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### Plant Growth, Action of Manures

#### Rothamsted Research

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## SCIENTIFIC PAPERS

### PLANT GROWTH, AND ACTION OF MANURES

(Departments of Botany, Chemistry, Insecticides and Fungicides; Field Experiments Section; Woburn Experimental Station; and Imperial College Staff.)

#### (a) PLANT GROWTH

- I. E. J. RUSSELL and D. J. WATSON. "*The Rothamsted Field Experiments on Barley 1852-1937. A. The Older Rothamsted Experiments.*" *The Empire Journal of Experimental Agriculture*, 1938, Vol. VI, pp. 268-292.
- II. E. J. RUSSELL and D. J. WATSON. "*The Rothamsted Field Experiments on Barley 1852-1937. Pt. II. Effects of Phosphatic and Potassic Fertilizers; Deterioration under Continuous Cropping.*" *The Empire Journal of Experimental Agriculture*, 1938, Vol. VI, pp. 293-314.

A review and summary of the results of experiments on barley carried out at Rothamsted, Woburn and other centres from 1852 to 1937.

Parts I and II deal with factors which affect yield, and Part III (in the press) with the factors which determine the quality of the grain.

In Part I, it is shown that the relation between the yields of grain and straw is very close, so that the variation in the ratio of grain to total produce is small. Further discussion is therefore confined to the yield of grain. An account is given of the effects of soil type, seasonal climatic factors and nitrogenous fertilizers. Different forms of nitrogenous fertilizer are compared, and the effects of rainfall and of time of sowing on the response to added nitrogen are discussed.

In Part II phosphatic and potassic fertilizers are considered. It is shown that these are usually of less importance than nitrogenous fertilizers. Other factors discussed are:—farmyard manure; soil reaction; fallowing; deterioration of yield under continuous cropping with barley; undersowing with clover.

- III. D. J. WATSON and E. C. D. BAPTISTE. "*A Comparative Physiological Study of Sugar-beet and Mangold with respect to Growth and Sugar Accumulation. I. Growth Analysis of the Crop in the Field.*" *Annals of Botany*, 1938, New Series, Vol. II, pp. 437-480.

A study was made of the growth of sugar-beet and mangold sown on six occasions at intervals of a fortnight in 1934. Samples were taken at fortnightly intervals to determine (1) dry weight of lamina, petiole and root; (2) water content of lamina, petiole and root; (3) leaf area per plant.

Sugar-beet ultimately attained a greater dry weight than mangold, the difference being mainly in the leaves. The dry weight of lamina and petiole continued to increase for a longer period in sugar-beet than in mangold.

Later sowing decreased the dry weight of root at all sampling times, but in the later stages of growth it caused a marked increase in lamina and petiole dry weights.

The water content of mangold was very much greater in all parts of the plant than in sugar-beet. Later sowing caused an increase of water content.

The number of leaves per plant was greater in sugar-beet than in mangold owing to a slightly higher rate of production and a lower death rate. Later sowing increased the rate of production. The rate of leaf production was correlated with mean temperature,  $Q_{10}$  being 3.1.

The variation of leaf area per plant was similar to that of lamina dry weight. The effect of sowing date on leaf area was greater than on leaf weight.

The Relative Growth Rate was slightly greater in sugar-beet than in mangold; it decreased throughout the growth period, falling eventually to zero.

Later sowing increased the Relative Growth Rate in the early stages, due to an increase in the Leaf Weight Ratio ; Unit Leaf Rate was unaffected by date of sowing.

- IV. D. J. WATSON and I. W. SELMAN. "*A Comparative Physiological Study of Sugar-beet and Mangold with respect to Growth and Sugar Accumulation. II. Changes in Sugar Content.*" *Annals of Botany*, 1938, New Series Vol. II, pp. 827-846.

An account is given of the changes during growth in the sucrose and reducing sugar content (expressed per 100 g. of dry matter and per 100 g. of water) of the lamina, petiole, and root of sugar-beet and mangold sown on six occasions in 1934.

Sugar-beet had a higher content of both sucrose and reducing sugars than mangold, except that the sucrose content of the lamina was almost the same in the two plants, and in the root the reducing sugar content was greater in mangold. In general, both the sucrose and reducing sugar content of all parts of the plant increased steadily with time.

The sucrose content increased through the plant in the direction from lamina to root. The reducing sugar content was highest in the petiole, and was greater in the lamina than in the root. It is pointed out that this does not necessarily imply that translocation takes place against a gradient of sugar concentration, for gradients falling in the direction of movement may exist in the conducting tissues, which are masked in the mass analyses of lamina, petiole, and root. The data give little direct evidence on the mechanism of translocation, but they serve to illustrate some fallacies in the arguments of Davis, Daish, and Sawyer for the view that sucrose in the leaf is an immediate product of photosynthesis and that carbohydrate is translocated as hexose.

There is no clear distinction in the root between a phase of growth and a phase of sucrose storage, for the very young roots have a high sucrose content. Growth and accumulation of sucrose proceed together.

On the mean of all sampling times, a significant increase of sucrose content was found in the leaf lamina, between 10 a.m. and 4 p.m. The corresponding increase in reducing sugar was smaller and not significant. The average changes during the day in the sugar content of the petiole were almost the same as those of the leaf lamina, but were not significant. There was no indication of any diurnal variation in the root.

Later sowing caused an increase in the reducing sugar content and, to a less extent, in the sucrose content of the leaf lamina, in the later stages of growth. The reducing sugar content of the petiole was similarly affected, but the sucrose content of petiole and root was always depressed by later sowing. The reducing sugar content of the root was also slightly decreased. These results suggest that the effect of later sowing, previously demonstrated, in increasing the size and weight of the leaves, was caused by a restriction of the movement of carbohydrate out of the leaf, rather than by an increased ability of the leaf to utilize assimilate in growth.

Later sowing depressed the total yield per acre of sucrose in the root.

- V. F. J. RICHARDS. "*Physiological Studies in Plant Nutrition. VIII. The Relation of Respiration Rate to the Carbohydrate and Nitrogen Metabolism of the Barley Leaf as Determined by Phosphorus and Potassium Supply.*" *Annals of Botany*, 1938, New Series, Vol II, pp. 491-534.

Barley was grown in sand culture at three levels of phosphorus nutrition. In three other series phosphorus and potassium were reduced proportionately.

Very considerable treatment differences were obtained in growth rate, final yield and weight of corresponding leaves ; these being almost entirely due to phosphorus and nearly independent of variation in potassium supply at any one phosphorus level.

Water content differences were comparatively slight.

Changes in respiration rate undergone during the first few hours in the dark are described and the results of Gregory and Sen (1937) confirmed.

Respiration rate was greatly reduced by phosphorus deficiency, the change with supply being greatest at comparatively high levels. When phosphorus

and potassium were simultaneously proportionally reduced, the fall in respiration was at first more gradual than when phosphorus alone was altered, but at lower levels the resultant change was greater.

Progressive phosphorus deficiency led to progressive reduction in protein content and progressive and considerable increase in amino nitrogen.

Total sugars and sucrose were in general reduced by phosphorus deficiency, while reducing sugar was increased.

Respiration was generally closely related to nitrogenous substances in the series with high potassium and phosphorus supply. As the level of phosphorus supply falls the content of reducing sugar becomes of increasing importance which is interpreted as evidence for hexose as substrate and the importance of phosphate for its breakdown.

- VI. W. E. BRENCHLEY. "Comparative Effects of Cobalt, Nickel and Copper on Plant Growth." *Annals of Applied Biology*, 1938, Vol. XXV, pp. 671-694.

A general review is given of the distribution and the physiological importance of nickel and cobalt, in relation to plants and animals.

Experiments on barley and broad beans were carried out in water cultures with the sulphates and chlorides of cobalt, nickel and copper. In every case a range of low concentrations did little or no damage, but toxic action occurred abruptly above a concentration which varied with the species and with the compound. With barley, copper was the most poisonous element in either compound, but the differences were not striking. Low concentrations of the sulphate were innocuous, but parallel low strengths of the chloride caused a slight significant depression in growth. With broad beans, cobalt was much more poisonous than either nickel or copper, particularly with the sulphate. No slight depression with low concentrations of the chloride was noticeable with this species.

The morphological response to toxicity varied with the element concerned. Copper, in poisonous strengths, caused shortening and "bunching" of barley roots, whereas nickel and cobalt permitted the growth of elongated roots of a very attenuated nature. The individuality of plant response to poison was frequently shown by the great variation in growth in the borderline concentrations just below those which caused marked depression of growth.

#### (b) ACTION OF MANURES

- VII. H. H. MANN. "The Weed Herbage of a Slightly Acid Arable Soil." *Journal of Ecology*, 1939, Vol. XXVII, pp. 89-113.

The weed herbage was studied on a light sandy loam of slightly acid character which has been under continuous wheat or barley cropping for over fifty years. The several plots had various manurial treatments to 1926 and no manures since that date. A fallow taken in 1934 and 1935 enabled the general character of the weeds to be determined during the season.

With most of the important annual weeds in the soil, roughly half the year's growth of plants germinated before the end of April. This does not apply to individual weeds as the dominant one (*Spergula arvensis*) germinates at any time in the year, while some of the others, notably *Polygonum aviculare* (March to May), *Gnaphalium uliginosum* (June to September) and *Chenopodium album* (May and June) were very seasonal.

A single year's fallow, even when accompanied by frequent cultivations, is not very effective in getting rid of the annual weeds. Two years' fallow brings about, however, a fairly large reduction, except with *Stellaria media* and *Poa annua*, neither of which appeared to be appreciably altered in amount.

Acidity of the soil induced by previous manuring with sulphate of ammonia, had a very great influence on the weed herbage, and when the pH value was lower than 5.0, the annual plants consisted almost entirely of *Spergula arvensis*, with a small amount of *Polygonum aviculare* and *Poa annua*. *Matricaria inodora*, though an acid loving weed, disappeared almost entirely when the pH value was less than 5.4, but was also reduced in amount when the pH value was greater than 5.8. *Polygonum aviculare* and *Poa annua* are by far the least sensitive to changes in acidity of all that were found on the plots studied.

The effect of long continued application of mineral manures was very small on the number of plants per unit area, except in the case of *Vicia hirsuta*,

which appeared as a serious weed only in the plots which had received mineral manures or farmyard manure, and then only when the pH value was over 5.6. The annual addition of farmyard manure for fifty years left a legacy of an increased amount of most of the weeds.

The effect of lime on the weed herbage is almost entirely governed by the change in acidity thereby induced. The lime did not appear to have a specific effect on any of the annual weeds examined.

The perennial weeds which tended to take possession of the plots were two "twiches," namely *Holcus mollis* and *Agrostis stolonifera*, which became serious in the more acid plots, while the more usual twitch (*Agropyrum repens*) was wholly absent in this sandy acid land. *Rumex acetosella* was common on the more acid plots and could not be got rid of even by a two years' fallow. *Equisetum arvense* occurred largely, though there was no sign of wetness anywhere in the field, and seemed to be rather encouraged by the fallowing of the land. *Convolvulus arvensis* only occurred in plots which had had mineral manures or farmyard manure in the previous half century, but its amount was hardly affected by even a two years' fallow.

- VIII. J. T. MARTIN, H. H. MANN and F. TATTERSFIELD. "The Manurial Requirements of *Pyrethrum* (*Chrysanthemum cinerariaefolium* Trev.)." *Annals of Applied Biology*, 1939, Vol. XXVI, pp. 14-24.

A small field experiment upon the manurial requirements of the insecticidal pyrethrum plant, grown upon sandy soil of low fertility, is described. Lime had the effect of producing slight, but not significant, increases each year in the yield of flowers and their content of the pyrethrins, and decreased the percentages of plant failures in the fourth and fifth years of the experiment. There was a significant depression in the yield of flowers in the year after the single application of double dressings of the manures, but no effect in later years. The yearly application of moderate dressings of manures gave significant increases in the yield of flowers in the second and fifth years, and significant increases in the pyrethrin I content of the flowers in the fourth and fifth years of the experiment.

- IX. H. H. MANN. "Investigations on Clover Sickness." *Journal of Agricultural Science*, 1938, Vol. XXVIII, pp. 437-455.

If a clover sick soil be defined as one on which a normal crop of clover cannot be grown, but on which only small dwarfed plants are produced, the clover sickness can be found in the absence of the usual fungi to which it has been attributed, and also in the absence of the eelworm (*Anguillulina dipsaci*) which generally accompanies it.

In the particular soil examined, no manuring with lime, potash, or phosphates, or with easily available nitrogen in the form of potassium nitrate had any considerable effect in enabling good growth of clover to be obtained. Two methods, however, were capable of temporarily giving good crops. The first was the heating of the moist soil to a temperature of 60 to 70° C. for 1 to 2 hours. The effect of this treatment, however, passed off in a few months after one or two crops of clover had been obtained. The second method was the application of a very large dressing of farmyard manure. This was at first quite effective, but the quantity needed was not such as could be used in practice. Where nearly 10 per cent. of the weight of the soil was added in the form of wet farmyard manure, the effect continued even after four successive crops of clover had been grown: where 3 per cent. of the soil weight was added, the benefit very rapidly passed away after the second crop.

- X. E. M. CROWTHER and R. G. WARREN. "Report on Pot Culture, Laboratory Work and Other Investigations." Appendix I to the Fifteenth Report of the Permanent Committee on Basic Slag, Ministry of Agriculture, 1937, pp. 4-11.

In pot cultures four types of basic slag were compared for perennial ryegrass and turnips on an acid Scottish soil and on a neutral sand-bentonite mixture with two depths of incorporation of the basic slags. The turnips in spite of damage by pests responded to slags on both soils, but the ryegrass

responded only on the artificial soil. The fact that rye-grass grew well on a soil on which turnips had failed completely from phosphate shortage in the field in the previous season suggests that some of the poor residual effects observed in field experiments are due to the ability of other crops to utilise soil phosphates which are not available to swedes. In the pot experiments in the soil but not in the sand the turnips gave better results when the slags were concentrated in a narrow band than when they were distributed more diffusely.

In conjunction with the Forestry Commission two experiments were laid down on young trees in Scotland to test three rates of application of three slags and mineral phosphate.

- XI. E. M. CROWTHER and R. G. WARREN. "*Report on Pot Culture, Laboratory Work and Other Investigations, 1937.*" Appendix I to the Sixteenth Interim Report of the Permanent Committee on Basic Slag, Ministry of Agriculture, 1939, pp. 4-9.

The pot experiments of the previous year were continued with clover, perennial rye-grass and timothy. In the sand cultures, from which about half of the citric soluble phosphoric acid of the slags had been removed in the previous year's crops, the clover failed and the two grasses did not grow well. In the soil all three crops grew well but the responses to basic slag residues were so small that it was not possible to differentiate between slags or between the responsiveness of the different crops.

Laboratory extractions under controlled pH values brought out the unexpected result that the relative solubilities of two medium soluble slags were different in citric acid and in other acids at the same pH value.

- XII. E. M. CROWTHER (with D. N. McARTHER). "*Report on Field Experiments in 1936.*" Appendix II to Fifteenth Interim Report of the Permanent Committee on Basic Slag, Ministry of Agriculture, 1937, pp. 12-22.

Four field experiments were conducted on swedes to compare two rates of application of three less soluble types of slag with four rates of application of a high-soluble slag. The yields from the less soluble slags were generally similar to those from high soluble slag supplying equal amounts of citric-soluble phosphoric acid. The phosphoric acid contents of the dry swedes were increased considerably by the higher rates of application of the more soluble slags and this allowed comparisons of the slags to be made over a much wider range than was possible from the yields alone.

- XIII. E. M. CROWTHER (with D. N. McARTHER). "*Report on Field Experiments in 1937.*" Appendix II to the Sixteenth Interim Report of the Permanent Committee on Basic Slag, Ministry of Agriculture, 1939, pp. 10-22.

Five experiments similar to those of 1936 again gave very steep response curves to basic slag, one-eighth of the customary dressing of high-soluble slag doubling the yield of swedes. Such results emphasise the importance of working well below the upper limit of yield in comparing the availabilities of different slags. The results were generally related to the amounts of citric soluble phosphoric acid supplied, except that those from the more soluble of the two medium-soluble slags were definitely better than would have been expected on this basis. This failure of the citric acid method was far more striking than in any of the three preceding years.

#### STATISTICAL METHODS AND RESULTS

(Department of Statistics ; and Field Experiments Section)

##### (a) THEORETICAL

- XIV. F. YATES. "*An Apparent Inconsistency Arising from Tests of Significance Based on Fiducial Distributions of Unknown Parameters.*" Proceedings of the Cambridge Philosophical Society, 1939, Vol. XXXV, Part IV.