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FUTURE IMPORTANCE OF ZINC AND OTHER MICRONUTRIENTS FOR RICE IN ASIA

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Rice is extensively cultivated under submerged soil condition. Lowland rice has less chances to suffer from nutritional deficiencies, except for nitrogen, than upland crops. One of the reasons for this tendency is that most of lowland rice fields are located on alluvial soils which are better in nutritional supplying power than other types of soils. In addition to this, following reasons are also counted for this tendency: Supply of nutrients through irrigation water, mobilization of nutrients caused by chemical changes of the soil under submerged condition, and the characteristics of rice plant in nutrient requirement.

However, as rice cultivation is becoming more and more intensified and is expanding to the area where rice has not been planted intensively, various nutritional disorders are posing problems.

Needless to mention that application of phosphorus and potassium is important to obtain a high grain yield on soils which are low in these elements. It has been also quite well established that rice responds to application of silica in the grain yield on soils low in supply of this element. In some soils, accumulation of ferrous iron, hydrogen sulfide, organic acids, etc. under reduced condition at high levels retards the growth of the plant. Such types of disorders are commonly called as "physiological diseases" and are limiting the grain yield in various areas in rice growing Asian countries.[1)]

Until recently micronutrients were not at all considered to be of practical importance in lowland rice. However, several years back zinc deficiency was found in India, and after that it is now being realized that deficiency in this element is quite wide spread.

Zinc Deficiency

Occurrence: Zinc deficiency of lowland rice was first suspected in Pant Nagar, Uttar Pradesh, India in 1964,[2] and was confirmed later.[3] Following the finding of this case, it has been also reported in Kala Shah Kaku, Lahore, West Pakistan; Minglanilla, Cebu, the Philippines, and Chiba, Japan.[4] It was also found in Ngale, Ngawi, Indonesia.[5] These places where zinc deficiency had been identified are listed in Fig. 1.

The "Khaira" diseases of India, "Hadda" of West Pakistan, "Taya-Taya" of the Philippines have been known for a long time among local farmers though the causes were unknown. These disorders are now proved to be zinc deficiency.

The "Akagare Type II" has long been considered to be caused by organic acids, soluble ferrous iron, and hydrogen sulfide in combination with potassium deficiency. However, this disorder is also proved to be zinc deficiency at least on certain soils.

The "Mentek" in Indonesia can not be considered as a disorder caused by a single factor. It includes various disorders. One type had been proved to be virus disease. However, at least some cases of the "Mentek" is also caused by zinc deficiency.

As mentioned above several cases of zinc deficiency have been reported in Asian rice growing countries within only a few years and are being added. The area affected by this disorder in Asia is estimated to be more than one million hectares.[6] It exists extensively in West Pakistan, the dry areas of India, such as Uttar Pradesh, Andra, and Mysore, and also in Central Java, and also exists in a smaller extent in the Philippines, Taiwan and Japan.

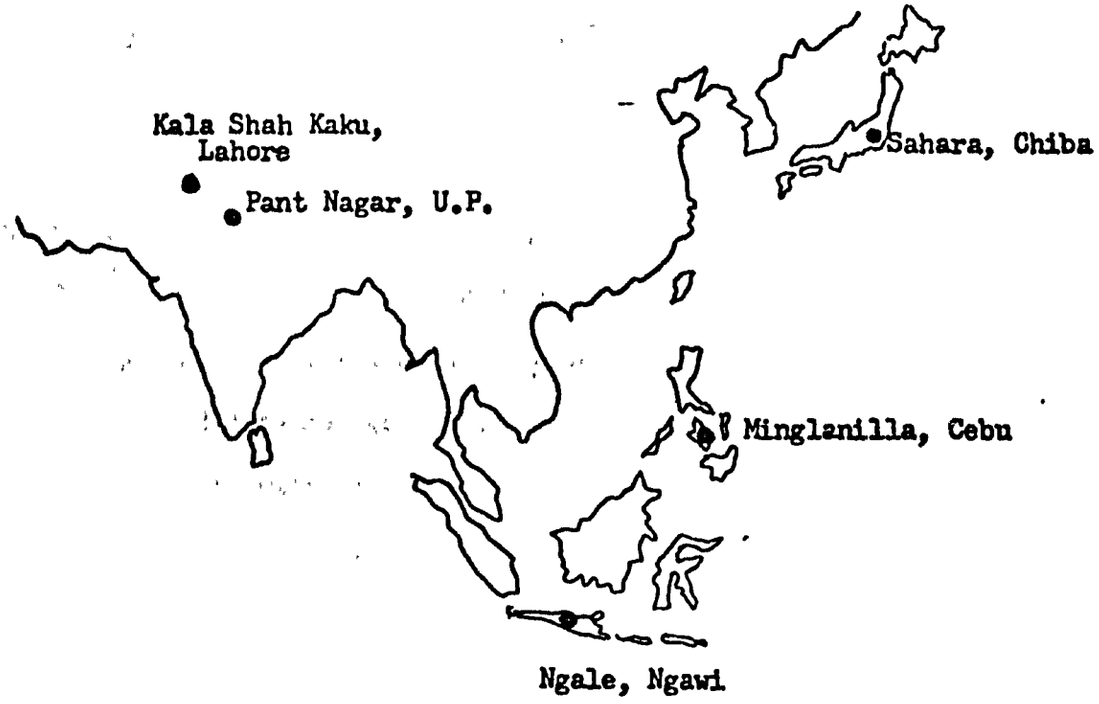

Fig. 1. Places where zinc deficiency of rice has been identified in Asia

Characteristics of Deficiency: At early stage of zinc deficiency the mid-ribs of the young leaves, especially the base, become chlorotic. When the deficiency advances brown blotches and streaks develop in lower leaves, growth is stunted, but tillering may continue. The size of the leaf blade is reduced, but that of the leaf sheath is little affected.

In the field, uneven growth and delayed maturing are characteristics of zinc deficiency. Frequently the plants suffer from deficiency at early growth stage, but recover later.

The critical levels of zinc in the rice plant associated with deficiency symptoms is about 10 to 15 ppm Zn. In some cases plants having about 20 ppm Zn have deficiency symptoms.

Characteristics of Soils: Field deficiency of zinc in rice so far reported are occurring on calcareous soils with high pH, above 7.5. The higher the soil pH, the lower the zinc content of the plant (Fig. 2).[3] The concentration of zinc in the soil solutions decreases by an increase of the soil pH with liming.[4] These phenomena suggest that a primary cause of deficiency is fixation of zinc in calcareous soils, but is not due to absolute deficiency of zinc in the soil.

It was demonstrated that addition of cellulose accelerates zinc deficiency,[3,4] suggesting that soil reduction is also related to the deficiency. This findings agree with field observation that drainage alleviates zinc deficiency.

Zinc is immobilized in roots in the presence of an excess of bicarbonate ion.[7] This may be part of the reason that zinc deficiency occurs at early stages of growth in calcareous soils. In submerged soils, particularly when organic matter is applied, abundant carbon dioxide is produced during the early

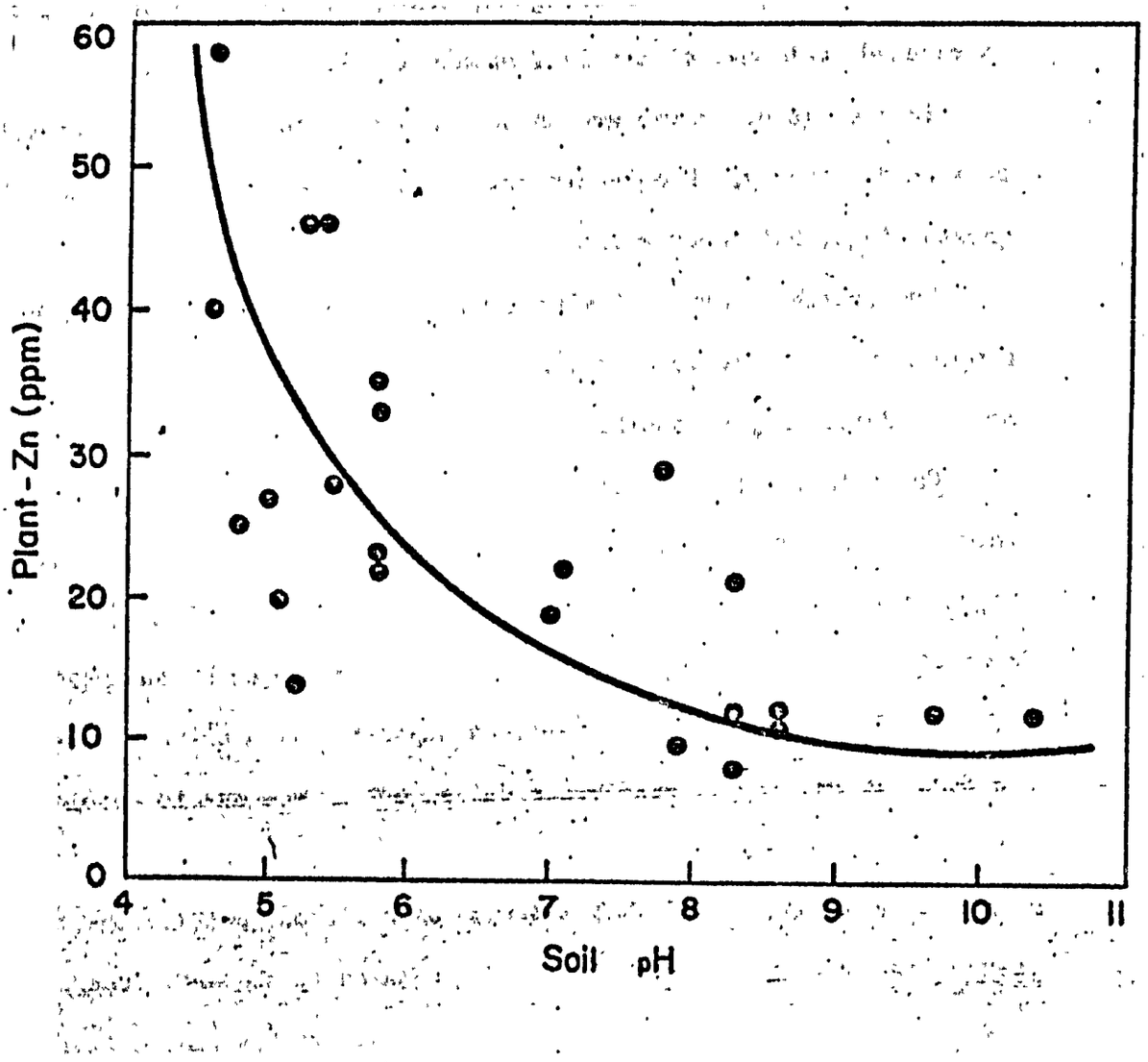

Fig. 2. Relationship between soil pH and plant zinc content (Yoshida and Tanaka)

period of submergence and, since the soil is alkaline, is converted to the bicarbonate ion.

Another possibility is that under reduced conditions zinc may be combined with hydrogen sulfide to form zinc sulfide with extremely low solubility.

There is large area of rice fields on calcareous soils with high pH. however, zinc deficiency is limited to only a few. Studies are needed on soil factors associated with zinc deficiency in calcareous soils. Such studies are vital if rice growing to be extended to arid areas where soils are more or less calcareous.

Remedy: Application of zinc sulfate is effective (Table 1).[8] Top dressing of it after the observation of zinc deficiency symptoms was as effective as a basal dressing. Foliar spray of zinc sulfate solution ~~is~~ also give[s] a positive effect. Dipping seedlings in one percent ZnO suspension was found to be the most practical way of correcting zinc deficiency.

Application of mineral acids, such as HCl to adjust soil pH is effective in some soils,[9] although practical significance of this method has to be tested in future.

Ammonium salts are better nitrogen source than urea because ammonium salts causes a decrease of soil pH, whereas urea causes an increase of soil pH (Table 2).[4] Calcareous soils are frequently low in phosphorus supply. No interaction between phosphorus application and degree of zinc deficiency has been observed.[6]

Other Micronutrients

So far as I am aware, no other micronutrient is reported to limit the yield of lowland rice in Asia.

Table 1. Effect of zinc application on grain yields of rice at Kala Shak Kaku Government Rice Farm, West Pakistan (Yoshida, McLean, Shafi and Muller)

Zinc application		Grain yield (kg/ha)	Duncan's Multiple range test
Nursery (kg/ha)	Field (kg/ha)		
0	0	4315	a
0	10[x]	5982	bcd
0	100[x]	6516	cd
0	10[xx]	6008	bcd
0	100[xx]	6915	d
100	0	5253	abc
100	10	6170	bcd
Dipping seedlings in 1% ZnO_2 suspension		5258	bcd
Spraying zinc at 10 kg/ha when the first symptoms appeared[xxx]		5713	bcd

x Zinc sulfate was applied before puddling.
xx Broadcast zinc after puddling.
xxx 1 gram of zinc sulfate in 3.8 liter water.

Table 2. Effect of various nitrogen fertilizers on the growth and zinc content of the rice plant on Sahara soil (Tanaka, Shimono and Ishizuka)

	Plant weight (g per plant)	Zn (ppm)	Soil pH
Urea	4.4	11	7.4
Ammonium sulfate	7.0	17	6.8
Ammonium chloride	7.8	20	6.7

(Sahara soil, 0.25 g N per 1 Kg soil).

In some soils, such as sandy soils on which "Akiochi" occurs and also acid soils with which rice suffers from iron toxicity, application of manganese dioxide often gives positive effect. However, the effect seems to be due to adjustment of soil Eh rather than as nutrient.[10] Interaction between iron and manganese is sometimes important when iron toxicity develops due to a high level of ferrous iron in the soil solution. Retarded uptake of manganese by hydrogen sulfide is also a cause of the trouble.

In upland rice, iron deficiency and manganese deficiency is rather common. Since these elements are reduced and are high in solubility under submerged condition, upland rice has more chances to suffer from deficiency in these elements. Application of sulfuric acid to the soil and also of organic substances are effective to correct iron deficiency of upland rice. This method may be used to raise seedlings on upland nursery beds with a high soil pH.[11]

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