COMPLEXITIES IN PLANT NUTRITION AND THEIR RELATION TO MANURING PRACTICE

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In a recent article (Tolhurst, 1959) dealing with the more obviously practical aspects of manuring, I mentioned that the problems there encountered could often be increased by the inevitable splitting-up of the manurial chemicals into highly reactive component parts. The reactions which occur between the manure and the soil are of great practical importance, but in the present note I wish to emphasise the parallel group of reactions between the manurial components and the plant, hoping thereby to promote a better understanding of some of the reports on manurial experiments which have been and will be issued (Tolhurst, 1960). Unless there is an appreciation of the basic priciples involved in plant nutrition, here referring to the uptake of plant food from the soil, it is highly probable that successive reports will give the impression of undue fickleness.

Plant roots are not merely syphon tubes but are very active organs which have to work in order to extract most of the required plant food. To do this they must themselves be fed, relying on the manufacture of carbohydrates in the leaves to provide fuel. To a certain extent, roots are selective in their uptake of nutrients, but this feature is easily upset, sometimes because there is an unusually large amount of one plant food in the neighbourhood of the roots.

It is well known in physiological research that a delicate balance may have to be kept between certain nutrients, if both are to be taken up by a plant in adequate amounts. Two plant foods which show a strong *antagonism* are calcium and potassium. If the proportion of calcium in the soil is increased too greatly, then potassium deficiency will occur inside the plant, even though the external supply of potassium to the roots would have been sufficient had there been less calcium. Similarly, an undue increase in potassium will lower the efficiency of uptake of calcium. In this instance, the ratio between the two plant foods is of paramount importance, while the actual level of each nutrient is of much less importance. Instances are known where plants may be able to absorb sufficient magnesium from a particular soil if nitrogen is applied in the nitrate form, but may suffer from magnesium deficiency if ammonium is used as the source of nitrogen. This appears to be a direct effect of the latter form of nitrogen and the examination of magnesium deficiency symptoms arising in this way would involve more than a simple analysis of magnesium levels.

Not all nutrients display antagonistic tendencies and instances are known where the presence of one plant food may increase the uptake of another nutrient; for example, ammonium nitrogen favours the uptake of phosphate by many plants. This is true *synergism*, but an impression of synergism may arise in a devious way. Suppose that nutrient x depresses the uptake of nutrient y and vice versa (antagonism). A third nutrient, z, may then be introduced into the region of the plant roots which also depresses the uptake of y, thereby allowing a freer passage to x. The final picture could thus be that nutrient z assists (synergises) the uptake of nutrient x. We have reason to believe that something of this nature has actually occurred on one of our long-term manurial trials, involving boron, calcium and potassium as nutrients x, y and z, respectively (Tolhurst, 1960.)

Even when plant foods have passed such obstacles and have been transported into the foliage of a plant, in apparently sufficient quantity, it may still be found that symptoms of malnutrition may occur. Iron, an essential nutrient for plants, is notoriously subject to interference within the plant. Several elements, some themselves essential plant foods, if present in the plant tissues in too great proportions, may transform iron into a form which is largely useless to the life cycle within the cells. It has often been observed that iron-deficient leaves, obviously suffering severely, have more iron than corresponding healthy leaves. Manganese, again an essential plant food, is perhaps the chief culprit, and we have evidence that an excessive uptake of manganese by tea is not uncommon, giving rise to a chlorosis of the leaves which can be partially cured by iron-containing sprays. The reason for the accumulation of manganese in the bush is probably linked with the use of sulphate of ammonia as a manure. We do not suspect, however, a synergism of nutrient uptake, whether direct or indirect, but rather a straightforward chemical reaction between the soil reserves of manganese and the manure. It may further be of interest to note that some species of plants have been known to take up more manganese when grown under conditions of higher intensity of light, thus introducing yet another complicating factor, and one which has to be borne in mind when assessing the value of soil analyses for manganese. It is also known that many plants, and perhaps all, require higher levels of potassium in the foliage if they are to remain free from deficiency symptoms when grown under high intensities of light. Here, the interpretation of chemical analysis of the leaf would need to take such factors into account, and we have already begun to use more than one standard of interpretation for potash deficiency in tea, according to the climatic zone.

On the face of it, such studies have a nightmarish quality, and it may be seen why in this subject we are so rarely able to give a direct answer to an apparently simple question. It may also be seen why field trials of considerable complexity are necessary, with repetition under different conditions. We not only have to determine the optimum *level* of each plant food to be applied as manure, but also the safest *ratios* between two or more nutrients and, as these two considerations may affect each other, we would need to experiment with varying combinations of the chosen treatments. We would have as many different *levels* as we wished, and we would have to consider five major manurial nutrients, nitrogen, phosphorus, potassium, calcium, magnesium, even if we were to omit actual treatments with the micro-nutrients, *viz.* manganese, iron, boron, etc. If we were to design an experiment with all possible combinations of five nutrients each at three levels we should have 243 different plots, even without replication. It would still be necessary to repeat this pattern to test the influence of different soil types and climatic conditions, which can, as has been hinted above, play their own part in deciding the efficiency of manurial levels and ratios. Now suppose that various methods of distribution and timing of the manure mixtures were to be tested as well, and possibly different methods of cultivation. The number of combinations would reach four figures for each experimental site, and to avoid this we resort to statistical techniques whereby smaller experiments can be designed to test some of the many possible combinations. Such mathematical designs also enable us to decide to what extent a difference in, say, yield between two treatments is likely to have been due to the treatments themselves or to some unknown factor, or to the large number of factors that we call chance. In other words, we aim to estimate the odds for and against a certain result occurring if a certain treatment were to be repeated elsewhere, or were to be recommended for practical adoption by estates.

Yield records provide an excellent and eminently practical way of finding out how the bush has reacted to various treatments. They are not so helpful in deciding why such responses have occurred, and still less helpful in predicting what may happen in the future. Therefore chemical analysis, both of the soil and of the bush, has to be brought into the picture, but bearing in mind that caution is required in the application and interpretation of such analysis. There are many and varied methods, for example, for the extraction of nutrients from the soil but it is not possible *a priori* to use the results of any one of these methods in predicting the ability of a soil to supply nutrients to the tea bush, until we have actually assessed the reaction of the bush itself to that particular soil. Several examples quoted in these notes will have shown how complex the interaction between bush, climate, and soil can be, and may serve to show why we place so much stress on the necessity for well planned field trials, under varied conditions, run in conjunction with chemical investigations.

References

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