# 20. ZINC DEFICIENCY OF RICE PLANT IN WEST PAKISTAN AND ITS IMPROVEMENT

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## Introduction

West Pakistan grows rice on abut 3.6 million acres which, as seen from table 1, are concentrated mainly in two tracts viz: Lahore Division in the Lahore Region, and parts of Hyderabad and Khairpur Divisions in the Hyderabad Region. In the Lahore Division, Basmati rice which has long, slender and scented grains and very good cooking quality, is grown on about 0.9 million acres. The distribution of area in different Divisions of West Pakistan is given in Table 1.

**Table 1. Distribution of Area and Production of rice in West Pakistan.**

Area =00 acres
Production=00 tons rice

| Division | Area and production | | | |
|---|---|---|---|---|
| | 1967-68 | | 1968-69 | |
| | Area | Production | Area | Production |
| Peshawar Region | | | | |
| Peshawar | 1,012 | 322 | 1,168 | 454 |
| Dera Ismail Khan | 136 | 45 | 119 | 75 |
| Lahore Region | | | | |
| Rawalpindi | 992 | 489 | 952 | 531 |
| Sargodha | 1,454 | 679 | 1,316 | 798 |
| Lahore | 10,954 | 5,312 | 11,418 | 6,732 |
| Multan | 2,358 | 982 | 2,829 | 1,690 |
| Bahawalpur | 741 | 250 | 579 | 307 |
| Hyderabad Region | | | | |
| Khairpur | 10,034 | 4,409 | 10,380 | 6,254 |
| Hyderabad | 7,279 | 2,231 | 7,319 | 4,110 |
| Quetta | 13 | 6 | 19 | 6 |
| Kalat | 112 | 30 | 85 | 28 |
| Karachi | 4 | 7 | 4 | 1 |
| Total West Pakistan | 35,084 | 14,747 | 36,069 | 20,911 |

* Estimate of Rice crop in West Pakistan for the year 1968-69 (Dept. of Agri. West Pakistan).

The soil, climatic conditions and methods of rice growing in the two regions are quite different. In the Hyderabad Region, the soil is clay loam. The rainfall is only 2-3 inches per annum. The land is prepared in dry condition, filled with water and rice is transplanted

The Lahore Region receives about 20-22 inches rainfall per annum. The soil contains greater percentage of silt and most of the rice growing areas have a hard pan at 1-2 feet depth. The chemical analysis of some of the soils in the main rice tracts of the Lahore Region is given in Table 2.

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**Table 2. Soil analysis in selected locations in the Lahore Region of West Pakistan** (Yoshida, 1969)

| Location | pH ($H_2O$) | Organic carbon (%) | Available Phosphorus (ppm)* | CEC (me/100g) | Exchange cations (me)** | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | $Ca^{+2}$ | $Mg^{+2}$ | $K^+$ | $Na^+$ |
| Kala Shah Kaku Research Station | 7.9 | 0.98 | 3.8 | 11.4 | 31.60 | 3.06 | 0.45 | 1.03 |
| Manga | 8.6 | 0.25 | 3.4 | 5.2 | 28.88 | 3.44 | 0.58 | 0.33 |
| Bhai Pheru | 8.6 | 0.39 | 6.4 | 8.9 | 11.00 | 30.47 | 0.80 | 1.03 |

* By Olsen's method.

** Not corrected for free carbonates.

It may be seen from Table 2 that the soils are alkaline. The sum of cations extracted by IN $NH_4AcO$ exceeds the CEC Value. The major cations in the $NH_4AcO$ extracts are calcium and magnesium. Effervescence takes place upon addition of Hydrochloric acid to the soils. This indicates that the soil are calcareous.

Rice is grown as a low land transplanted crop. The land is generally prepared by puddling under wet conditions and kept flooded for 20-25 days before transplanting rice. The crop is irrigated from canals. The irrigation system is basin type. About three inches deep water is kept standing in the field till about a fortnight before harvesting. The varieties grown upto 1966 were tall and weak stemmed and were prone to lodging with the result that only small quantities of fertilizers could be applied. The average yield of these varieties is about 1,500kg per hectare. A very few diseases attack rice crop in West Pakistan. It had, however, been observed during the last 30 years that in certain highly alkaline and otherwise very inferior soils, the crop suffered from a disease 2-3 weeks after transplanting during extremely hot and dry season but its cause was not known. Some of the fields brought under cultivation for the first time for reclamation showed the worst symptoms. In severe cases, the crop is completely wiped out. The only known way to remedy this disorder was to remove water from the field and to dry the soil completely before reflooding. In the earlier reports of Kala Shah Kaku Station, though it wes considered to be a physiological disease, yet it was erroneously called paddy blast. It is locally known as *"Hadda"* or *"yarqan"* (jaundice).

### Symptoms of the disease

The main symptoms of this disease are as under :

1) The lower leaves develop rusty dots which coalesce to form dark brown blotches and streaks. A few days later, the entire leaf appears brownish and ultimately dries. In places where the crop is very succulent due to the application of more nitrogenous fertilizers, the leaves break from the centre and dry in a few days. In severe cases all fully developed leaves turn brown and ultimately die leaving only young green leaves. The plant gives a bushy look with very small leaves.

2) The growth is arrested and the plants remain stunted.

3) The tillering is checked. The affected plants produce less tillers than unaffected ones.

4) The diseased plants have week root system and can be uprooted easily. The roots of such plants are reddish brown or dark reddish brown mingled with black or rotten ones.

It has been observed that the plants in low lying patches are severely affected and that drainage alleviates the disorder. These conditions suggest that the occurrance of the disorder is associated with reduced conditions in submerged soils. Most of the affected plants recover but those severely affected ultimately die.

5) The disorder is aggravated by the application of higher doses of fertilizers. The response to fertilizer application at Kala Shah Kaku Station is, therefore, reduced. At Dokri Station where there is no such problem, the response to fertilizer is remarkable while at Kala Shah Kaku the application of increased fertilizer decreased the yield due to this disorder as shown in table 3.

**Table 3. Fertilizer trial on IR 8 at two locations in West Pakistan 1966.***

| Fertilizer applied (kg/ha) | | | Grain yield (kg/ha) | |
|---|---|---|---|---|
| N | $P_2O_5$ | $K_2O$ | Dokri | Kala Shah Kaku |
| 0 | 0 | 0 | 5,610 | 5,735 |
| 0 | 45 | 45 | 7,140 | 5,476 |
| 34 | 45 | 45 | 8,770 | 5,153 |
| 67 | 45 | 45 | 9,240 | 5,569 |
| 101 | 45 | 45 | 9,250 | 4,903 |
| 134 | 45 | 45 | 10,270 | 4,936 |

* Annual progress report 1966 Accelerated Rice Research Project, West Pakistan.

The symptoms described above resemble those of *Akagare* disease reported in Japan. Baba *et. al.* (1) classified this disease into three major types: I, II, and III. The major conditions causing *Akagare* reported by them are (a) poor natural supply of potassium, (b) a high content of easily decomposable organic matter, (c) the production of much hydrogen sulphide in the soil, (d) the low iron content of the surface soil ($Fe_2O_3$ content below 0.3 percent) which induces a rapid decline in Eh and the evolution of $H_2S$ in the soil, (e) an excess of ferrous iron, and (f) the abnormal reducing power of soil ($Eh_6$ below 100mV) (Yamaguchi, Shiratori, and Koizumi, 1957; Yamaguchi, 1961). It was further reported that potash deficiency was mainly responsible for occurrance of *Akagare* type I. Large application of potash reduced the occurrance of type II but not as effectively as in the case of type I. The occurrance of type II is favoured by large nitrogen application. It is also pronounced with deep submergence, the addition of butyric acid to the soil, and the strong soil reduction caused by the addition of starch or powdered filter paper. The symptoms can be alleviated by sub soil and surface drainage.

A similar disease known as "*Khaira*" has been reported from Pant Nagar, Uttar Pradesh, India. Nene[7] reported this disease to be caused by zinc deficiency. Yoshida and

**Table 4. Soil analysis of the areas where soil disorder occurs** (Yoshida).

| Local name of disease | Location | Soil properties | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | pH($H_2O$) | Organic carbon % | CEC me/100g | Exchange me/100g | | | |
| | | | | | $Ca^{+2}$ | $Mg^{+2}$ | $K^+$ | $Na^+$ |
| *Khaira* | Pant Nagar, U.P., India | 8.3 | 1.28 | 12.4 | 25.2 | 8.7 | 0.4 | 0.7 |
| *Hadda or Yarqan* | Kala Shah Kaku, West Pakistan | 7.9 | 0.98 | 11.4 | 31.6 | 3.1 | 0.5 | 1.0 |
| *Akagare* II | Sahara, Chiba, Japan | 8.0-8.5 | — | — | — | — | — | — |

Tanaka[12] confirmed Nene's conclusion. Nene[8] reported it to be related to low available Zinc in the soil and low Zinc content of the plant. Application of Zinc sulphate corrected the disease and increased the yield. Foliar spray appeared best. *Akagare* II in Japan is also now considered to be caused by Zinc deficiency. The soils of these two places are similar to that of the Kala Shah Kaku station as given in Table 4.

It is apparent from table 4 that the disorder occurs in high pH calcareous soil.

### Introduction of new varieties and soil disorder.

At the Kala Shah Kaku station, the disorder became more pronounced with the introduction of dwarf varieties which are heavily fertilized. During 1967, IR 8 a high yielding, short statured and stiff stemmed, variety was planted on West Pakistan in about 10,000 acres. It was heavily fertilized with nitrogenous and phosphatic fertilizers to obtain maximum yield. It suffered badly from the disorder at a number of places 2-3 weeks after transplanting. The symptoms, however, disappeared 10-15 days later. It has been estimated that about 1 million acres of the rice crop can suffer from the disorder under favourable conditions.

Dr. Yoshida, the Plant Physiologist IRRI and Dr. Tanaka, Hokkaido University, Japan were invited to visit Pakistan in September, 1967, to find out the cause of this disorder. They collected diseased and healthy plant samples for analysis. Soil samples from the worst affected area were also flown to the Philippines for green house studies. The analysis of affected plants from West Pakistan and other countries is given in Table 5.

**Table 5. Nutrient contents of rice plants.**

| Disease | N % | P % | K % | Ca % | Mg % | Na % | Si % | Fe ppm | Mn ppm | Zinc ppm |
|---|---|---|---|---|---|---|---|---|---|---|
| Khaira disease (India) | 2. 26 | 0. 06 | 3. 32 | 0. 48 | 0. 31 | 2. 97 | 5. 97 | 735 | 138 | 7 |
| Hadda (West Pakitan) | 2. 44 | 0. 25 | 3. 30 | 0. 14 | 0. 27 | 0. 70 | 6. 70 | 954 | 558 | 9. 8 |
| Akagare II (Japan) | — | — | 2. 30 | — | — | — | 5. 45 | 370 | 225 | 7 |
| Healthx plants (East Pakistan) | 1. 54 | 0. 18 | 2. 23 | 0. 18 | 0. 15 | 0. 30 | 8. 6 | 784 | 421 | 22 |

It may be seen from Table 5 that the rice plant samples collected from the problem areas show very low zinc content. The zinc content of the plants collected from East Pakistan, where this disorder is not a problem, had a zinc content of 22 ppm whereas the plants from the problem areas had a zinc content of less than 10 ppm. Ishizuka and Tanaka (1962)reported critical zinc content of more than 15ppm while Yoshida and Tanaka[11] reported that the critical zinc content of the plant should be 10 ppm.

The combined information form field observations and chemical analysis of the plant and soil samples suggested that the disorder observed in the Lahore Region of West Pakistan was due to zinc deficiency and that its occurrance was associated with high pH or calcareous soil.

### 4. Green house experiments with Kala Shah Kaku soil in IRRI by Dr. Yoshida (1968).

Dr. Yoshida conducted a number of greenhouse experiments with Kala Shan Kaku soil to confirm the conclusion drawn from field observations and plant analysis. He was able to reproduce the disorder in the greenhouse. He added zinc to some beakers, but not to others. About two weeks after transplanting, the plants without added zinc started to develop interveinal chlorosis at the base of the lower leaves. Browing and stunted growth followed. This observation confirmed the previous finding that the soil disorder at Kala Shah Kaku is caused by zinc deficiency.

(1) **Effect of zinc application on dry weight and zinc content of the plant.**

In order to find out the effect of zinc application on growth and other characters a preliminary experiment was laid out with different zinc concentrations. The data are given in Table 6.

**Table 6. Effect of zinc application on dry weight and zinc content of the rice plant on Kala Shah Kaku Soil*** (Yoshida)

| Zinc added (ppm) | Dry weight (g/pot) | Zinc content | Symptoms |
|---|---|---|---|
| 0 | 1.0 | 9 | Severe |
| 2 | 2.4 | 14 | None |
| 4 | 1.9 | 18 | 〃 |
| 8 | 2.9 | 23 | 〃 |
| 16 | 2.7 | 23 | 〃 |
| 32 | 2.9 | 34 | 〃 |

* The plants were harvested 5 weeks after transplanting.

It may be seen form Table 6 that without added zinc the symptoms appeared, the growth was stunted and the zinc content of the plant fell below the critical level. The addition of even small quantity of zinc improved growth and zinc content of the plant. These results also confirm the findings that zinc deficiency is the cause of soil disorder in Kala Shah Kaku soil.

(2) **Factors affecting zinc uptake by the rice plant.**

A number of factors affect the uptake of zinc by the rice plant. Some of these are described below :-

1) **Total and available zinc content of soil and the rice plant (Yoshida).**

The zinc content of the rice plant grown in different types of soils varying in total and available zinc content is given in Table 7.

**Table 7. pH, total and available zinc content of the soils and the plant** (Yoshida)

| Country | Expt. No. | Soil | pH | Total Zn(ppm) | Available Zn*(ppm) | Plant Zn (ppm) |
|---|---|---|---|---|---|---|
| India | 5 | Lateritic | 5.3 | 23 | 3.4 | 46 |
| | 10 | Usar | 10.4 | 75 | 3.1 | 12 |
| | 13** | Calcareous | 8.3 | 75 | 4.3 | 8 |
| | 15 | Regur | 7.8 | 82 | 4.3 | 29 |
| | 18 | Lateriric | 5.1 | 110 | 3.1 | 20 |
| Pakistan | 2*** | Calcareous | 7.9 | 99 | — | 10 |
| | 6 | Calcareous | 8.6 | 75 | — | 11 |
| | 7 | Calcareous | 8.6 | 92 | — | 12 |

* 0.1N HCI Soluble.
** Pant Nagar, U.P., India.
*** Kala Shah Kaku, Lahore, West Pakistan.

It may be seen from Tadle 7 that neither total zinc nor available zinc content of the soil was related to plant zinc content. The problem soils appear to contain an adequate amount of zinc.

2) **Effects of cellulose on occurrence of the disorder.**

Dr. Yoshida observed in several of his greenhouse experiments that the zinc deficiency symptoms did not appear consistently. As the disorder in the field is usually found in lowlying patches, it was thought that the addition of organic matter may be aggravating the disorder. The effect of the addition of cellulose on the disorder was, therefore, studied. The results are given in Table 8.

**Table 8. Effects of cellulose on appearance of zinc deficiency, dry weight, and zinc content on Kala Shah Kaku soil*.**

| Zn(ppm) | Cellulose (%) | Dry weight (g/pot) | Zn content (ppm) | Symptoms |
|---|---|---|---|---|
| 0 | 0 | 7.7 | 14 | Moderate |
| 10 | 0 | 12.7 | 27 | None |
| 0 | 0.5 | 2.2 | 10 | Very severe |
| 10 | 0.5 | 5.9 | 20 | Very slight. |

* The plants were harvested 5 weeks after transplanting.

It may be seen from Table 8 that the addition of cellulose to the problem soil aggravated the disorder and retarded the growth remarkably, and that the addition of zinc partially counteracted the effects of the cellulose. These results that the application of cellulose affected not only the availability of zinc and/or uptake of zinc by the rice plants, but also other factors retarding the rice plant growth.

3) **The effect of soil pH on availability of zinc.**

The relationship between soil pH and plant zinc content is given in Fig 1, from which it may be seen that as the soil pH increases, the plant zinc content decreases indicating that high pH is affecting zinc availability of the soil. This relationship, however, requires more careful examination. Ponnamperuma *et. al*[9] have shown that the pH of alkaline soils is reduced and that of acid soil is increased under submerged conditions. There is, therefore, a

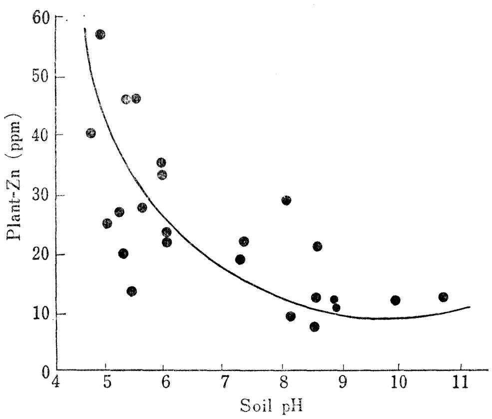


**Fig. 1. Relationship between soil pH and plant zinc content.**

possibility that pH *per se* may not be a factor in zinc deficiency, but that the other properties associated with high pH (such as the presence of large amounts of Calcium carbonate) may as reported by Navort[6] be responsible for the decreased available zinc in the soil.

### 4) Effect on nitrogen, bicarbonate ion concentrations, and pH of culture solutions on uptake and distribution of $^{65}$zn in the rice plant.

Since the disorder has become more severe with the introduction of improved varieties which are heavily fertilized, the effects of nitrogen nutrition on zinc uptake by the rice plant were studied using radioactive zinc. The effects of bicarbonate ion and pH were also studied because high concentrations of bicarbonate ion in submerged soils are caused by the addition of organic matter. The results are given in Table 9 from which it may be seen that the absorption of $^{65}$Zn by the rice plant, both in concentration and in total uptake, increased with increasing concentrations of nitrogen in culture solutions.

**Table 9. The effects of pH, nitrogen, and bicarbonate ion concentrations of culture solutions on the adsorption of $^{65}$Zn by the rice plant[a].** (Yoshida)

| Nitrogen (ppm) | Bicarbonate[b] (m. Mol) | Dry weight(g/pot) | | cpm/0.1g dry matter | | Total cpm x $10^3$/plant | | Total |
|---|---|---|---|---|---|---|---|---|
| | | Top | Roots | Top | Roots | Top | Roots | |
| pH 5 | | | | | | | | |
| 20 | 0 | 19.3 | 4.2 | 581 | 8,037 | 11.2(25)[c] | 33.8(75) | 45.0 |
| 40 | 0 | 37.5 | 6.2 | 1,376 | 13,250 | 51.6(39) | 88.2(61) | 133.8 |
| 80 | 0 | 48.7 | 5.3 | 1,778 | 26,950 | 85.6(38) | 142.9(62) | 229.5 |
| pH 8 | | | | | | | | |
| 20 | 0 | 18.3 | 4.0 | 705 | — | 12.9 | — | — |
| 40 | 0 | 38.0 | 6.0 | 1,069 | 17,790 | 40.6(28) | 106.8(72) | 147.4 |
| 80 | 0 | 54.3 | 6.6 | 1,350 | 20,970 | 73.3(35) | 138.4(65) | 211.7 |
| 40 | 10 | 38.2 | 8.3 | 1,199 | 16,510 | 45.8(25) | 137.0(75) | 182.8 |
| 40 | 50 | 39.4 | 6.3 | 698 | 24,360 | 27.5(15) | 153.5(85) | 181.0 |

[a] Measurement of radioactivity was made 6 hrs. after $^{65}$Zn was added to culture solutions.
[b] Bicarbonate was added as $NaHCO_3$.
[c] Figures in parenthesis show relative amount of radioactivity in top and root portions.

The increased supply of nitrogen promoted growth of the rice plant. This result suggests that when growth of the rice plant is improved as a result of fertilization, the requirement for zinc by the rice plant is also increased. This requirement may not be met in soils where availability of zinc is rather low. The pH only slightly affected the absorption of $^{65}$zn in concentration as well as total uptake. The high concentration of bicarbonate ion, however, remarkably altered the distribution of $^{65}$Zn between plant roots and top. A much higher amount of $^{65}$Zn was found in the plant roots in the presence of 50 m.M bicarbonate ion than in any other treatment. This immobilization of zinc in the roots may be one of the reasons why application of cellulose aggravates zinc deficiency.

### 5) Mobility of $^{65}$Zn absorbed via roots and leaf in the rice plant.

$^{65}$Zn was applied in the roots as well as on the leaf. The mobility and distribution of $^{65}$Zn is given in Table10 and graphically presented in Fig.2.

It may be seen from Table10 that a higher amount of zinc absorbed through the roots went to the upper leaves. A similar trend was also found when zinc was absorbed through the leaves. These experiments show that (i) zinc is relatively mobile in rice tissues, (2) the movement of zinc is directed preferably towards the youngest leaf irrespective of the location at which zinc enters the plant (3) zinc can be supplied both to the rice plant either by foliar application or soil application. The tendency of zinc to move into young leaves

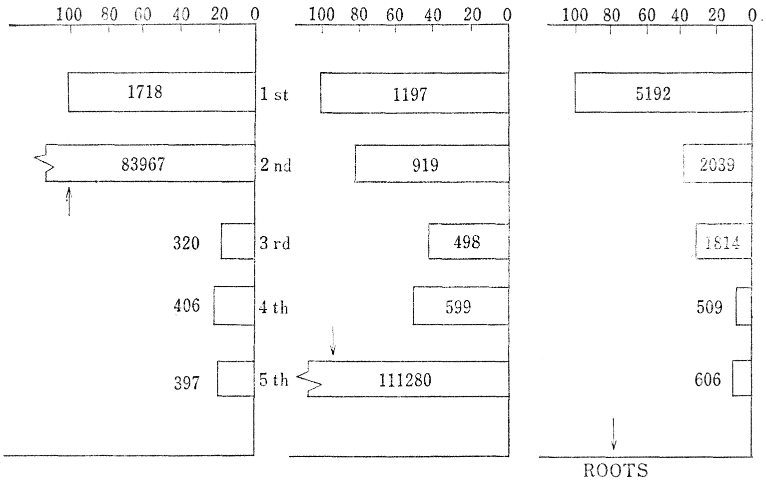


**Fig. 2. Distribution of radioactive zinc in rice leaves as affected by position of the zinc application.**

**Table 10. Mobility and distribution of $^{65}$Zn absorbed via roots and leaf** (Yoshida).

**(a) Via roots.**

| Leaf No. [a] | cpm/0.1 g dry matter | |
|---|---|---|
| | pH 5 | pH 8 |
| 1. | 4,745 | 5,192 |
| 2. | 2,144 | 2,039 |
| 3. | 985 | 1,814 |
| 4. | 659 | 509 |
| 5. | 925 | 606 |

**(b) Via a leaf**

| | | |
|---|---|---|
| 1. | 1,050 | 1,197 |
| 2. | 435 | 919 |
| 3. | 844 | 498 |
| 4. | 269 | 599 |
| 5 [b] | 115,931 | 111,280 |

[a] Counted from the top on main culm.
[b] $^{65}$Zn was applied to this leaf.

may explain why brown dicoloration of leaves starts with the lower leaves. Sharma *et. al*[10). however, reported that young leaves were more severely affected than the old ones.

**6) Effect of phosphate application on zinc deficiency.**

Several workers have reported that the application of phosphates induces zinc deficiency. Sharma *et. al*[10). reported that with the application of 100 ppm P the rice leaves turned brown in the beginning of the 5th week and later became brownish black. Four days later, similar symptoms developed where 25ppm P had been applied whereas no symptoms appeared without P application. The application of 25ppm P reduced zinc concentration in the tops by about 50 percent. There was more decrease in Zn concentration in the tops with increasing rates of P. It was also shown that the availability of zinc increased at higher temperature. It was reported by Sharma[10], Ellis *et.al*[4]., Martin, Mclean and Quick[5] that more zinc became available at higher temperature (30°C) due to favourable microbial activities. Burleson *et. al*[3]. concluded that P induced zinc deficiencies were probably enhanced by cold, wet soil during the early part of the growing season due to restricted root development. This observation was confirmed by Ellies *et.al.*[4]. Sharma *et. al*[10]. reported that P application did not affect zinc concentration in the roots but reduced zinc concentration in the tops. On the other hand, there was more concentration of P in the tops than in the roots. At 15°C, applied Zn increased Zn concentration in the roots but not in the tops. The temperature had a marked effect on absorption and also on the translocation of Zn to the tops.

It has heen observed at Kala Shah Kaku during the last several years that the crop transplanted in the middle of April does not show zinc deficiency symptoms whereas the crop transplanted in the beginning of July shows severe symptoms. The temperature during April is about 35°C against about 40°C in the beginning of July. The nursery is sown in the middle of March when the temperature is about 27°C. It has been reported by Ponnamperuma, that the temperature below 25°C retards P release. This decrease in P availability may increase the availability of zinc which may be taken up by the seedlings in the nursery and consequently no zinc deficiency symptoms appeared in the field. The observation made at Kala Shan Kaku that zinc deficiency symptom are very severe during hot and dry season are also contrary to the results reported by Sharma *et.al*[10].

Very little phosphatic fertilizers were being applied to local varieties of wheat and rice. With the introduction of dwarf wheat and rice varieties, about 60 lbs of $P_2O_5$ is being applied to each of these crops during one year. The flooding of the soil increases the concentration of P in the soil solution by 100-fold. It is, therefore, possible that available zinc in the soil may be taken up by P to form zinc phosphate which is highly insoluble. It is, therefore, possible that zinc deficiency in the plant may be induced by excess of phosphorus. However, more work is required in this direction. It has been observed that the zinc deficiency symptoms are more severe in the fields where a combination of P and N fertilizer is applied and as the dose of N is increased, the symptoms become more severe.

## Field Experiments.

A number of experiments have been conducted during 1968 and 1969 at the Experimental Farm Kala Shah Kaku, West Pakistan to confirm the results of the green house studies and to compare different methods of zinc application in the field. The properties of the soil where the experiments were laid out are given in Table 2.

### (1) Effect of zinc application on growth and grain yield-1968.

The experiment consisted of 16 treatments. Zinc sulphate was applied to nursery bed or main field or both at different rates. Application of organic matter (wheat bhusa) was combined with zinc sulphate application to test if the organic matter aggravated zinc deficiency in the field. Dipping of seedlings in one percent zinc oxide suspension was done for about 10 seconds just before transplanting. Foliar spray of zinc sulphate was done by dissolving zinc sulphate at 1 $gm/m^2$ Zinc in 3.8 liters of water. The variety used was IR 8.

Characteristic zinc deficiency symptoms were observed on the seedlings in the nursery bed, suggesting that zinc deficiency started at seedling stage. In the main field visible symptoms appeared about 12 days after transplanting. About a week or 10 days later, there was a marked difference in growth as well as in visible symptoms between the treatments with or without zinc application. The seedlings which had received zinc application in the

**Table 11. Effects of zinc applications on grain yields of rice at Kala Shah Kaku Government Rice Farm, West Pakistan.**

| Treatment No. | Zinc applications | | Organic matter application to the field (tons/ha) | Grain yield (kg/ha) | Duncan's multiple range test[2] | Tillers per plant (days after transplanting) | | Height at maturity (inches) | Days transplanting to flowering | Percentage sterility |
|---|---|---|---|---|---|---|---|---|---|---|
| | Nursery (kg/ha) | Field[1] (kg/ha) | | | | 30 | 90 | | | |
| 1. | 0 | 0 | 0 | 4315 | a | 14 | 18 | 31 | 83 | 16 |
| 2. | 0 | 0 | 5 | 4159 | a | 19 | 17 | 32 | 80 | 24 |
| 3. | 0 | 10 | 0 | 5982 | bcd | 21 | 16 | 38 | 73 | 6 |
| 4. | 0 | 10 | 5 | 6147 | bcd | 24 | 18 | 38 | 73 | 11 |
| 5. | 0 | 100 | 0 | 6516 | bcd | 25 | 18 | 38 | 73 | 8 |
| 6. | 0 | 100 | 5 | 6655 | d | 25 | 18 | 39 | 72 | 11 |
| 7. | 100 | 0 | 0 | 5253 | abc | 19 | 19 | 37 | 74 | 8 |
| 8. | 100 | 0 | 5 | 4968 | ab | 19 | 21 | 35 | 75 | 8 |
| 9. | 100 | 10 | 0 | 6170 | bcd | 23 | 17 | 38 | 73 | 10 |
| 10. | 100 | 10 | 5 | 6020 | bcd | 24 | 17 | 38 | 74 | 7 |
| 11. | Dipping seedlings in 1% ZnO suspension | | | 5858 | bcd | 23 | 17 | 38 | 74 | 8 |
| 12. | Spraying zinc at 10kg/ha at first symptoms | | | 5713 | bcd | 17 | 17 | 36 | 75 | 15 |
| 13. | Broadcast zinc at 10kg/ha after puddling | | | 6008 | bcd | 26 | 18 | 37 | 74 | 9 |
| 14. | Broadcast zinc at 100kg/ha after puddling | | | 6915 | d | 26 | 18 | 38 | 73 | 8 |
| 15. | Broadcast zinc at 10kg/ha at first symptoms | | | 5690 | bcd | 17 | 17 | 37 | 76 | 6 |
| 16. | Broadcast zinc at 100kg/ha at first symptoms | | | 6170 | bcd | 20 | 19 | 38 | 74 | 9 |

[1] Zinc sulfate was applied before last puddling for the treatments from Nos. 3 to 10.
[2] Any two means followed by the same letter are not significantly different at the 5% level.

nursery also did not show deficiency symptoms. Foliar spray or top dressing of zinc sulphate after the appearance of symptoms caused a remarkable recovery in plant growth within a week following application. The detail of treatments, yield and other characters are given in Table 11, from which it may be seen that all zinc applied treatments except Nos. 7 and 8 showed significantly higher grain yield than the no zinc treatments. The application of organic matter did not show any effect although it aggravated zinc deficiency in the greenhouse experiments. The application of zinc to nursery though corrected deficiency symptoms and increased the yield by about a ton per hectare, yet the difference was not statistically significant. This indicates that nursery bed application alone is not sufficient to bring about a significant increase in grain yield. The dipping of seedlings in 1% ZnO suspension was quite effective in correcting zine deficiency symptoms and increasing yield.

Zinc deficient plants showed limited tillering at early stage, stunted growth, delayed maturity and greater sterility. There were also several empty hills due to death of plants.

### (2) Residual effects of applied zinc material on growth and grain yield of rice at Kala Shah Kaku-1969.

The trial conducted in 1968 was repeated during 1969 in the same field with the same layout to see the residual effect of zinc applied during 1968. 150 lbs N and 60 lbs $P_2O_5$ per acre were incorporated into the soil at final harrowing. The same variety IR 8 was trans-

**Table 12. Residual effect of zinc on growth and yield of rice 1969.**

| S. No. | Zinc application | | Organic matter application to field Tons/ha | Average height (cm) a) | Average tillers/ plant a) | Zinc deficiency symptoms* b) |
|---|---|---|---|---|---|---|
| | Nursery kg/ha | Field kg/ha | | | | |
| 1. | 0 | 0 | 0 | 70.0 | 16.0 | 4 |
| 2. | 0 | 0 | 5 | 62.7 | 16.0 | 4 |
| 3. | 0 | 10 | 0 | 77.0 | 19.7 | 1 |
| 4. | 0 | 10 | 5 | 78.8 | 17.0 | 2 |
| 5. | 0 | 100 | 0 | 78.8 | 18.1 | 1 |
| 6. | 0 | 100 | 5 | 83.0 | 19.1 | 1 |
| 7. | 100 | 0 | 0 | 64.6 | 16.6 | 4 |
| 8. | 100 | 0 | 5 | 60.2 | 16.8 | 4 |
| 9. | 100 | 10 | 0 | 83.0 | 18.7 | 1 |
| 10. | 100 | 10 | 5 | 77.0 | 20.3 | 2 |
| 11. | Dipping of roots of seedlings in 1% ZnO suspension. | | | 78.4 | 17.3 | 1 |
| 12. | Spraying Zinc at first signs at 10kg/ha | | | 82.0 | 18.8 | 2 |
| 13. | Broadcast on surface after puddling at 10kg/ha | | | 78.2 | 18.4 | 1 |
| 14. | Broadcast on surface after puddling at 100kg/ha | | | 82.3 | 19.6 | 0 |
| 15. | Broadcast at the time of first symptoms at 10kg/ha | | | 79.6 | 18.9 | 2 |
| 16. | Broadcast at the time of first symptoms at 100kg/ha | | | 80.3 | 18.8 | 1 |

Transplanted on 27 Jun. 1969.

a) 40 days after transplanting.

* 20 days after transplanting.

b) Zinc deficiency symptoms ratings:

0=no symptoms, 5=severe symptoms.

planted on 27 Jun. '69. Only the growth data are available at present and the same are given in Table 12. The data show that all treatments with last year's applied zinc did not show zinc deficiency symptoms, whereas the control and the nursery bed zinc applied treatments had moderate deficiency symptoms. Zinc applied treatments had greater height and more tillers. The dipping of the seedlings in 1% ZnO suspension last year also showed residual effect. These observations show that zinc applied once can serve the purpose for at least two years. Higher doses had more residual effect.

### (3) Effects of zinc application on growth and yield of rice at Kala Shah Kaku 1969.

To confirm the results of the previous year, another trial with the addition of another zinc preparation sequestrene ($Na_2Zn$) was laid out during 1969. The data on the height, tillers and zinc deficiency symptoms are given in Table 13. The data confirm the earlier findings that field incorporation or surface application at puddling or top dressing at the appearance of first symptoms increased the height, tillers per plant and produced few zinc deficiency symptoms as compared with the control. Sequestrene proved comparatively less effective than ZnSO4 probably because of the lower rate of application. Nursery bed application was also less effective.

### (4) Effects of nitrogen application and variety on growth and yield of rice.

As stated earlier the application of increased rates of N promotes the growth of the plant and consequently raises the requirements for zinc and other elements. The presence of zinc in limited quantities creates zinc deficiency symptoms. A trial was, therefore, laid out to study the effect of zinc application with and without N applicatoin on different

**Table 13. Effect of zinc application on growth and yield of rice.***

| S. No. | Treatments | Average height (cm) | Average no. of tillers/plant | Zinc deficiency symptoms a) |
|---|---|---|---|---|
| 1. | Control | 40.0 | 9.0 | 4 |
| 2. | Field incorporation of zinc at 10kg/ha | 53.8 | 12.7 | 2 |
| 3. | Field incorporation of zinc at 100kg/ha | 39.4 | 14.3 | 1 |
| 4. | Nursery-bed application of zinc at 100kg/ha | 42.3 | 19.1 | 3 |
| 5. | Nursery-bed application at 100kg/ha field incorporation of zinc at 10kg/ha | 49.2 | 15.0 | 2 |
| 6. | Seedling dipped in 1% ZnO suspension | 48.5 | 12.0 | 2 |
| 7. | Spray of zinc on first symptoms at 10kg/ha | 43.4 | 0.3 | 3 |
| 8. | Broadcast of zinc after puddling at 10kg/ha | 49.8 | 12.6 | 2 |
| 9. | Broadcast of zinc after puddling at 100kg/ha | 51.0 | 13.3 | 1 |
| 10. | Broadcast of zinc at first symptoms at 10kg/ha | 44.5 | 11.6 | 4 |
| 11. | Broadcast of zinc at first symptom at 100kg/ha | 43.8 | 10.0 | 3 |
| 12. | Drying at first symptoms | 37.4 | 8.0 | 4 |
| 13. | N application in split doses | 45.3 | 10.4 | 2 |
| 14. | Broadcast of seduestrene at 6.7kg/ha before transplanting. | 48.1 | 13.1 | 3 |
| 15. | Broadcast of sequestrene at first symptoms at 6.7kg/ha | 40.2 | 10.0 | 4 |
| 16. | Spray of sequestrene at first symptoms at 3.3kg/ha | 40.0 | 7.4 | 4 |

* 20 days after transplanting.

a) Zinc deficiency symptoms ratings.

0 = no symptoms. 5 = severe symptoms.

Table 14. **Effect of zinc application with or without nitrogen on growth etc. of rice 20 days after transplanting, 1969.**

| S. No. | Treatment | | IR 8 | | | IR 184 | | |
|---|---|---|---|---|---|---|---|---|
| | N kg/ha | Zn kg/ha | Average height (cm) | Tillers/ plant | Zinc deficiency symptoms | Average height (cm) | Tillers plant | Zinc deficien-cy sym-ptoms* |
| 1. | 0 | 0 | 41.0 | 7.1 | 2 | 37.7 | 4.7 | 1 |
| 2. | 50 | 0 | 42.8 | 9.7 | 3 | 32.6 | 5.4 | 2 |
| 3. | 100 | 0 | 37.6 | 7.6 | 3 | 33.2 | 4.5 | 3 |
| 4. | 150 | 0 | 42.8 | 7.9 | 3 | 34.8 | 3.3 | 3 |
| 5. | 0 | 100 | 42.5 | 7.8 | 0 | 44.8 | 5.5 | 0 |
| 6. | 50 | 100 | 43.5 | 10.4 | 0 | 50.0 | 8.1 | 0 |
| 7. | 100 | 100 | 46.5 | 14.6 | 0 | 49.4 | 7.8 | 0 |
| 8. | 150 | 100 | 48.0 | 12.3 | 0 | 51.7 | 8.3 | 0 |

* Zinc deficiency symptoms ratings:
0=no symptoms, 5=severe symptoms.

varieties. It can be seen from Table 14 that the application of N without Zn did not increase the height and number of tillers per plant rather it increased the severity of zinc deficiency. With the application of zinc sulfate, the zinc deficiency symptoms did not appear and the height and number of tiller per plant increased as the N dose was increased. IR 184 showed more severe symptoms than IR 8.

## Diagnosis of zinc deficiency of the rice plant.

The data of greenhouse and field experiments have conclusively shown that the physiological disease of rice known as *"Hadda"* or *"Yarqan"* in the central parts of West Pakistan is caused by zinc deficiency in the plant. A proper diagnosis of the same can be made by a combination of the following :-

1) **Visual symptoms.**

The midribs of the youngest leaves, especially the base, become chlorotic. The general symptoms are the appearance of brown blotches and streaks in lower leaves followed by stunted growth.

2) **Soil properties.**

The soils having a pH of above 7.5 and calcareous nature are conducive to zinc deficiency.

3) **Plant zinc content.**

If plant zinc content is less than 10 ppm, zinc deficiency is very likely to occur. The chances are less with a zinc content of 10-20 ppm.

4) **Foliar spray of zinc sulphate.**

A spray of 0.5% zinc sulphate solution will remedy the deficiency symptoms within a week after application and improvement in growth will take place.

## Remedial measures of zinc deficiency of the rice plant.

The following measures can be adopted to cure zinc deficiency of the rice plant:

1) Drying of the field.

In case of mild deficiency, a change of water 3-4 times will improve the crop and zinc deficiency symptoms will not appear in the new leaves. If the symptoms are severe, the field should be dried to such an extent that soil surface cracks. The crop will start vigorous growth after irrigation.

2) Split application of fertilizers.

The entire quantity of nitrogenous fertilizer may not be applied before transplanting in one lot as in this case severe zinc deficiency symptoms develop and the entire crop may be wiped out. About 33% of the fertilizer should be applied 10-15 days after transplating, 33% 30-35 days after transplanting and 33% at panicle initiation.

3) The nursery may be applied 440 kg zinc sulphate per hectare before sowing.

4) The roots of the seedlings may be dipped in 1% zinc oxide suspension before transplanting.

5) The application of 44kg zinc sulphate per hectare will save the crop from zinc deficiency symptoms.

6) If the zinc deficiency symptoms appear the crop should be sprayed with 44kg zinc sulphate per hectare or the same quantity should be broadcasted in the field.

7) Use of resistant varieties or the varieties which recover earlier.

Of all the recommendations, the dipping of seedlings in 1% ZnO suspension appears to be the cheapest. About 1 lb of zinc oxide costing about US 60 cents is required to dip nursery for one acre. Field application of zinc sulphate is very costly and cannot be recommended to the farmers at present.

## Problems Requiring Further Study.

The experiments conducted so far have shown that the physiological disease of rice prevalent in the central region of West Pakistan is caused by zinc deficiency of the plant and that it can be cured by zinc application in any form. The following problems in this connection need further study.

1) Time of application of fertilizers in relation to zinc deficiency.

2) The relationship between phosphate application and zinc deficiency.

3) Determination of ways and means to increase availability of zinc present in the soil.

4) Evaluation of different sources of zinc to find out some cheaper material for curing zinc deficiency.

5) Determination of optimum dose of zinc for obtaining economical out-turn. A minimum dose of 44kg zinc sulphate per hectare has been tried. A lower dose may also be effective for curing zinc deficiency. Roy[13] reported that rice responded only to 11 kg $ZnSo_4$ per hectare.

## Summary

Zinc deficiency, a physiological disorder, was noticed about 30 years back in the Central Zone of West Pakistan and was then erroneously called paddy blast. Recently, the judicious use of nitrogenous and phosphatic fertilizers, needed to obtain the potential yields of dwarf high fertilizer responsive varieties, markedly increased the scourge. The fertilizer response realised in this region was lower as compared to that of southern region, where this disorder is not present. This situation necessitated studies to find out the cause and remedy of this disorder.

Dr. Yoshida, the Plant Physiologist of IRRI, conducted greenhouse studies with Kala Shah Kaku soil to determine the cause of disorder. He was able to reproduce this in the greenhouse. The analysis of plant and soil samples collected from the problem area showed that soils are not deficient in zinc, but it was not available to the plants, a property of the calcareous soils which have high pH. The inclusion of cellulose in his experiments showed that cellulose aggravated this disorder. He also applied radioactive zinc ($^{65}Zn$) to the roots and leaves and observed that zinc absorbed from the roots or from the lower leaves is directed to the upper leaves, which explained why the brown discoloration starts from

the lower leaves. All these studies established the fact that there is no other cause of this disorder except the zinc deficiency in the plant.

A field experiment conducted at Kala Shah Kaku in 1968 showed that application of zinc in any form is effective in alleviating this disorder and yield increased from one to two tons per hectare. Incorporation or surface application of zinc at puddling is as effective as top dressing when zinc symptoms appear. Of all the treatments, dipping of seedlings in 1% ZnO suspension is more economical. The trial is being repeated to study the residual effects of zinc. From growth data available now, it appears that soil retains enough zinc that the second crop can be grown successfully without additional zinc application. Further experiments, in progress, confirm the earlier results. Another zinc preparation sequestrene ($Na_2$ Zn) appears quite promising. Further studies are needed to find out the cheap material and its economical rate of application visa-a-vis time of fertilizer application.

## Discussion

**M. W Thenabadu**, Ceylon : Can you please give an explanation as to why Zn-deficiency disorder can be remedied by removal of water from the field and drying the soil completely ?

**Answer** : The exact chemical change involved is not known. It appears that due to removal of water and drying the soil, oxidised conditions are created. This change of reduced soil to oxidised soil appears to be responsible for increasing availability of zinc present in the soil.

**Soebijanto**, Indonesia : In table 11, dipping seedlings in 1% $ZnSO_4$ gives significant increase. Application of 100kg/ha $ZnSO_4$ on the nursery did not increase yield significantly. What would be the explanation ?

**Answer** : The seedlings were dipped in 1% ZnO suspension and not in $ZnSO_4$. The application of 100kg/ha $ZnSO_4$ to nursery alone did not increase the yield significantly probably because the seedlings had not taken enough zinc from the nursery bed to be sufficient for the entire life of the plant. The ZnO being insoluble in water, might have been absorbed slowly as and when needed by the plant. It was also near the roots of the plant.

## References for Paper 20


1. Baba, I. Inada, K. and Tajima. K. 1964. The Mineral Nutrition of the Rice Plant IRRI. 1964. Johns Hopkins Press Baltimore Maryland.
2. Bauer, A. and Lindsay, W. L. 1965. Soil Sci. Soc. Amer. Proc. 29. 413-416.
3. Burleson, C. A., Dacus, A. D. and Gerard, C. J. 1961. Soil Sci. Soc. Amer. Proc. 28. 83-86.
4. Ellis, R., Davis, J. F. and Thurlow, D. I. 1965. Soil Sci. Soc. Amer. Proc. 28. 83-86.
5. Martin, W. E., Mclean, J. C. and Quick James. 1965. Soil Sci. Soc. Amer. Proc. 29. 411-413.
6. Navrot, J., *et al.* 1967. Plant & soil. 27. 141-147.
7. Nene, Y. L. 1966. Bull. Ind. Phytopath. Soc. No. 3. 97-101.
8. Nene, Y. L. 1968. Int. Rice Commission News Letter 17(1) 1-7.
9. Ponnamperuma, F. N., *et al.* 1960. Soil Sci. 101. 421-431.
10. Sharma, K. C., Krantz, B. A., Brown. A. L. and James Quick. 1968. Agronomy Journal Vol. 60, pp 652-655.
11. Thorne, W. 1957. Advances in Agronomy. Academic Press. Inc. New York. 9. 31-65.
12. Yoshida, S., and Tanaka, A. 1969. Soil Sci. & Plant Nutrition (Tokyo) 15, 75.
13. Roy, B. P. 1967. Technology, India 4. 146-147.