ROTHAMSTED RESEARCH

Report for 1953

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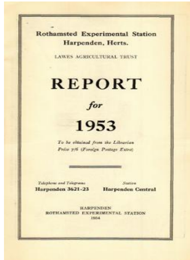
Rothamsted Experimental Station
Harpenden, Herts.

REPORT
for
1953

Botany Department

D. J. Watson

D. J. Watson (1954) *Botany Department ;* Report For 1953, pp 68 - 74 **- DOI: https://doi.org/10.23637/ERADOC-1-75**

BOTANY DEPARTMENT

D. J. WATSON

Dr. Winifred Brenchley, who was head of the department from 1906 until she retired in 1948, died on 20th October, 1953. The department is proud of her achievements in many branches of agricultural botany, and especially of her pioneering work in the field of trace-element nutrition. All those who worked with her remember with gratitude the help that she gave with unfailing kindness and cheerfulness.

D. J. Watson was invited to give two lectures in a course on Photosynthesis organized jointly by the Netherlands Association for Agricultural Science, the Netherlands Institute of Agricultural Engineers and the Agricultural University of Wageningen, and held at Wageningen in September.

J. M. Thurston was asked to contribute a review of research on wild oats to the First National Weed Control Conference, at Margate in November.

PLANT NUTRITION

Dependence of manganese, molybdenum and vanadium toxicity on iron supply (K. Warington)

The toxicity of vanadium to flax, soybean and pea grown in solution culture has previously been found to depend on the concentration of iron on the solution (1952 Report, p. 65); it was more severe when the supply of iron was low, and could almost be eliminated if sufficient iron was given. Toxic effects of manganese and molybdenum have now been shown to depend similarly on iron supply (59).

Excess manganese (10 p.p.m.), molybdenum (40 p.p.m.) and vanadium (2·5 p.p.m.) all caused chlorosis of the shoot in soybean and flax, when the concentration of iron in the culture solution was low (1–5 p.p.m. Fe, according to the crop). Manganese excess had little effect on the root system, but molybdenum induced slight, and vanadium severe, root abnormalities. Raising the iron supply to 20 or 30 p.p.m. counteracted both the chlorosis and the root symptoms. Frequent small doses of iron proved less efficient in overcoming molybdenum or vanadium toxicity, but not manganese toxicity, than the same amount of iron given in larger quantities at longer intervals. When the concentration of Mn, Mo or V was low, iron had little effect on growth, but later experiments on flax and peas showed that iron given at the higher rates may itself be harmful.

Spectrographic analyses of soybean shoots (by H. H. le Riche, of the Soil Survey) showed that where increased iron supply had counteracted chlorosis caused by high Mn or V, the content of the toxic element per cent of dry matter was also reduced, but the content of Mo was not consistently changed by high iron supply. Root material is being analysed to find out whether the reduced content of Mn and V in the shoot resulted from decreased absorption or restricted translocation. The total iron content per cent of dry matter of the shoot was scarcely affected by variation in iron

https://doi.org/10.23637/ERADOC-1-75

supply, but it was greatly reduced by the high concentrations of Mn, Mo or V.

Nutrient uptake by excised roots (E. C. Humphries)

The rates of uptake of nitrogen, phosphorus and potassium from a nutrient solution by excised barley roots increase with increase in the reducing sugar content, but not with the sucrose content, of the roots (1952 Report, p. 66). Experiments have been made to find out whether glucose and fructose both influence nutrient uptake. Barley was germinated and grown in darkness for about nine days, supplied only with water. The low-sugar, low-salt roots so produced were cut off and placed in 0·01M-KCl solution to which 0·5 per cent glucose, fructose or sucrose had been added. The uptake of potassium in a 4-hour period, measured by the change in concentration of the solution, was then compared with the uptake from a solution without added sugar. Both glucose and fructose increased the rate of K uptake by about 15 per cent. The effect of sucrose was variable; the reason is not known and needs further investigation. Analyses of root samples, to measure the effect of the external sugar supply on the nature and amount of sugars present in the roots, are not yet complete.

Nutrient uptake from leaf sprays (G. N. Thorne and D. J. Watson)

Chemical analyses of material from sugar-beet plants, grown in soil in pots with factorial N, P and K fertilizer treatments, and sprayed daily with water or with solutions supplying N, P or K separately (1952 Report, p. 67) showed that uptakes of N, P and K from sprays were increased by N fertilizer, and unaffected by P fertilizer; K fertilizer reduced the uptake of K from spray. Increased nutrient uptake brought about by spraying was less effective in increasing dry matter yield than equivalent increase in nutrients brought about by fertilizer application, presumably because supply from the spray occurred later in the growth period than supply from fertilizers.

In this and earlier experiments the increased nutrient content of sprayed over unsprayed plants usually represented only about 50 per cent of the quantity of nutrients applied in the spray, as estimated from the difference between the volume of spray lost from the spray gun and the amount collected on blotting-paper placed round the plants during spraying. Analyses of the water used to wash the leaves before the plants were harvested showed the presence of only trivial amounts of P and K, and no N, so the incomplete recovery of nutrients from sprays cannot be attributed to nutrients accumulated on the outside of the leaves and washed off before harvest.

Another possible explanation of the apparent low recovery is that absorption of a nutrient by leaves from spray may reduce uptake of that nutrient by the roots, so that the difference in nutrient content between sprayed and unsprayed plants may not be a correct measure of uptake from the spray. This was tested by using isotopes to label nutrients supplied either to the roots or the leaves, so that amounts entering the plant by each route could be determined. Sugar-beet plants growing in soil were sprayed either with water or with ammonium nitrate solution labelled with ^{15}N, and swedes growing in a ^{32}P-labelled nutrient solution were sprayed with water or normal sodium phosphate solution. In neither experiment was the nutrient uptake by the roots of the sprayed plants significantly less than that of controls sprayed with water, and, as before, only about half of the estimated nitrogen or phosphorus supply from the spray was recovered in the plants. It is still not possible to account for all the nutrients supplied in leaf sprays, and the fate of the fraction not recovered in the plant needs further investigation.

Further experiments were made on the effects of nutrient sprays on field crops (1952 Report, p. 67). As before, ammonium nitrate applied to winter wheat as a solution sprayed on the leaves during May and June produced about the same incease in grain yield as an equal quantity of ammonium nitrate applied to the soil at the same times, or as an equivalent top-dressing of "Nitro-Chalk" in April. The recovery of nitrogen in the crop was similar for all three methods of application. The effect of the spray treatment was no greater on plants that had previously received a spring top-dressing of nitrogen.

Earlier experiments had shown that the protein content of sugar-beet tops could be greatly increased by repeated spraying of the leaves with solutions of ammonium nitrate or urea in late September, without harmful effects on the yield of sugar, and spraying was more efficient than soil applications. As repeated spraying with a high volume of dilute spray would be impracticable on a commercial scale, an experiment was made to see whether similar results could be obtained from a single low-volume spraying with a nearly saturated urea solution. Two rates of spraying, supplying 32 and 64 lb. N in 12·5 and 25 gal. per acre respectively, were tested and compared with similar amounts of N given in four high-volume sprayings with a dilute solution. The concentrated spray caused some scorching of the leaves, especially at the higher rate of application, but increased the nitrogen content of all parts of the plant to about the same extent as the repeated spraying treatment did. Spraying at the higher rate increased the nitrogen content of the leaf lamina by 45 per cent, while equivalent applications of urea to the soil produced no detectable increase; the recovery of nitrogen from spray was much less than in previous experiments. The yield of sugar was slightly reduced by spraying, especially with concentrated solution at the higher rate.

The potash content of lucerne tops was increased by 24 per cent at the first cut and 35 per cent at the second cut by spraying with a solution of potassium sulphate, although the yield was unaffected (1952 Report, p. 68). The increases represent recoveries of 38 and 18 per cent of the potash applied. The increase in potash content produced by equivalent applications to the soil were only about one-third of those due to spraying.

Beneficial effects on plant growth from applications of phosphorus-containing insecticides, that could not be explained by control of insect damage, have been reported by several observers. It was suggested that these effects might be due to absorption through the leaves of the phosphorus contained in the spray, though the amounts of phosphorus involved seem to be far too small to be capable of producing measurable effects on growth. Brussels sprouts plants grown in pots, with or without phosphate added to

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the soil, were sprayed six times with water, or with " Pestox III " or " Systox ", or with sodium phosphate solutions supplying the same amounts of phosphate as the insecticides. All the plants were kept free from insects by nicotine fumigation. None of the phosphorus-containing sprays had any detectable effect on the appearance, dry weight or phosphorus content of the plants, although large responses to the phosphate applied to the soil showed that the plants were very sensitive to change in phosphorus supply.

WEED STUDIES

Germination and dormancy of wild oats seeds (J. M. Thurston)

In the field experiment testing the effects of depth of sowing and varied cultivation treatments on wild oats seeds sown in October 1950 (1952 Report, p. 69) fewer seedlings of both *Avena fatua* and *A. ludoviciana* appeared in 1952–53 than in either of the two previous seasons. Less than 4 per cent of the seeds of *A. fatua* sown in 1950, and only 0·1–0·3 per cent of the seeds of *A. ludoviciana*, produced seedlings in 1952–53. Germination in both species appears already to be declining in the third year of the experiment, although so far less than 20 per cent of the seeds sown have produced seedlings that emerged above ground. Germination on plots ploughed in autumn or spring was similar to that on undisturbed plots, as in the previous year; frequent harrowing again slightly reduced the number of seedlings; deep-sown plots produced more seedlings than shallow-sown.

The wild oats infestation on the continuous spring-sown barley plots of Hoosfield consists of *A. fatua*, while that on the autumn-sown wheat plots of Broadbalk is nearly all *A. ludoviciana* with a few *A. fatua*. Since seeds of *A. ludoviciana* germinate mainly in autumn and winter, seedlings of this species are destroyed by cultivations for a spring-grown crop, and this presumably accounts for the absence of *A. ludoviciana* on Hoosfield. On the other hand, it is not obvious why *A. fatua*, which germinates in spring, should not become established in an autumn-sown crop. The rare occurrence of *A. fatua* in rye crops in Sweden has been attributed to the production by rye roots of a substance that inhibits germination of *A. fatua* seeds. A new field experiment was started on a heavily infested site in Hoosfield to test whether autumn or spring sowing is the main factor affecting the establishment of *A. fatua* in a cereal crop, or whether different cereals have specific effects. The germination and growth of *A. fatua* was compared on plots left fallow, or sown with wheat, rye or barley in autumn, or with barley in spring. In April the number of wild oats seedlings was inversely related to the weight of crop, the well-established autumn wheat and rye having least, autumn barley rather more and spring barley more still. All the cereal crops reduced the number of wild oats seedlings compared with fallow. This result indicates that the inhibitory effect of cereal crops depends on the size of the plants at the time when the wild oats are germinating, and does not suggest that rye or wheat have specific inhibitory effects. The crops were cut green, before the wild oats produced visible seeds, to avoid re-infestation. Just before cutting, the wild oats had fewer spikelets per plant and seeds per spikelet on the rye and wheat plots than on the barley plots, and many fewer than on the fallow plots. Thus, autumn-sown cereals tend to reduce re-infestation with new seeds of *A. fatua* by reducing both the population of wild oats plants and their seed production.

In a pot culture experiment, plants of both wild oats species were grown outdoors or in a glasshouse, with and without shading, and with two rates of nitrogen application, to determine whether temperature, light intensity and nitrogen supply affect the onset of dormancy in the developing grain. Samples of ears were taken at intervals after emergence. Glasshouse conditions and shading both greatly increased the percentage of sterile spikelets. The percentage of viable seeds of both species, and of dormant seeds of *A. fatua*, increased more rapidly in the glasshouse than out-of-doors, but there was little dormancy in unripe seeds of *A. ludoviciana*. In another set of pots the effect of removal of whole panicles or parts of panicles on the growth, viability and dormancy of the remaining seeds was studied; this is relevant to attempts to control wild oats by cutting off the inflorescences above the cereal crop before the emergence of the cereal ears. The results of these experiments are not yet complete.

Physiological Studies on Virus Infection

Effect of a dark period on susceptibility of leaves to infection (E. C. Humphries, in collaboration with B. Kassanis, Plant Pathology Department)

The number of necrotic local lesions produced by tomato aucuba mosaic virus on tobacco leaves is increased if the plants are kept in darkness before inoculation, and the effect becomes progressively greater with lengthening of the dark period up to nine days. When plants are returned to daylight after a dark period before being inoculated, the number of lesions decreases as the length of the light period increases. The variation in lesion counts was shown to be closely correlated with changes in the nitrate content of the leaf lamina (1952 Report, p. 71); nitrate accumulates in leaves of darkened plants and decreases again when the plants are restored to daylight. Further experiments have consistently shown this correlation, but variation in lesion counts on similarly treated replicate leaves did not always reflect variation in nitrate content. Dry matter content decreases and the water content increases when tobacco plants are held in darkness, and these changes are both correlated with number of lesions. At present it seems possible that lesion count per unit area of leaf may be independently related to the nitrate, dry matter and water contents per unit leaf area, but this needs further investigation. Variation in nitrate content of the leaves induced by nitrogenous fertilizer had no effect on lesion numbers. Repeated spraying of the leaves with potassium nitrate solution before inoculation reduced the number of lesions, but this was presumably an effect of the salt outside the leaves, for addition of potassium nitrate to the inoculum also reduced the number of lesions.

Another way of increasing the susceptibility of tobacco plants to aucuba mosaic virus is to keep them at 37° C. in the light for one or two days; this treatment also has been shown to increase the nitrate content of the leaves.

Nitrate accumulates in discs of leaf lamina floated on water and held in darkness, and this suggests that the nitrate accumulated in leaves of darkened plants originates from proteolysis in the leaf, and is not transported from other parts of the plant.

Effect of infection with tobacco mosaic virus on the respiration of tobacco leaves (P. C. Owen)

Further work has been done to find out the conditions in which infection with tobacco mosaic virus affects rate of respiration of tobacco leaves (1952 Report, p. 72). In winter experiments, leaves rubbed with infected sap and immediately detached from the plant had a higher respiration rate in the first twenty hours after inoculation than comparable leaves rubbed with healthy sap, but no consistent increase by infection was found in summer. Experiments are in progress to find out whether this seasonal fluctuation can be related to variation in light intensity or day length.

Leaves taken from systemically infected plants three to four weeks after inoculation and showing mosaic symptoms usually had a lower respiration rate than comparable healthy leaves.

Effect of virus infection on transpiration (P. C. Owen)

Sugar-beet plants infected with beet yellows virus in the field appear to wilt less readily than healthy plants. The possibility that this might be due to a reduction by infection in the rates of transpiration was tested on plants grown in pots by measuring the rate of water loss from attached leaves to a stream of air drawn over them. The rate of transpiration per unit area was lower for leaves of infected plants that showed yellows symptoms than for comparable healthy leaves, but young infected leaves not yet showing symptoms had a slightly higher transpiration rate than healthy controls.

Systemic infection with tobacco mosaic virus caused a small increase in transpiration rate of attached tobacco leaves; infection with aucuba mosaic virus had a similar but larger effect.

Effect of infection with beet yellows virus on sugar beet (D. J. Watson and P. C. Owen)

Much time was spent on an attempt to measure the diurnal CO_2 exchange of whole sugar-beet plants grown in pots, with the object of determining the extent to which changes in the rates of photosynthesis and respiration are responsible for the reduction in net assimilation rate caused by infection (1952 Report, p. 73). No useful data were obtained, because the automatic gas-sampling unit previously used for respiration measurements with air-flow rates of about 200 ml./minute, was found to be unreliable for the high flow rates (3–4 litres/minute) necessary for the photosynthesis measurements. The unit has now been redesigned, and the investigation will be continued in 1954.

Growth Analysts

Dependence of net assimilation rate on leaf area index (D. J. Watson)

Previous work has shown that future improvements in crop yield are more likely to be effected through increase in leaf area per unit area of land (leaf area index; LAI) than through improved photosynthetic efficiency as measured by net assimilation rate (NAR). As LAI increases, NAR must eventually begin to decrease through reduction in mean light intensity at the leaf surface caused by mutual shading of leaves, and possibly because of a fall in the atmospheric CO_2 concentration in the crop caused by crowding together photosynthesizing leaves. Such an interdependence of NAR and LAI presumably must set an upper limit to the rate of dry matter production per unit area of land, and hence to yield.

The effect of increasing LAI and NAR was measured in a field experiment on kale. Starting with a uniform population of closely spaced plants, LAI was varied by removing varying fractions of the plant population on different plots, and NAR was determined from the dry matter increments in a subsequent growth period. NAR was found to be independent of increase in LAI up to about 2·5, but decreased by about a quarter when LAI was increased from 2·5 to 4. This result shows that increase in leaf area per unit land area may lead to reduced photosynthetic efficiency of the leaves, even within the range of leaf area that can be achieved by present cultural methods, but the experiment needs to be repeated at different stages of growth and on other crops.