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Physiology of Iron Toxicity in Rice (*Oryza Sativa* L.) and its Amelioration

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SUMMARY

In subtropics, Bronzing (iron toxicity) is one of the major nutritional disorders that causes low rice yield in acid soil condition (pH≈5.5) due to leaching of base cations during the high rainfall in summer. Due to iron-bearing minerals in soil, iron content in ground water remains always high (e.g. 0.25-93.8ppm) in some districts of Assam, and unless purified it's not fit for irrigation in cultivable land. The critical concentration of iron for rice crop varies greatly within a wider range *i.e* 45-500ppm. In excess, iron breaks down lipids in membrane by virtue of oxy radicals, and alters membrane permeability, dysfunctions all cellular activities like photo-assimilation leading to imbalance in source-sink relationship, and produces chaffy grains and reduces yield. Besides the common practices (viz., potash application, water management, adoption of iron tolerant genotypes etc.), assuming use of lime costly, and lime induced deficiencies of major nutrients, loading of calcium (≈500ppm) through root dip treatment prior to transplanting, is effective as prophylactic measure against iron toxicity in rice. Calcium ion or its modulator protein i.e. Ca-Calmodulin (CaM) repairs membrane, activates NAD kinase to revive photo-assimilation, prevents bronzing, maintains high density grains and increases yield in rice.

INTRODUCTION

In Assam, rice (*Oryza sativa* L.) is cultivated over an area of 2.525 million hectares as Kharif (70%), Ahu (23%) and Boro (7%) paddy. Rice is the staple food of more that 70 per cent people in the region. However, the productivity (2-3 tons per hectare) of most of the traditional genotypes is far below the national average. Besides occasional drought and flood situations, soil acidity with low pH (≈5.5) causing iron toxicity (bronzing) is one of the major nutritional disorders that causes physiological aberrations in rice lessening productivity **(**Begum and Bharali, 2016**).** The leaching of base cations due to heavy rainfall in the summer season, leads to build up of high amount of available Fe^{2+} (0.25 to 93.8ppm), and exchangeable H^+ in soil solution **(**Borah and Borkakty, 1997**).** So, application of natural ground water as such using shallow tube wells generates iron toxicity problem, and it creates physiological disorders. It comprises of chlorophyll discoloration and chaffy grains in the crop cultivated at places having high iron bearing minerals., or even at high altitude (>1200 m) with high deposition of alluvial soil on the down hills of the Himalayas along with the flood water in rainy seasons **(**Singh et al., 1992**).** The iron toxicity turns green leaves into yellowish, molded with dark brown spots or flecks followed by radish brown coloration **(**Borthakur and Baruah, 1990**).** So, available iron at low pH is absorbed and transported passively into the fixed intracellular space (Donnan Free Space) of plant cell (Brown and Wells, 1988), and accumulated Fe^{2+} becomes yield limiting **(**Bridgit et al., 1993**).** In general, **i**ron toxicity in rice has been ameliorated by broadcasting of potash to soil and spraying it on plants, water management, use of gypsum and FYM and inclusion of iron tolerant varieties. Based on the requirement, lime is commonly used to raise the soil pH and bring down availability of soluble Fe^{2+} (Patra and Mohanty, 1994), but in the event of soil pH greater than 5.7 up to 6.5 also induces deficiencies of many nutrients including Mg, K, Mn, Zn, B, P, and even Fe (Sanyal and De Datta, 1991). Therefore, physiology of iron toxicity with special reference to its mitigation with Ca^{2+} uploaded following root dip treatment of juvenile nursery seedlings before transplanting (Begum and Bharali, 2016; Sarma and Bharali, 2015) into main bed is focused in this paper.

Discussion

The prevalence of iron toxicity is known differently elsewhere around the globe. For instance, in India, the disorder is called *Dakhina* in Champaran, *Bhabani* in Darbhanga, *Ufra* in Mazaffarpur, *Chatra* in Sahabad and *Bhangiphuti* in Sambalpur, *Strait-head, Yellowing or Browning in Orissa*, and Bronzing in Assam. Also, it's recognised as *Akiochi* in Korea, *Akagree* in Japan, *Penyakit* merah in Malya, *Mentek* in Indonesis, *Pansuk* in Bangladesh and *Brobnzing or Browning* in Sri Lanka; *Brusone*, *Crodatura* in Italy, *Faille* in Spain, *Suffocating* in Taiwan. In the process of bronzing, iron concentration in soil and time after transplanting of plants are combined factors for its extent of damage. For instance, at 400ppm Fe^{2+}green leaves are slowly turned yellowish at thirty days after transplanting. However, it recedes after seventy days after transplanting. Rice shows potassium deficiency symptom at 150- 450ppm available iron in soil solution. Leaf chlorosis is observed at 350-450ppm, dark brown spots followed by Bronzing appears at 450-780ppm, and a concentration of available iron between 800-1200ppm in soil becomes lethal to the plants. It's quite amazing that iron concentration as low as 45ppm causes Bronzing, whereas a concentration as high as 500ppm may not show the Bronzing in rice**.** However, in general, 300ppm iron on plant dry weight basis is considered as a tentative critical limit of iron for Bronzing in rice in the Himalayan region **(**Tanaka and Yoshida, 1970**)**.

As evidenced, significant reductions in total chlorophyll and total soluble protein contents occur in rice plant grown with excess iron in the growth medium **(**Baruah and Nath, 1996**)**. In an increase of iron, the membrane integrity is disrupted as iron binds to the cell membrane. Higher iron concentration dissociates plasma membrane especially in root cells. Iron helps in catalytic conversion of H_2O_2 to oxygen radical responsible for breakdown of lipids (Price and Hendry, 1991**)**. Since, the structural integrity of the membrane of lipid is disrupted; permeability property is altered resulting in increased rate of solute leakage from the interior of the cell (protoplasm). Then, the root cell no longer functions normally. Thus, it reduces the rate of nutrient absorption by root cells. The development of leaf area and shoot growth in conjunction with chlorophyll contents are retarded directly under higher iron condition. In contrast, Calcium is a counteractive cation for inorganic and organic anions in the vacuole. Calcium helps in maintenanance of cell integrity (Epstein, 1972). Calcium bridges phosphate and carboxylate groups of phospholipids and protein at membrane surface **(**Legge et al., 1982**)**. Calcium ion prohibits the deleterious effects of iron on differential sensitivity of rice varieties **(**Sarma and Bharali, 2015**). ** The physiological response of plants to Calcium is concentration limited. In optimal concentration (i.e. 500ppm), Ca^{2+} protects membrane from free radical or peroxidative damage in membranes. Bridging of membranes involving phosphate and COOH- groups, is brought about by Ca^{2+} to maintain its permeability (Bharali and Bates, 2004**)**. The general mechanism by which Ca^{2+} modulates a response is through a change in its concentration. At an elevated level, Ca^{2+} binds either directly to a protein response element or to the modulator protein, Calmodulin (CaM). The Ca^{2+}-CaM complex binds further to the response element that causes activation, and allows for the subsequent reactions that comprise the response (Bharali and Chack, 2018**)**. The most of the CaM activated NAD kinase is localized in the chloroplast stroma (Jarrett et al., 1982). NAD kinase is an important regulatory component in the light induced conversion of NAD to NADP, the terminal acceptor of photo system I. The light stimulated Ca^{2+} uptake into the chloroplast is not only important in the regulation of NAD kinase but photosynthetic metabolism also because it would trigger the production of NADP with the end result of providing NADPH for the reductive pentose phosphate pathway. So, Ca^{2+} helps in assimilate production (High density grains in rice) and trigger yield of rice crop.

CONCLUSION

Iron beyond critical concentration is phytotoxic in rice crop in acid soil with low pH which leads to physiological aberrations viz., chlorophyll discoloration, alteration of membrane permeability due to its break down, and yield reduction. Root dip treatment overnight with Calcium solution (viz., 500ppm) before transplanting is a prophylactic measure to overcome iron toxicity in rice as it rejuvenates cellular activities, and helps in rice grain production in acid soil condition.

REFERENCES

Baruah, K.K. and Nath, B.C.(1996) Changes in growth, iron uptake and metabolism of rice seedlings at excess iron in growth medium,. *Indian J. of Plant physiol.* (New series).1: 114-118.

Begum, M. and Bharali, B. (2016) Calcium ameliorates Bronzing in rice (*Oryza sativa* L.) under field condition . *Indian Journal of Plant and Soil,Vol.3(2):13-22*

Bharali, B. and J.W. Bates (2004) Influences of extracellular calcium and iron on membrane sensitivity to bisulphite in the mosses *Pleurozium schreberi* and *Rhytidiadelphus triquetrus. Journal of Bryology*, 26:53-59.

Bharali, B. and Chack, S. (2018) Impact of aerosols of oxidized and reduced nitrogenalong with light regime, physiological drought, and substratum types on wheat (*Triticum aestivum* L.) crop. *Advances in Agriculture and Environmental Science,* 1(1):40-47.Barthakur, H.P. and Baruah, R.C. (1990) Report on iron toxicity problems of ground water of Assam incrop production. *Agri. Chem. Resh. Unit. Direc. Resh., AAU*, Jorhat.

Bora, D.K. and Borkakati, K (1997) ‘Soil Acidity’ In: ‘Managing Acid Soils for Sustainable Agriculture’ Review of Soil Rrsearch in Assam, H.P. Borthakur, Dept. of Soil Science., AAU, Jorhat, 22-40.

Bridgit, T.K., Potty, N.N., Markutty, K.C. and Anilakumar, K., (1993) Anionic relation to iron in rice culture in lateritic soils. *Proceedings of Fifty Kerala Science Congress*, 28-30; Kotyam. pp.140-141.

Brown, D.H. and Wells, J.M. (1988). Sequential elution technique for determining the cellular locations ofcations. In: *Methods in Bryology*. Ed. Glime, J.M. Nichinan, Japan. Hatori Botanical Laboratory.

Epstein, E. (1972) *Mineral Nutrients of Plants: Principles and Perspectives*. John Wiley and Sons, New York.

Jarrett, A.W., Brown, C.J., Black, C.C. and Cormier, M.J (1982). Evidence that calmodulin is in the chloroplastof peas and serves a regulatory role in photosynthesi. *J.Biol. Chem.* 257: 13795-804.

Legge, R.L. Thompson, j.E., Baker, J.E. and Lieberman, M. (1982), The effect of calcium on the fluidity of phase properties of microsomal membranes isolated from post climacteric golden delicious apples. *Plant and Cell Physiol*.; 23: 161-169.

Patra, B.N. and Mohanty, S.K. (1994) Effects of nutrients and liming on changes in pH redox potential and uptake of iron and manganese by wetland rice in iron toxic soil. *Biology and Fertility of Soils* 17(4):285-288.

Price, A.H, and Hendry, G.A.F.(1991) Iron catalysed oxygen radical formation and its possible contribution to drought damage in nine native grasses and three cereals. *Plant Cell and Environment.* 1991; 14: 477-848.

Sanyal, S.K. and De Dutta, S.K.(1995) Advances in soil science, 16:1.In: Acid Soil Management.Edt. by Mohsin, M.A., Sarkar, A.K. and Mathur, B.S., pp44.

Sarma, P. and Bharali, B.(2015), Effects of Calcium on Physiology of Rice (*Oryza sativa* L.) under iron toxic condition. *Indian Journal of Plant and Soil.* 2(2): 47-54.

Singh, B.P., Das, M., Ram, M., Dwivedi, B.S. and Prasad, R.N.(1992), Characterisation of Fe-toxic soils andaffected plants in Meghalaya. *J. Indian Soc.Sci.*; 40: 329-428.

Tanaka, A. and Yoshida, S. (1970). Nutritional disorders of the rice plant in Asia, IRRI, Tech. Bull. No. 10.