SHIRISH CHANDRA AGARWALA

(11 May 1919 – 24 July 1995)

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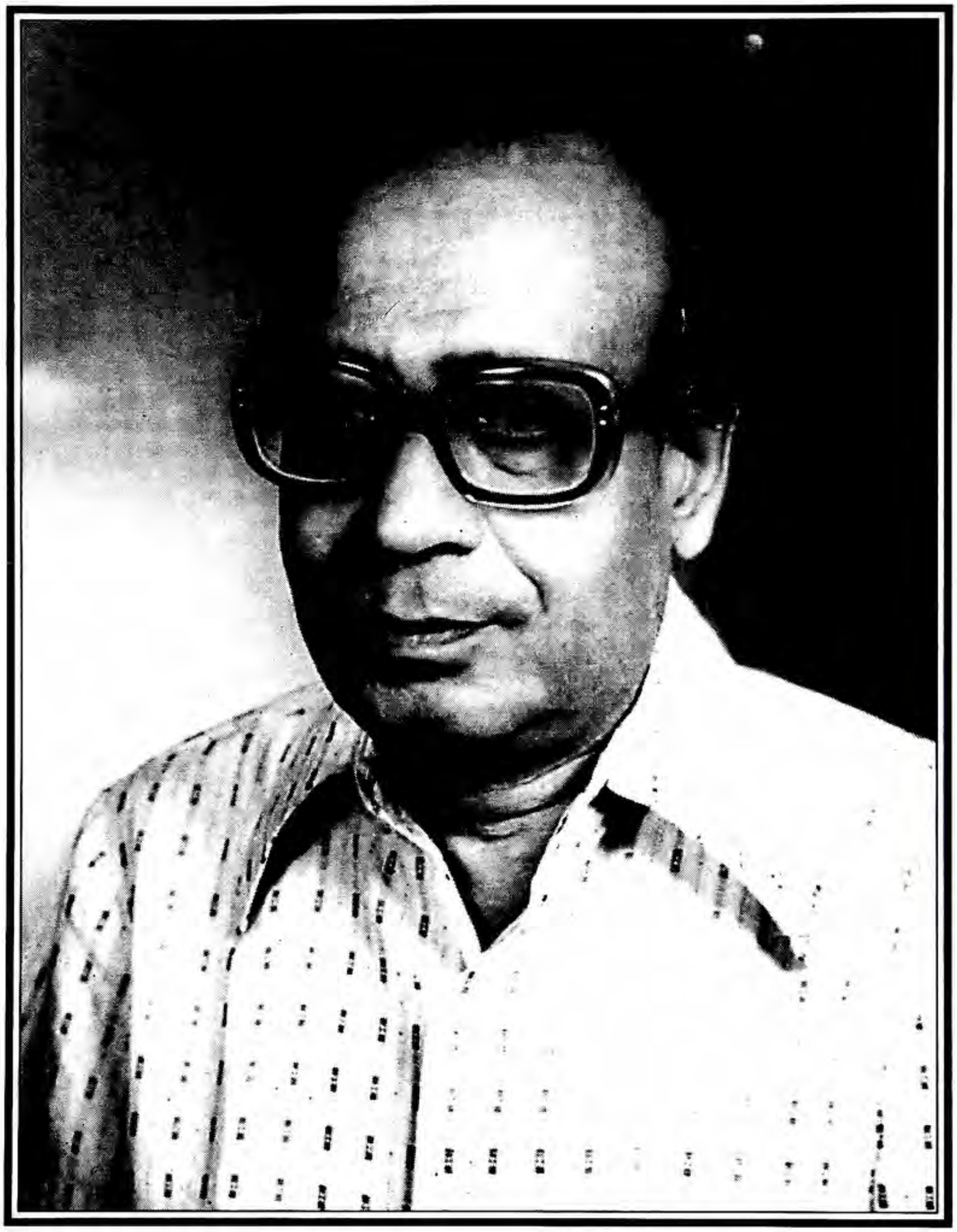

SHIRISH CHANDRA AGARWALA

(1919-1995)

Elected Fellow 1978

EARLY EDUCATION

SHIRISH CHANDRA AGARWALA was born on the 11th of May 1919 in Lucknow. He took his PhD in 1947 from Lucknow University. He started work as a Research Scholar in 1950 at the research station, Long Ashton in UK, which was affiliated to the University of Bristol under Dr EJ Hewitt, FRS. The contributions of Agarwala made between 1950 and 1952 are summarized in the book entitled *Science and Fruit* edited by Wallace, FRS and Marsh as perhaps the most important recent achievements to clear evidence of essential roles of Mo in cauliflower other than that involved in nitrate reduction. He took his second PhD in 1953.

RESEARCH CAREER

On return to India, he established a school of plant nutrition at the Botany Department, Lucknow University. Since then, he was engaged in different facets of plant nutrition, plant soil interrelationship, soil fertility in Uttar Pradesh soil, in alkaline and alkaline saline soils with the active collaboration of his research associates (Principal Associate, Professor CP Sharma) like NK Mehrotra, C Chatterjee, PN Sharma, BD Nautiyal and Mrs Nautiyal. Along with Prof CP Sharma, he published two books, one on *Recognising Micronutrient Disorders of Crop Plants on the Basis of Visible Symptoms* and the other on *Micronutrients in Agriculture* in 1979.

Prof Agarwala joined Lucknow University in 1953, steadily grew from Lecturer to Reader, Professor and finally as Head of the Department. He retired in 1979. Even after retirement, he worked as Officer-in-Charge of the ICAR projects on Micronutrients and Sugarcane.

RESEARCH CONTRIBUTIONS

(a) Deficiency and Toxicity of Essential Elements

The symptoms of deficiency and toxicity of iron, copper, manganese, boron, molybdenum and zinc have been described by Professor Agarwala and his associates with colour plates in most Indian crop plants, eg. wheat, maize, barley, sorghum, green gram, black gram, mustard, groundnut, sesame, sugarbeet, soybean and sunflower. Many of the symptoms have been recorded for the first time. The critical values of deficiency, sufficiency and toxicity of different elements of the Indian crop plants were determined for the first time. This information helps in diagnosing the deficiency of micronutrients under field conditions.

Typically in mustard deficiency of molybdenum depressed the nucleic acids DNA and RNA. Apart from the reduction in the activity of nitrate reductase, the activity of some iron enzymes was also depressed and the activity of ribonuclease and acid phosphatase was stimulated in molybdenum deficiency. In sugarbeet and sugarcane, copper deficiency depressed fresh weight and concentration of sucrose, DNA and RNA and the activities of polyphynol oxidase, cytochrome C oxidase catalase and peroxidase activities in the presence of cycloheximide, but that of polyphynol oxidase increased in the absence of inhibitor. Excess supply of heavy metal induced iron deficiency along with specific effects of toxicity of these metals in barley. Iron enzymes uptake were depressed in plants suffering from heavy metal toxicity.

In most plants, iron supply was not related to tissue iron concentration in leaves but tissue iron extracted 1N HCl, 1N oxalic acid, 0.1N EDTA, 1N Citric acid and 0.1N DTPA was related to iron supply. Rice plants showed induced iron deficiency effects in sand or solution culture with nitrogen supplied as nitrate and iron as ferric citrate or Fe EDDHA, in which plants other than rice grow normally. The iron requirement of rice with nitrogen was 28 ppm instead of 5.6 ppm.

For the first time, symptoms of acute zinc and molybdenum deficiency were reported in sugarcane and along with the metabolic changes including sucrose concentration in juice in the deficiency of zinc and molybdenum. Two isoenzymes of aldolase in the deficiency of copper, zinc, manganese and iron were noted indicating that these micronutrients are involved in maintaining the integrity of enzyme. Barley, grown in sand culture at low levels of iron, contained 2 to 5 times as much copper, molybdenum, manganese and zinc as plants grown with adequate iron supply. The accumulation of P, Cu, Zn and Mo due to low Mn supply was less pronounced than normal supply in barley. The rice variety Sabarmati was suitable for low zinc soils and gram variety T1 for soils prone to iron deficiency. In gram, susceptibility to iron chlorosis was related to genotypic differences in uptake and translocation of iron. The symptoms of iron, manganese, copper, zinc, molybdenum and boron deficiencies in some fruit trees like papaya, guava and mango were reported.

(b) Deficiencies of Micronutrients and Male Sterility

In a series of papers published between 1979 and 1991, he established that some micronutrients have a role in reproduction and may cause male sterility. Experiments performed in refined sand on maize showed that in Mo deficiency the size of the tassles, male flowers, and anthers are reduced. Anthesis was suppressed or delayed and anthers had fewer and smaller pollen grains that lacked dense cytoplasmic contents, appeared shriveled and had poor viability. Because of Mo deficiency the activity of starch phosphorylase was decreased in mature and freshly shed pollen and activities of invertase and acid phosphatase also decreased at all the five stages of pollen development. The activity of catalase and peroxidase was increased by Mo deficiency at all these stages and that of ribonuclease at four stages of pollen development.

In zinc deficient wheat plants, heading and anthesis were delayed and size and pollen producing capacities of anthers were reduced. In more severe zinc deficiency the florets failed to open and sporogenous tissue Zn deficient pollen grains had less dense cytoplasmic contents than the normal pollen grains. In Zn deficiency viability of pollen grains was decreased and the activities of catalase and peroxidase were increased. On withdrawing Zn at the onset of male reproductive phase from maize grown at adequate Zn, the zinc content in anthers was reduced to a low level and the development was not normal. In some other anthers of these plants, vessels were formed instead of sporogenous tissue. These indicated that zinc requirement for the development of anthers could not be met or by mobilization of Zn from earlier growth when zinc supply was adequate. When Zn was restored to the erstwhile Zn deficient maize, healthy vegetative growth was resumed. Zn concentration in leaves was increased but anthers did not produce normal pollen grains and her development remained arrested in the young pollen grain stage. It appeared that Zn deficiency at the crucial phase of early division caused an irreparable damage to the developing pollen grains. It seemed that Zn requirement for pollen formation and generation is akin to its requirement for the development and viability of the human specimens.

It was shown that copper deficiency retards the development of ears, anthers and pollen grains in wheat. In severe deficiency of copper, florets fail to open and anthers which were largely empty failed to dehisce. Pollen grains produced in Cu deficiency were of a smaller size which were also reported by Graham. They hacked dense cytoplasmic contents as also starch and this may explain reduced *in vitro* germination of pollen grains in Cu deficiency. Pollen bearing other copper deficient plants showed marked decrease in activities of catalase, peroxidase and cytochrome oxidase and a marked increase in ribonuclease and aldolase activity. The observation of Lohnis (1937, 1940) that boron deficiency retards the development of pollen grains was confirmed. It was shown that in severe deficiency of B, maize plants fail to produce tassels with functional flowers which were delayed in moderate B deficiency. In a large number of B deficient plants the stamens lacked sporogenous tissue and appeared as appendages or staminodes. Stamens of B deficient plants showed a marked decrease in pollen producing capacity, pollen size and pollen germination. Among the many enzymes assayed in B deficient maize, the decrease in activity of invertase might be associated with low germination of B deficient maize pollen.

In Mn deficiency in maize, tasseling was poor and another development as delayed and these produced fewer and smaller pollen grains with reduced *in vitro* germination of pollen grains. Ovule fertility was not significantly depressed but seed setting was. Thus it was concluded that severe deficiency of Mo, Cu, Zn, B and Mn might cause male sterility in some plants.

(c) Plant Soil Relationship and Fertility

Agarwala and his associates published more than 25 papers on soil plant relationship and soil sterility including a review of the work on micronutrient disorders on salt affected soils which are mostly alkaline. In six representative profiles drawn from each of the principal types in Uttar Pradesh, total and available micronutrients, Fe, Mn, Mo, Cu, boron and Zn were determined. Alluvial soils were low in Mo, whereas in semi desert soils boron and Cu were low. Alluvial Mo and Cu were the lowest among the soils reported in the world.

As compared to the contiguous normal soils, the holomorphic soils of UP have lower available soil contents of Fe, Mn, Cu and Zn and higher available contents of B and Mo. Available B is related to ESP in slightly saline highly sodic soils. Griggs available soil Mo is reported to be low in sub surface horizons of non saline sodic soils but high in surface horizons of saline sodic soils. Halomorphic soils have higher water soluble sodic contents of Fe, Mn, Cu, Zn, Mn and B. Compared to normal soils the holomorphic soils of the Bundelkhand and the alluvial regions have a higher magnitude of micronutrient (Fe, Mn, Cu and Zn) deficiencies. The crop plants growing on halomorphic soils of UP do not accumulate B and Mo in toxic amounts. These soils respond to Zn, Fe, Mn and Cu amendments.

Resolving the complexity of alkalinity and salinity was also attempted. In artificially alkalized soils symptoms of Zn, Cu and Fe were manifested on mixing the soil with adequate quantities of the soils of essential elements other than elements under test. Boron deficiency symptoms appeared when salinity was raised. A method of determining the total and available Mo in soils has been standardized. Many samples from UP were analysed for available Fe, Mn, Cu and Zn contents. 40 to 50 % of such soils were found to be deficient in Zn and some in Cu in Western U.P.

(d) Interaction between Micronutrients and Macronutrients

In more than twelve papers published between 1985 and 1992, the metabolic changes owing to interaction between micronutrients and macronutrients were reported. In cauliflower, the depressions due to iron deficiency in dry matter, leaf iron, chlorophyll, starch, proteins, RNA and specific activities of catalysts and peroxidase were mitigated to variable extents by the combined deficiencies of Fe-Mg, Fe-Mn and Fe-Mn-Mg. On the other hand, the activities of Mg-ATPase and RNAse were enhanced by Fe deficiency which was depressed by the combined deficiency of Fe-Mn, Fe-Mg, Fe-Mn-Mg. In the latter two, the activity of pyruvate kinase was depressed.

In another experiment in which the interaction of Fe with Mn was studied in rice it was shown that by lowering the supply of Mn the induced iron deficiency effects is reduced dry matter, chlorophyll and the specific activities of catalase, succinic dehydrogenase and aconitase, were considerably mitigated in the nitrate treatment with both iron sources. It was also reported that excess sulphur interacted with Cu deficiency. When the supply of excess sulphur at adequate Mo level partially alleviated, the effects of copper deficiency viz. Cu deficiency symptoms ease in dry weight, seed yield and activity of cytochrome C oxidase. This effect was discernible even at excess Mo level. In study of interaction of copper and molybdenum in maize, it was shown that the effect of Mo deficiency at normal Cu reduction in dry weight, leaf Mo, chlorophyll, protein N, nitrate deductase activity and increase in peroxidase are accentuated by excess Cu supply.

The depression in growth, dry weight soluble protein and specific activities of nitrate reductase, catalase, peroxidase, succinic dehydrogenase, aconitase, aldolase and phosphatase in iron deficient *Aspergillus niger* felts was accentuated by Mo deficiency but its deficiency increased the iron concentration in the felts. This indicates that Mo deficiency depresses the physiological availability of iron and might be involved in the synthesis of specific protein moieties of catalase, peroxidase and succinic hydrogenase. Contrary to the observation in higher plants the activity of acid phosphatase was depressed by Mo deficiency at all levels of iron supply in A niger.

AWARDS AND HONOURS

Professor Agarwala was elected Fellow of the Indian National Science Academy in the year 1978. He was awarded Birbal Sahni Gold Medal in the year 1980.

Professor Agarwala passed away on the 24th of July 1995.

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