Thurston.)

Competition between crop and weeds

Weed density and crop yield. The results of the experiment in 1959 to measure effects of varying densities of different weeds on yield of spring wheat (*Rep. Rothamst. exp. Sta.* for 1959, p. 83) have been statistically analysed, but their interpretation still presents difficulties. In two wheat fields, 90 small plots were protected with polythene sheet when the field was sprayed with hormone weed-killer, and the weeds of each species were counted or estimated. The yields of wheat on the unsprayed areas and on contiguous sprayed areas were determined. Partial regression coefficients of the yield of the unsprayed plots on log weed density were calculated. When the yield of sprayed plots was included as an additional independent variate in the regression, to correct for variation in fertility between the unsprayed plots, the accuracy of the regressions on weed density was not improved. The explanation may be that the yield on the sprayed plots was already affected by the weeds present before spraying, or that the spraying was only partially effective in eliminating weed competition.

The only weed species that affected the wheat yield in both fields significantly were *Atriplex patula* (orache) and *Polygonum aviculare* (knot grass). Within the range between 10 and 3,000 seedlings/sq. yd., a ten-fold increase in density decreased wheat yield by 10% for

A. patula and 6% for *P. aviculare*; 100 plants/sq. yd. decreased wheat yield by 20% for *A. patula* and by 12% for *P. aviculare*. *Chenopodium album* (fat hen) had no significant effects on yield, although there were up to 3,000 seedlings/sq. yd., but few of these survived to become mature plants.

In 1960 the experiment was repeated on two fields of winter wheat, where the principal weed species at the time of spraying in spring were *Polygonum aviculare*, *P. convolvulus* (black bindweed), *P. persicaria* (red shank), *Poa* spp. (meadow grass), and autumn-germinated *Galium aparine* (cleavers) and *Stellaria media* (chickweed). Inspection of the data, now being analysed on the electronic computer, suggests that only weeds that germinated in the previous autumn (particularly *Galium*) had much effect on yield. Similar observations were also made on a barley experiment on weed control by a triazine herbicide. (Welbank and Witts.)

Survey of competitive effects of common weed species

Two more experiments of the type already described (*Rep. Rothamst. exp. Sta.* for 1958, p. 86, and for 1959, p. 84) were done to measure the effects on the growth of single plants of wheat or kale of growing 16 weed plants with them in the same pot. *Chenopodium album* as a standard was compared with *Matricaria maritima* ssp. *inodora* (scentless mayweed), *Polygonum convolvulus* and *Veronica persica* (Buxbaum's speedwell) in the first experiment, and with *Alopecurus myosuroides*, *Anagallis arvensis* and *Sinapis arvensis* (charlock) in the second. *Atriplex patula* was also included in both experiments, but again it did not germinate satisfactorily. Pre-treatment of the seeds of some species, e.g., by chilling or treatment with sulphuric acid, was necessary to make them germinate, and it was difficult to time the treatments to obtain simultaneous germination of all species and crops. This may account in part for some of the differences between species.

In the first experiment *Polygonum* had a greater competitive effect than the other weeds; *Matricaria* and *Veronica* had similar effects, less than that of *Chenopodium*. The percentage reduction of crop yield by *Chenopodium* decreased with increase in nitrogen supply, but with the other species there was no evidence that competition was for nitrogen.

The test of *Chenopodium* in the second experiment was invalidated by delayed germination. *Anagallis* had a negligible effect on the crop. *Alopecurus* had slightly less effect than *Polygonum* in the first experiment. *Sinapis* was the most aggressive of the weeds tested. It decreased the dry weight of kale by 95%, and of wheat by 80%, and although this large effect may have been partly caused by earlier germination of the pre-chilled weed than the crop, *Sinapis* is evidently a very powerful competitor. (Welbank.)

Competitive effects of Agropyron repens *(couch grass)*

The work in 1958 and 1959 to find whether the harmful effect of *Agropyron repens* on crops can be attributed to competition for nutrients in the soil (*Rep. Rothamst. exp. Sta.* for 1959, p. 84) was continued with a test of the effect of phosphorus supply on competition with radish, and its interaction with nitrogen supply.

Although increase in P supply increased the dry weight of radishes grown alone, the competitive effect of *Agropyron* could be explained by its effect on N uptake.

When rhizomes and roots of *Agropyron* decay in poorly aerated soil, substances toxic to seedlings are formed (*Rep. Rothamst. exp. Sta.* for 1959, p. 85). The rate at which these substances are produced was studied by adding pieces of rhizome to moist Woburn soil in glass jars, which was incubated at 20°. In some jars aeration was impeded by adding water and closing the mouth of the jar with a bung. Extracts of the soil were filtered and assayed by measuring their effects on radicle and hypocotyl elongation of rape seedlings. The first measurements were made after 12 days, and there was little increase in toxicity at later times. Evidently toxicity developed rapidly in the early stages of decay, and changed only slowly thereafter. Anaerobic preparations decreased radicle growth by 55% and aerobic preparations by only 5–10%. Toxicity was the same whether fresh rhizomes or rhizomes killed by drying or freezing were used. The harmful effects of anaerobic preparations on hypocotyl growth were much less than on radicle growth, and aerobic preparations tended to increase hypocotyl length. The toxicity of the extracts was unaffected by autoclaving for 25 minutes at a pressure of 15 lb./sq. in. (Welbank.)