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The Place of Minor Elements in Growing Food Crops with Special Reference to Rice

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With more refined methods of chemical analysis and experimentation, a larger number of elements has been found in recent years to be essential for the healthy growth of plants than was previously supposed. Attention has also been focussed on the infertility of soils due to deficiencies of the so-called 'minor' or trace elements. Plants in general need about a dozen elements for proper growth. These may be grouped into (a) the primary major elements consisting of nitrogen, phosphorus and potassium; (b) the secondary major elements like calcium, magnesium and sulphur; and (c) minor elements consisting of iron, manganese, boron, zinc, copper and molybdenum. This last group is needed only in very low concentrations, varying from half to 400 parts per million of the nutrient solution. The terms major and minor are not to be taken as referring to the relative value of these elements to plants, since all are essential, but only as indicating the relative quantities needed by the plant. It would seem preferable to use the term "trace elements" in place of the term minor elements, as less liable to cause confusion.

Besides these twelve elements, plants have been found to contain normally, silicon, chlorine, sodium and aluminium and occasionally chromium, cobalt, iodine, lead and selenium as well, but these should be regarded more as adventitious elements that are not really essential, though some of these are claimed by certain workers to be helpful for better plant growth. These are referred to here merely to point out that they should not be confused with the essential trace elements mentioned above.

The relation of trace elements to the nutrition of the rice plant has not so far been studied in India to anything like the same extent that the primary major elements nitrogen, phosphorus and potassium have been studied. It has also been a common criticism that the average rice yields in India are very low compared to those reported from countries like Japan, Italy and Spain.

Infertility of soils due to deficiencies of trace elements is nowadays well recognised and is being studied with great attention in Western countries. During the war years field experiments were conducted in England on wheat, potatoes and broad beans as part of a programme of work on mineral deficiency sponsored by the Agricultural Research Council. The crops were sprayed with solutions containing different proportions of trace elements like *Fe*, *Mn*, *Cu*, *Zn*, and *B* and it was found that yields were often improved to a remarkable degree by such treatments. For instance, a field of potatoes showed very distinct foliar symptoms of manganese deficiency. A closer study revealed that zinc was also deficient, and when both the elements were supplied at the same time in spray form of their salts, the yield of tubers was increased from seven tons to nearly eleven tons per acre. In Holland, a type of crop failure known as "reclamation disease" has been traced to a deficiency of copper in the soil and found to be remedied by dressings of a few pounds of copper sulphate per acre.

For Indian crops and soil conditions there is unfortunately no data which can be taken as a guide, but considering the general low level of nutrition under which nearly all our crops are raised, it seems likely that addition of trace elements might improve the yields in most localities. Where new areas are reclaimed and put under food crops as part of a general Grow-More-Food Campaign it would be found that many of the nutrient elements are in a form unavailable for the good growth of plants.

A brief account of the relationships that exist between trace elements in rice nutrition is given in the following paragraphs. Incidentally it may also be useful to touch upon the three secondary major elements viz., calcium, magnesium and sulphur in relation to rice growing, although strictly speaking, they do not come under the category of minor elements.

Calcium. The quantity of calcium that is present in the average soil is usually so large that it is very seldom that we find a soil that does not contain sufficient amounts to supply the nutritional needs of cereals, though they may be sometimes insufficient for leguminous crops. Cereals rarely take up more than 25 lb. of calcium from an acre of soil, whereas legumes take up to 100 lb. per acre. The available experimental evidence of response of rice to liming is not very definite. Small doses of slaked lime of 5 to 10 cwts. per acre appear to mobilize the available phosphorus in the soil and increase the P_2O_5 content of grain and straw, and incidentally improve also the green colour of the foliage, but the effect is too small to be of any practical use.

Magnesium. A deficiency of magnesium is seen first on the older leaves, in common with deficiency symptoms of other major elements like nitrogen, phosphorus and potassium. In all these cases, there is rapid senescence, but colour differences and other features serve to differentiate between these different elements under field conditions. On the other hand, a deficiency of calcium or sulphur in rice affects the younger leaves first, which show chlorotic symptoms. It has also been found that a deficiency of trace elements like iron, manganese or boron affects first the younger leaves of rice.

Sulphur. It is a strange but undeniable fact that although sulphur is absorbed by plants in amounts often exceeding that of phosphorus, very little is known about the relation of this element to rice nutrition. Sulphur-deficient rice plants are distinctly chlorotic. This chlorosis is liable to be confused with the paleness caused by nitrogen deficiency, but a closer examination of affected plants would show that sulphur-deficient plants have a well-marked yellowish-green colour which is more pronounced on the younger leaves whereas in nitrogen-deficient plants the older leaves are paler than the young leaves. In leaf size, tillering and plant height also, *S* deficient plants are much below normal. As the season advances these chlorotic plants turn deep green in colour and remain green at harvest time, in marked contrast to the golden colour of normal ripe plants. The yield of both grain and straw are greatly reduced in plants suffering from a lack of sulphates. Similar symptoms characteristic of *S* deficiency are observed in other crops also, such as maize, sugarcane, lucerne, tobacco and citrus trees.

Analytically, *S* deficiency in rice is associated with an accumulation of nitrogen in the grain and straw. On manuring with sulphates this abnormal nitrogen content becomes normal. Iron and manganese content also tend to be lower than normal in *S* deficient plants. Ten pounds per acre of sulphur or its equivalent weight as sulphates is sufficient to correct the symptoms characteristic of sulphur deficiency. Applications of farmyard manure are not ordinarily sufficient to correct the deficiency, where it is acute enough to manifest itself on the foliage of rice plants.

Iron. A chlorosis caused by the deficiency of iron is perhaps the best known disorder of the rice plant. The symptoms are: (1) Reduction in height, leaf area, tillering and root development; (2) A marked paleness of the young leaves although the older leaves may often remain green. Rice requires iron throughout its growth period. Under greenhouse conditions iron deficiency can be easily produced either by witholding iron from the culture solution or by maintaining an alkaline reaction or by increasing the level of phosphorus when iron gets precipitated and becomes unavailable for plant growth. Under such controlled conditions, maximum growth is obtained with 32 parts of iron per million of the culture solution, though good growth is possible even with amounts as low as 8 parts per million. Below 2 p. p. m. however, iron-deficiency symptoms become apparent on the plants.

Under ordinary wetland conditions, iron chlorosis in rice is fortunately not very common, though it does occur sometimes in highly calcareous soils. This is because soluble iron is present in sufficient amounts in such waterlogged conditions, particularly when there is sufficient organic matter incorporated as green manure. When iron deficiency actually develops, as on calcareous soils it is useless to expect to correct it by adding iron salts to the soils. Repeated sprayings with a solution of ferrous sulphate are necessary to correct the disorder. For most soils, farmyard manure or other organic manures usually suffice to prevent iron deficiency. The total iron content of a rice crop is about 1 lb. per acre, which corresponds to about 5 lb. of ferrous sulphate. An excess of iron is not known, at least so far, to be toxic to the rice crop.

Manganese. In the case of rice, both iron and manganese are needed in much larger amounts than for other crops. The two elements also form a sort of complementary pair in rice nutrition; thus an excess of soluble *Mn* leads to iron unavailability and induces iron deficiency symptoms of chlorosis. Manganese deficiency may occur in very light sandy soils as well as in calcareous soils, but not as a rule in soils that are acidic in reaction. Specific instances where this element is deficient for rice plants seem to be rare under field conditions, although the deficiency can be readily induced in pot cultures. In rice-growing the danger is more from an excess of manganese rather than its deficiency, as the element readily goes into solution in water-logged soils and reaches toxic limits of concentrations. Under such conditions relief can be obtained by spraying the crop at frequent intervals with a solution of ferrous sulphate. Addition of iron salts to the soil is not very effective. Other means of reducing the manganese content to non-toxic limits are (1) by drying the soil before preparing the land for growing rice; (2) by the use of leguminous green manures and (3) by massive additions of calcium carbonate to the soil.

Boron. Boron deficiency in the case of rice is practically unknown under field conditions, although it has been reported in various crops, especially as a result of overliming the soil. Such lime-induced boron deficiency is believed to be due to the excessive absorption of Boron by microorganisms. In ordinary fertile soils, the available boron content is about 2 parts per million, corresponding to 5 lb. of Boron or 25 lb. of Boric acid per acre. Since the Boron content of an acre of rice is below 2 oz. *B* deficiency for rice would be most unusual.

Zinc. Zinc deficiency in rice has been reported from pot cultures but not so far under field conditions. At concentrations below 0·2 p. p. m. of zinc, the leaves of young rice plants become chlorotic and the plant becomes stunted. Rice growth is optimum at 0·8 p. p. m. of zinc and keeps good upto 2 p. p. m. but beyond that, toxic symptoms, in the form of a general chlorosis set in. A deficiency of zinc is likely to occur in leached sandy soils, and in calcareous or over-limed soils. The small amounts of zinc needed by rice soils can usually be secured by the use of town compost.

Copper. A deficiency of copper causes wilting in rice plants with marginal chlorosis of the young leaves. Grain formation is also very much impaired. For ordinary field conditions, about 25 lb. of copper sulphate per acre would seem to be a safe dose where a deficiency of this element is to be corrected, although cases have been reported where 100 to 200 lb. per acre had proved highly beneficial in increasing the grain yield in rice. Fifty to seventy-five pounds of blue vitriol are used as a remedy for die-back in orange trees in the citrus groves of California and Florida. Newly reclaimed areas, in many parts of the World have been found to be liable to produce copper deficiency in the crops grown thereon. So this has to be looked out for and avoided in our province, wherever new areas are programmed to be brought under rice cultivation.

Molybdenum. In solution cultures rice plants appeared taller and healthier when ammonium molybdate was added to supply 1 p. p. m. of molybdenum, but an absence of the element did not induce any well-marked deficiency symptoms.

Silicon. Rice, barley, maize, sunflower and red beet are the crops that have been reported to show a favourable response to added silicon, but the essentiality of this element is not yet fully established for crop growth. Sodium fluoride has been reported by some Japanese workers as inducing a stimulating effect on rice growth, at the rate of 1 oz. per acre and toxic above 1 lb. per acre. Potassium iodide also stimulated growth at 0·5 oz. per acre and proved toxic above 3 oz. per acre.

Summary:

The nutrient roles of the trace elements in plant growth are briefly outlined. When new areas are reclaimed and put under food crops it is likely that many of the trace elements are in a form that is unavailable for plant growth. In the case of rice, iron and manganese are needed in larger quantities than for other crops. They form a complementary pair in rice nutrition: thus an excess of *Mn* in a soluble form, leads to the iron becoming unavailable and sets up iron deficiency symptoms. Judging from the remarkable results reported from England during the War years, of growing potatoes, wheat and other crops in newly-reclaimed waste lands it would seem worth studying the effect of spraying suitable concentrations of trace element salts on rice yields. This is an aspect that merits a fuller study in view of the importance of food crops at present and rice in particular.