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FEEDING OF PLANTS THROUGH LEAVES

by

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FROM the point of view of the health of plants, optimum leaf function is of paramount importance. The leaves are the chief organs of photo-synthesis in the plant, the efficiency of which determines crop health and yield. The composition of the leaves of a plant reflects to a very large extent the nutrient conditions of the soil environments. This fact is, of late, being largely used by agricultural advisers to determine from the analysis of the leaves of plants the nutrient status of the soil, the existence of nutrient deficiencies, the optimum needs of the crop, etc. Thus, the phosphate content of herbage has for long been recognised as a good reflection of the available phosphate supply in the soil. The mineral contents of plant leaves can be adjusted within limits by suitable use of fertilizers and the dependence of the relative concentrations of the cations in the leaves of a plant on their relative concentration in the soil as available or exchangeable ions, has now been put on a semi-quantitative basis for several crop plants.

The soil system as the usual environment for plant feeding

The time-old method of crop fertilization is by the application of the manure or fertilizer to the soil around the plant roots. From this medium the nutrients pass into the root system and then to the leaf tissue where most of the bio-synthetic products of the plant are first formed. The end products are then translocated into the appropriate part of the plant system.

The response of the plants to the manures or fertilizers applied to the soil depends upon many factors such as the type of soil, the nature of the crop grown, the method of planting, previous record of soil management practices, the kind and amount of fertilizer used, climatic conditions, etc. Under certain combinations of soil and climatic conditions several crops do not respond to manures supplied. Individual fertilizer ingredients behave differently in the soil. They are not so readily available to the plant and are not utilised immediately they are applied. Phosphatic and potassic fertilizers get fixed into the soil to varying degrees depending upon soil composition. In the case of potassium and nitrogen, there is the possibility of leachage losses, particularly in sandy soils in regions of heavy rainfall. These considerations show that although the method of soil fertilization is the accepted traditional practice, it is not always that it fulfils the desired purpose of feeding the plant to the extent expected or required.

Extra root or aerial fertilization of plants

As a result of continued cropping and the use of more highly purified and concentrated materials for manurial purposes deficiencies of certain elements of plant nutrition like iron, manganese, zinc, copper, boron, molybdenum, calcium, magnesium and sulphur frequently appear in cultivated plants. Only in very recent years, our knowledge of these plant nutrient factors and suitable methods of diagnosing their deficiencies have been placed on a sound basis. Since most of these nutrients are needed only in very minute quantities, the practice of applying them by special methods such as spraying, dusting or injection into the plant became popular. Application of major nutrients by sprays to agricultural and horticultural crops is also being done on an increasing scale in the U.S.A. That the nutrients in the form of dilute aqueous solutions are easily absorbed from leaf surfaces and that this has the supreme advantage of acting effectively almost immediately have rendered the foliar feeding of plants a preferred method in several special cases.

With the recent improvements in the formulations of concentrated and highly soluble fertilizer materials and the development of convenient machinery for spraying insecticides, fungicides, weed-killers, hormones, etc., the spray method of application of fertilizers to plants has become more practicable. Experiments have proved that sprays containing several plant nutrients could easily get absorbed into the leaf and could increase the nutrient content of the plants by as much as 100 per cent and might in some circumstances cause similar increase in the dry weight. It need not be that nitrogen, phosphorus and potassium were all absorbed by the leaves because absorption of any one or two by the leaves, could increase the uptake of others by the roots also. For example, the use of nitrogen-containing sprays has been shown to help in increasing the absorption of phosphorus and potassium by the roots from the soil and that potassium sprays could increase the absorption of phosphorus from the soil. Trials carried out with individual nutrients and nutrients in combination showed that all the nutrients were absorbed through the leaves and that the uptake of any one of them was unaffected by the presence of others in the spray.

Methods of leaf feeding and limitations in use

Nutrients can be usually applied as dusts or sprays by convenient dusters and sprayers now available everywhere and without much cost. The former are used for pubescent leaves, and are cheaper although not as efficient as sprays. High water solubility is a necessary requirement for a nutrient to serve as a good spray material. This at once provides the facility of diluting the solution to the required or desired strength. The rate of spray application will have to be adjusted to suit the time of application, the nature of the crop, the size and extent of the foliage or the crown of the plant, etc. Concentrated sprays may lead to defoliation, leaf burn or leaf scorching and destruction of the growing points. Different plants require and tolerate different concentrations of salt solutions. The frequency of the spraying is also an important point deciding the effects. The concentration and frequency of application of the spray material have to be carefully explored in respect of each crop before large-scale spraying is adopted.

Nitrogen is the major nutrient which is most easily applied by the spray method, because both urea and ammonium nitrate are highly soluble and rich in nitrogen, and dilute solutions of these contain relatively high nitrogen concentrations. Urea usually scorches less than ammonium nitrate but both should be used with caution. Spray applications of phosphorus which is easily fixed in the soil, might be an economical method of using the element, but phosphorus appears to have been applied in sprays much less frequently than nitrogen. Examples of spray application of potassium are also scarce although reported results indicate that this method has been useful.

When nutrients are added to fungicidal or insecticidal sprays, the likelihood of the phytotoxicity of the spray solution being increased should be borne in mind. Lime addition is very helpful in such cases. Micro-nutrient deficiencies are in many cases due to the soil conditions and can, therefore, be better cured easily by spray than by soil applications. Corrections of manganese deficiency in pear and beet-roots and boron deficiency in turnips are good examples of such use. The usefulness of the foliar feeding is limited in the case of annual crops because those most in need of the fertilizer, viz., the young or starved crops have only small leaf area for effective absorption. It is thus necessary for leaf feeding to be effective that there must be sufficient leaf surface to retain the spray.

Trends of results reported

Foliar feeding of plants has now been practised by agriculturists in different parts of the world to a greater or lesser extent. It has no doubt shown to be able to reduce acute deficiency symptoms in several plants, but it has not afforded any effective control in several cases. Quite a good deal of information has been published of the experiences in plant nutrition studies by adopting the foliar feeding method in the case of a number of plants. In general, it was found that several plants such as barley, bean, tomato, sugarbeet, etc. grown in soil in pots receiving nutrient solutions containing N. P. and K. and a spreader had higher nutrient contents and dry weights than control plants sprayed with water and spreader only. Increase in nutrient content occurred with high or low levels of nutrient supply to the roots and was approximately proportional to the concentration of spray and to the frequency of spraying. The nitrogen content of sugarbeet plants was increased equally by spraying with solutions supplying ammonium sulphate, calcium nitrate or urea in equivalent concentrations. But very often the nature of the salt used for foliar feeding had some influence. For example, in the grapes, magnesium chloride sprays on the leaves, not only prevented chlorosis but also increased leaf concentration of magnesium, while either magnesium nitrate or other salts, or even chelated magnesium were found to be unsatisfactory as foliar sprays. Nutrient uptake from solution sprayed on leaves influenced uptake by the roots so that the additional amounts of the nutrients contained in the sprayed plants may be greater or smaller than the amount absorbed from the spray by the leaves. Spraying of potato leaves with 0.01 to 0.'5 per cent. solution of salts of copper, zinc, cobalt, manganese and boron increased tuber yields by 25 to 78 centners per hectare, the highest yield increase being registered in podzolic soils. Addition of glycerine to nutrient sprays increased the absorption of phosphorus and potassium and certain other minerals by the plant system. The rate of absorption was increased by addition of sugar to the spray. The inclusion of starch, molasses or sulphur bentonite in the sprays did not increase the effect of urea on shoot growth of peach, but molasses enabled greater quantities of urea to be applied without foliage injury. Mitigating the hazards of plant injury is a property possessed by sugar solutions when used in urea sprays.

The efficiency of the absorption has been found to vary with different species of plants. Coffee seedlings developed symptoms of interveinal chlorosis although adult coffee in bearing did not, when sprayed with urea solutions every week, for 24 weeks. Two successive sprays with 0.3 per cent. and 0.5 per cent. solutions of a 40 per cent. nitrogen fertilizer followed by spraying with a 0.5 per cent. solution of a complete fertilizer (0.7 per cent. each of N. P. K.), almost doubled fruit setting in olive. Several nutients like urea, potassium or calcium glycerophosphate solution, potassium chloride, orthophosphoric acid, etc., mixed with standard fungicides and hormones gave good results in the case of cocoa trees. The application of 44 per cent. organic nitrogen preparation at 5 lb. per 200 gallons of water has shown good possibility for figs, olives, walnuts but not for stone fruits. Pear and plum seedlings planted in well fertilized soils were sprayed with solutions containing all the major and micro-nutrients. At the end of one growing season the sprinkled pear seedlings showed an increased height growth of 23.8 per cent. and leaf growth of 11 per cent. over the controls, the corresponding figures for plum seedlings being 29 per cent. and 21 per cent. Studies on the effect of spraying and soil application and spraying of various doses of urea and ammonium sulphate on the yields and juice quality of sugarcane showed that the application of 20 lb. of nitrogen per acre as aerial spray following an application of 50 lb. of nitrogen per acre was as good as 100 lb. per acre applied in 2 doses to the soil in respect of yield. In regard to sucrose percentage, this was better than soil application alone. Spraying wheat with urea at a concentration as low as 1 per cent. in the absence of basal manuring resulted in a significant increase in the protein content and wheat yield. Spraying winter wheat at ear emergence with 3 per cent. ammonium nitrate at 10 gallons per acre also increased the yield and nitrogen content of grain and straw to the same extent as applying the same solution to the soil at the same time. Solutions of phosphorus and potassium increased the sugar content of beet in field experiments.

Urea used widely as a nitrogen leaf feed

Being a nitrogen-rich, soluble and an easily available fertilizer substance, urea has been very much used for the quick foliar feeding of nitrogen to plants. A very large number of papers on the use of urea for foliar spraying and its influence on several plants have been published. In trials carried out over three years the use of urea foliage sprays was compared with standard fertilizer schedules on some fruit trees. There was quick response to urea in leaf colour and fruit set if the trees were showing nitrogen deficiency symptoms. In field trials involving soil and/or foliar application of urea at the rates of one-third to three lb. per tree of nitrogen, spraying at one lb. nitrogen was found equivalent to soil treatment at two lb. nitrogen for the production of oranges. Higher rates especially when applied to the soils, produced fruits with thick peel, low juice per cent. and low vitamin C content. With an admixture of 2-4 Dichlorophenoxy acetic acid, urea sprays increased orange size. The uptake of urea was increased by high leaf nitrogen and is in general absorbed very quickly by apple leaves, figs and pears and several other species. Stone fruits (cherries and plums) are generally poor urea absorbers. The inclusion of maize starch, molasses or sulphur bentonite as fixatives in urea sprays did not increase the effect of urea to be applied without leaf injury in the case of the peach tree. It has been shown that in sandy soil with nitrogen deficiency leaf feeding of urea was as effective for apple trees as nitrogen application to the roots, and this also improved the colour of peach foliage. In apple, the leaf protein is increased in two to four days after treatment, particularly in young leaves. There is evidence to show that urea nitrogen appeared to be readily assimilated in the green leaves and did not affect juice quality in citrus. A significant positive correlation was shown to exist between leaf nitrogen and fruit yield in the first season in apple with urea leaf sprays. 0.1 per cent. sodium alkyl sulphate ('Dreft') is a good wetting agent for urea applications to leaves of vegetable crops like tomato, celery, cucumber and beans, the yield increases in all cases being significant. Mixed sprays of urea with fungicide and hormones have substantially reduced the withering of cocoa pods which is a physiological disease.

Preliminary attempts on feeding urea and other nutrients to seedlings and adult coconut palms through foliage have been taken up and are in progress in order to study the possibilities of leaf feeding of this crop.

Factors influencing the uptake of nutrient from leaves

Several factors influence the uptake of nutrient elements from leaf surfaces when fed as sprays. Among these may be mentioned the age and vigour of the plant, the time of the day when the spraying is given to the leaf, the temperature and humidity conditions as well as the concentration of the spray solution. Young foliage taken up nutrients more readily than old. Uptake usually increases with temperature. Acidity or alkalinity of the spray mixture has some influence on the uptake of the nutrients by the leaf. Leaf surface, upper or lower, has also got some influence. For example, in young apple leaves the lower leaf surfaces readily absorbed urea at a greater rate than did upper surfaces.

Properly timed sprays have been shown to increase the sugar content of beets, improve the set of cotton bolls, increase the yield of cabbage and other crops where low soil temperatures are not favourable to nutrient uptake by the roots. Whether the uptake of a nutrient by the leaf depresses its uptake from the soil has not been determined fully. To distinguish between nutrients absorbed by the two routes, use of labelled nutrients has been successful. None of the nutrients applied to the soil had any effect on the percentage of nitrogen that was retained on the leaf.

The uptake of phosphorus from a variety of compounds supplied in sprays has been studied and it was found that the growth of tomato, maize and beans was increased by orthophosphoric acid and potassium or ammonium phosphates, but magnesium and most organic phosphates had little effect. Foliar use of various salts containing P 32 and studied autoradiographically showed that the different compositions had no significant influence upon the rate of absorption. Absorption took place even after the dessication of the solution. The resorption of phosphate ions by the leaf epidermis may be limited predominently by internal factors. Phosphorus absorption from leaves and translocation to other parts of the plant are very rapid. The absorption of P 32 by swede leaves increased for two to three days after a single application and then remained constant for another ten days at about 50 per cent. of the amount applied. Trebling the concentration of the solution fed to the leaves increased the percentage absorbed slightly but significantly.

Potassium uptake by sugar-beet leaves from potassium chloride sprays was increased by nitrogen applied to the soil in the same way as was the nitrogen and phosphorus uptake. Leaf absorbed potassium appeared to be more when nitrogen was added to the soil and reduced by potassium. This may be due to the reduced uptake by plant roots with a high supply of potassium from the soil when sprayed with potassium containing solutions.

Several zinc and manganese chelates were used for figs on foliage sprays and the average twig growth was greater on all the treated plots than in the control. Foliage analysis showed that zinc was the readily absorbed element of all the nutrients used *viz.*, zinc chelates, potassium di-hydrogen phosphate, zinc sulphate+lime and zinc+manganese chelate or iron chelate. There was no evidence of potassium absorption in this case but confirmed earlier findings that phosphorus was readily absorbed. Indeed, soil deficiencies of iron and zinc are not at all easy to correct in mature fruit trees by soil application, and leaf feeding is the answer to this difficulty.

The fate of leaf-fed nutrients

Most of the nutrients retained by the leaves from sprays are absorbed. The percentage recoveries of nutrients from sprays are, therefore, greater than those obtained from the fertilizer applied to the soil. The dry weight increases per unit of nutrient absorbed through the roots, were found to be greater than for nutrients absorbed through the leaves. The mechanism of leaf absorption is not quite well understood. Phosphorus applied to the foliage is transmitted down the stalk to secondary shoots. There is evidence that nutrients like nitrogen from foliage sprays do not get accumulated in the leaf. Seventy per cent. of the nitrogen applied in leaf sprays in sugar-beets whether as ammonium nitrate or urea was recovered in the plant and 30 per cent. was found to be converted into leaf protein. Hydrolysis of the urea occurs in the plant leaves and this is taken as an index of the extent of utilisation of the urea nitrogen by the plant. In celery and potato the tolerance was higher than in cucumber, bean, tomato and maize. There is definite evidence that almost all the nutrients could be absorbed by the leaves from sprays, all traces retained by the leaf also being ultimately taken in.

Proprietary foliar fertilizers

Several commercial, highly soluble mixed fertilizers have been developed for application as sprays and are being marketed under different trade names such as 'Folium', 'Nu-Green', 'Uramon 50', 'Rapidgrow', etc. These are reported to have given beneficial results on different crops such as avocado, orange, strawberry, several avenue trees as well as roses, tomatos, yews and grasses.

Conclusion

Field experiments have established that the effects of nutrient sprays are usually of the same order as for soil dressings and rarely more than two or three times greater. Thus, it can be seen that foliar feeding does not result in any great saving in fertilizer. Nevertheless, this can be preferred to soil application under certain conditions with definitely better results, on occasions such as when the soil conditions or a competitive crop make the nutrients from the soil dressings unavailable, or as an accurately timed response to manures are required such as a change in the composition of a crop late in the season or as the routine applications of insecticidal or herbicidal sprays to which nutrients can well be added are made, or again as the growth of the crop prevents application of fertilizer to the soil but permits it to the leaves from a sprayer. Feeding of plants through the leaf is certainly liable to be more expensive. However, the effectiveness of the plant leaf to readily absorb mineral nutrients and show striking results in a very short time, the ability of the spray method as a tool to confirm mineral deficiencies in crops and the spectacular amelioration which some of the micro-nutrient sprays have brought about in several plant nutrient deficieney conditions etc. all give overwhelming support to the great importance of foliar feeding as a means of plant improvement.

Considering all the aspects of plant nutrition by the leaf feeding method in a review of the present position, Boynton (1954) concludes that in view of the complex physiological and economic problems, it seems unlikely that foliar application of nutrients will supplant the traditional method of soil application as a general fertilizer practice. It would be quite appropriate to conclude by quoting Dr. Thorne, a Rothemsted authority who wrote "although it is now well established that fertilizers applied in leaf sprays can be absorbed by crops and in some circumstances are more effective than fertilizers applied to the soil, the method is not likely to become very wide-spead". Doubtless, the method would remain satisfactory for elucidating a number of special problems such as theoretical studies on the mineral nutrition of plants.