

## ZINC FERTILIZATION EFFECTS ON AGRO-MORPHOLOGICAL AND QUALITY PARAMETERS OF COMMONLY GROWN RICE

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### ABSTRACT

Among the micronutrients, zinc deficiency is widespread throughout the world particularly in low land rice fields causing low yields and affecting nutritional quality of the produce. In present investigation, 26 rice cultivars including some locals, aromatics, HYVs and hybrids grown on an Inceptisols with no Zn, basal Zn and soil+foliar applied Zn were evaluated for agro-morphological and quality parameters in a strip plot design having three replications during *kharif* season for consecutive two years (2009 and 2010). Rice cultivars differed significantly in their native agro-morphological parameters as well as among cultivar categories. Grain and straw yield as well as harvest index of different cultivars showed wide variations both with and without Zn application. On average, grain yields of different rice cultivars increased by 29% and 22% with soil plus foliar and only soil application of Zn, respectively. Regarding yield efficiency, HYV showed highest efficiency followed by hybrid, aromatic and local cultivars, irrespective of Zn fertilization. Applications of Zn, both as basal and as soil+foliar application significantly reduced the Fe content in brown rice irrespective of the cultivar grown.

**Key words:** Rice cultivars, agro-morphological parameters, zinc, iron, brown rice

### INTRODUCTION

Micronutrient malnutrition affects nearly one-third of the world populations, particularly in developing and under-developed countries (Alloway, 2004). Among the micronutrients, Zn and Fe deficiencies are of major concern, not only in crop

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production point of view but also in animal and human nutrition. Zinc deficiency in lowland rice (*Oryza sativa* L.) fields occurred due to its chemical precipitation with sesquioxides and rendering it unavailable to plants (Mandal et al., 1992). Hence, lowland rice fields having marginal or medium status of available Zn could become Zn deficient under waterlogged conditions (Dobermann and Fairhurst, 2000). Response of rice crop to applied Zn towards yield increments as well as grain Zn enrichment was observed in India (Singh, 2009), Bangladesh (Rahman et al., 2008), Turkey (Cakmak, 2008) and China (Zou et al., 2007). Possibly, the cultivars also differ in their response to zinc fertilization in Zn-deficient soil. Genotypic variations in Zn uptake and utilization in Zn deficient soils have also been reported (Graham and Rengel, 1993; Fageria et al., 2002). An attempt has been made in this study to screen out twenty six rice cultivars including some locals, HYVs, hybrids and aromatics popularly grown in Indian subcontinent as to their important agromorphological and quality parameters.

### MATERIALS AND METHODS

The study was conducted in *kharif* season (summer) for the consecutive two years (2009 and 2010) at the Central Research Farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal, India located at 22° 58.114' N latitude and 88° 29.543' E longitude. The experimental plot remained fallow for last ten years and soils of the experimental plot had clay loam texture, pH 6.6 (Page et al., 1982), organic carbon 8.9 mg kg<sup>-1</sup> (Walkley and Black, 1934), available Fe 215.8 mg kg<sup>-1</sup>, available Mn 16.0 mg kg<sup>-1</sup>, available Zn 0.7 mg kg<sup>-1</sup> (marginally deficient since, critical limit of available Zn for anaerobic rice is 0.8 mg kg<sup>-1</sup>) and available Cu 6.0 mg kg<sup>-1</sup> (Lindsay and Norvell, 1978). Twenty six popularly grown rice cultivars including two locals, four aromatics, seventeen high yielding varieties (HYVs) and three hybrids with wide genetic variations were raised with standard management practices. Agro climatic parameters like rainfall, expand T<sub>max.</sub>, expand T<sub>min.</sub> and relative humidity prevailed over the location during June to September were 1265 mm, 32.0°C, 26.3°C and 97% during 2009 and 987 mm, 32.6°C, 25.1°C and 94% during 2010 respectively Paddy seeds were sown in a nursery bed following standard method. During nursery bed preparation the soil was puddled with the help of country plough. On the next day, nursery area was divided into narrow beds of 1m width and 10 m length. Drainage channel (30 cm wide) was made in between the seed beds. Urea and SSP were applied @ 22.5 and 50 g/m<sup>2</sup>, respectively. Three hand full seeds were uniformly broadcasted on the seed bed. The seed bed was saturated with water for first four days and then water level was increased gradually up to 5 cm as the seedlings started to grow. Seedlings were transplanted in the main field at the age of 25 days. Flood irrigation was done depending on rainfall during the growth period of the crop. Three Zn treatments viz., no Zn (Zn<sub>0</sub>), Zn @ 20 kg ha<sup>-1</sup> as zinc sulphate heptahydrate (ZnSO<sub>4</sub>.7H<sub>2</sub>O) as basal (Zn<sub>1</sub>) and Zn @ 20 kg ha<sup>-1</sup> as basal + two foliar sprays (Zn<sub>2</sub>) - one at pre-flowering and another at grain forming stage @

0.5%  $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$  were imposed. Zinc fertilizer was applied to soil at the time of land preparation through broadcasting followed by surface incorporation. Treatments were imposed in a strip plot design having three replications. Foliar application of Zn was practiced with a Knapshack sprayer (volume 14 litre) @ 4.42 kg  $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$   $\text{ha}^{-1}$  at evening hours of the daytime. As the rice cultivars varied widely in their genetic make-up, initiation of flowering was at different times in the growing season, therefore spraying was done at different days after transplanting according to the initiation of flowering. NPK fertilizers were applied as per the recommended dose in all the plots of the experimental field (80:40:40). Half of the dose of nitrogen was applied at the time of transplanting (through IFFCO::10:26:26 and urea) and the other half at tillering stage (through urea). The entire amount of P and K were applied at the time of transplanting (as IFFCO::10:26:26). The brown plant hopper (*Nilaparvata lugens*) and gundhy bug (*Leptocorisa acuta*) have been observed as major pests of rice during early crop establishing and milky stages, respectively. The Imidachloprid @ 100 ml  $\text{ha}^{-1}$  and Carbaryl @ 25 kg  $\text{ha}^{-1}$  were used on the crop and found to be most effective against BPH and gundhy bug infesting rice, respectively.

At maturity, the rice cultivars were harvested plot-wise and representative samples of grains were collected and subsequently processed for dry-ashing and then concentration of Zn and Fe in brown rice was measured by using an atomic absorption spectrophotometer (GBC *Avanta*). Important agro-morphological parameters of rice cultivars viz. number of tillers per hill at maximum tillering stage; plant height, panicle length (considering eight number of hills in each plot and their mean values were presented), test weight (thousands grain weight), grain and straw yields of each cultivars were measured plot-wise for the consecutive two years i.e. 2009-10 and 2010-11. Harvest index (HI) of different cultivars was calculated as grain yield divided by biomass yield (grain yield+straw yield).

Analysed data of the aforesaid trial pooled for the consecutive two years i.e. 2009 and 2010 are presented. Design of the experiment followed for statistical analysis was strip plot. Statistical analyses of the data for comparison among the treatments were done using SPSS 10.0 software package.

## RESULTS AND DISCUSSION

### *Number of tillers per hill at tillering stage*

Number of tillers per hill varied widely among the cultivars as well as within the categories of the cultivars and among the different categories of the cultivars, it was higher in hybrids followed by HYV, aromatics and locals irrespective of Zn application. Results further depicted higher number of tillers per hill from Zn treated plots compared to untreated control irrespective of the rice cultivars. On an average, number of tillers per hill of the tested cultivars varied from 9.7 to 22.8 with a mean value of 15.0 (Table 1). The highest number of tillers per hill (22.8) was recorded in the cv. Satabdi, a high yielding cultivar with basal application of Zn fertilizers but the

lowest number (9.7) was recorded in the cultivar IR 64, a high yielding cultivar in untreated control. On an average, 17% increase in the number of tillers per hill was found with basal application of Zn over control.

#### ***Plant height of the rice cultivars***

Results revealed that Zn application through both soil and soil plus foliar applications resulted a significant increase in plant height over control. The magnitude of such increase was higher with soil plus foliar application of Zn than only soil application irrespective of the cultivars tested. Among the rice cultivars, the highest value (203.1 cm) was recorded in Kalma 222, a local cultivar and the lowest (92.9 cm) was in IR 64, a high yielding cultivar. Results also revealed that there was an increase in its height to the tune of 3.6 and 7.3% with soil and soil+foliar application of Zn respectively over control (Table 1). Regarding different categories of the cultivars, results also showed that it was higher with locals followed by aromatics, HYVs and hybrids irrespective of Zn application methods.

#### ***Panicle length of the rice cultivars***

Like plant height, panicle length of rice cultivars was also influenced significantly by Zn levels as well as genotypes. Its magnitude varied from 19.8 to 33.7 cm with a mean value of 25.5 cm (Table 1). Results also showed that Zn application, on an average, caused an increase in its amount over control to the magnitude of 5.6% and 10.2% in soil Zn and soil plus foliar Zn respectively, irrespective of cultivars. So, from the results it can be opined that soil plus foliar application of Zn is conducive for increasing the panicle length. These results are in line with Bandara and Silva (2000) who reported an increase of 7% panicle length upon application of 2.5 kg Zn ha<sup>-1</sup>, while Fageria and Baligar (2005) showed significant genotypic variations among the rice genotypes upon application of Zn fertilizers as well as without Zn application. Results also showed that among the different categories of the cultivars Zn application was very effective in case of hybrid followed by aromatic, local and HYV.

#### ***Test weight (g) of the rice cultivars***

Test weights (thousand grain weight) of the rice cultivars were measured after drying (at 50°C) of the harvested grains containing 12-13% moisture. Results (Table 2) of test weight corroborated with those of panicle length, where it was found that Zn application caused a significant increase over control. Results further showed that similar to panicle length, soil plus foliar application was superior to only soil application. Panicle length varied from 95.3 to 293.3 g with a mean value of 199.1 g irrespective of cultivars and Zn application (Table 2). Results also showed that Zn application, on an average, caused an increase in panicle length to the tune of 3.9% and 5.3% in soil and soil plus foliar application of Zn respectively. Regarding relative efficiency about test weight of the different categories of the cultivars results showed that HYVs were more effective followed by hybrids, aromatics and locals. Bandara

and Silva (2000) reported 3.6% increase in test weight with application of 2.5 kg Zn ha<sup>-1</sup>, while Rahman et al. (2008) reported an increase in test weight upon Zn application @ 1.5 and 3.0 kg Zn ha<sup>-1</sup> but the effect was found non-significant. Similar trend of result was also reported by Pal et al. (2008). Increased test weight of rice cultivars upon Zn fertilization might be due to its involvement in the carbonic anhydrase activity and more carbohydrate accumulation in seeds.

#### ***Yield and harvest index (HI) of the rice cultivars***

Grain and straw yields recorded the similar trend of results like those of plant height and test weight where results showed a significant increase in their amounts upon Zn application. Results also showed that effect of Zn was further influenced by the method of application i.e. soil and soil plus foliar applications irrespective of the cultivars grown. Soil plus foliar application of Zn caused a significant increase in grain yield not only over control but also over only soil application of Zn. Highest grain yield was recorded with HYVs followed by hybrids>aromatics>locals. On an average, grain yield of rice cultivars varied from 10.8 to 35.3 q ha<sup>-1</sup> in locals and HYVs respectively when grown in native soil deficient in Zn. Highest grain yield of 66.7 q ha<sup>-1</sup> as well as lowest grain yield of 12.8 q ha<sup>-1</sup> was recorded in Swarna, a HYV and Kalma 222, a local cultivar respectively with application of soil +foliar spraying of Zn fertilizers (Table 2). The magnitude of increase in its amount over control was 29% and 22% in soil plus foliar and only soil application of Zn respectively. Therefore, it can be opined that soil plus foliar application of Zn was very effective than soil alone application. Regarding yield efficiency, HYVs showed the highest performance followed by hybrid, aromatic and local irrespective of Zn applications. Highest grain yield in HYVs than other cultivars might be related to their physiological efficiency, since Zn being metallic co-factor of a number of enzyme proteins influencing such activities in plants e.g. carbonic anhydrase and a number of dehydrogenases (Vallee and Wacker, 1970). Increased grain yield of 16.5% upon application of 2.5 kg Zn ha<sup>-1</sup> was reported by Bandara and Silva (2000) while 15% increase in grain yield upon application of 5 kg Zn ha<sup>-1</sup> was reported by Rahman et al. (2008); a significant increase in grain yield upon Zn fertilization and its variations among the upland rice cultivars was also reported by Fageria and Baligar (2005).

Straw yield (Table 2), on the other hand, was higher in locals (135.6 q ha<sup>-1</sup>) followed by hybrids (113.5 q ha<sup>-1</sup>), aromatics (107.0 q ha<sup>-1</sup>) and HYVs (86.0 q ha<sup>-1</sup>). On an average, its magnitude varied from 47.9 q ha<sup>-1</sup> to 145.1 q ha<sup>-1</sup> with a mean value of 90.2 q ha<sup>-1</sup> (Table 2). Results also showed that upon Zn application, magnitude of increase in straw yield was less than that of grain yield, where it recorded 12% and 17% increase over control in soil plus foliar and only soil application of Zn respectively. Results, therefore, revealed that Zn application was very effective to increase the grain yield compared to straw yield.

Harvest index (HI) i.e. transfer of photosynthates from shoot to grain of the cultivars was also estimated and the results revealed that Zn application recorded an increase in HI over control and the magnitude of increase was higher with soil plus foliar (7.5%) than soil alone application (6.3%) of Zn (Figure 1). Results also showed that among the different categories of the cultivars, HYVs were very efficient to transfer the photosynthates from shoot to grain followed by hybrids, locals and aromatics and this result was in corroboration with the grain yields of the cultivars discussed earlier. Results further revealed that HI values varied widely among the cultivars and it ranged from 0.085 to 0.509 with a mean value of 0.296. According to photosynthate translocation efficiency (i.e. HI) cultivars were grouped into four classes: very low HI i.e. < 0.2 (FR 43B, Kalma 222, Badshabhog, PA 6444, PHB 71, Gayasur and Gobindabhog), low HI i.e. 0.2-0.3 (Sabita, Lalat, Samba masuri sub1, Samba masuri, IR 64, Bhudev and PNR 546), medium HI i.e. 0.3-0.4 (Satya, Swarna, Satabdi, IR 36, Swarna sub1, Triguna, KRH 2, PNR 519, Khitish and Rasi) and high HI i.e. > 0.4 (GB2 and GB1). Results revealed that increased HI of rice was associated with higher Zn concentration in grains. The higher HI of the latter groups of cultivars recorded a greater amount of Zn in grains than the former groups upon soil+foliar application of Zn. This trend was just the reverse in only soil applied Zn fertilizers excepting with low HI (0.2-0.3) grouped cultivars (Figure 2).

#### ***Influence of Zn fertilization on Zn concentration in brown rice***

On an average, Zn concentration in brown rice of the tested cultivars varied from 22.9 mg kg<sup>-1</sup> to 79.7 mg kg<sup>-1</sup> with a mean value of 40.3 mg kg<sup>-1</sup> (Table 3). Results showed that Zn concentration in brown rice was higher in aromatics (32.0 mg kg<sup>-1</sup>) followed by HYVs (29.3 mg kg<sup>-1</sup>), locals (29.0 mg kg<sup>-1</sup>) and hybrids (25.9 mg kg<sup>-1</sup>). Results also showed that Zn content in brown rice varied significantly not only among the cultivars but also within the different categories of the cultivars. Most of the aromatic rice species, such as Jasmine and Basmati types, are high in both Fe and Zn (Senasdhira and Graham, 1999; Graham et al., 1999; Yang et al., 2007). Methods of Zn applications also showed significant variation between them and its magnitude was higher with soil plus foliar application of Zn than only soil application irrespective of the cultivars grown. Zinc application in soil increased the Zn concentration in brown rice to the level of 5.0 mg kg<sup>-1</sup> (17%) over the control; whereas, soil plus foliar applied Zn increased the same to the tune of 27.8 mg kg<sup>-1</sup> (95%) than no Zn treatment. Approximately two to three folds increase in grain Zn concentration upon soil plus foliar application was also observed by Cakmak (2008). Among the different categories of the cultivars Zn content in brown rice was higher with hybrid followed by local, HYV and aromatic upon soil plus foliar application of Zn. Highest increase in grain Zn content with soil+foliar application of Zn was found in Hybrids followed by HYVs than locals and aromatics.

***Influence of Zn on Fe concentration in brown rice***

As localization of Fe in rice kernel occurs in the surface bran layer and in embryo region, brown rice could be a good source of Fe for anaemic patients worldwide. Screening of rice cultivars as to their high Fe content in brown rice could be utilized in breeding purpose for production of high Fe containing transgenic rice cultivars. Loss of this Fe occurred to the extent of 65-70% during milling and this loss also varied among rice cultivars depending on size and shape of the rice kernel. So, white rice or polished rice would not be a good indicator of Fe availability to consumers. The present experiment also showed that Fe content in brown rice varied widely not only among the cultivars but also within the different categories of the cultivars. Results (Table 3) showed that Fe content in brown rice varied from 50.0 to 62.9 mg kg<sup>-1</sup> with a mean value of 54.4 mg kg<sup>-1</sup>. Native Fe content in brown rice of the tested rice cultivars was as follows: aromatics (72.0 mg kg<sup>-1</sup>) locals (66.9 mg kg<sup>-1</sup>), hybrids (58.0 mg kg<sup>-1</sup>) and HYVs (56.4 mg kg<sup>-1</sup>). Results further showed that application of Zn caused a significant decrease in grain Fe content over the control, irrespective of the cultivars and the magnitude of decrease was higher with soil plus foliar application of Zn (17.4%) than with only soil application (9.4%). Goirdano and Mortvedt (1972) also reported the antagonistic effect of Zn on Fe nutrition of rice regarding translocation within the plant as the pathway for Zn and Fe movement is same. Higher Fe content in grains of locals and aromatic cultivars than others might be due to high iron chelating phytosiderophore secretion from roots (Cakmak et al., 1996; Rengel et al., 1998) and more efficient utilization of iron from high iron containing soils (215 mg kg<sup>-1</sup> DTPA extractable Fe) of this region.

**CONCLUSIONS**

From the overall results it could be concluded that rice cultivars varied widely in their native agro-morphic parameters and grain Zn and Fe contents among the categories of locals, HYVs, hybrids and aromatics in native soil marginally deficient in available Zn. Application of Zn fertilizers both as basal as well as soil plus foliar application significantly influenced all the agro-morphological parameters tested viz., number of tillers per hill, plant height, panicle length, test weight, grain and straw yield of rice. The magnitude of increase in grain yield over control was 29% and 22% in soil plus foliar and only soil application of Zn respectively. Therefore, it can be opined that soil plus foliar application of Zn was very effective than soil alone application. Two foliar spraying of Zn (@ 0.5 % ZnSO<sub>4</sub>.7H<sub>2</sub>O) along with basal application (@ 20 kg Zn ha<sup>-1</sup>) increased the grain Zn content to the level of two to three times, while only soil applied Zn increased it very slightly indicating that basal application of Zn showed a trend to increase the grain yield, whereas, soil plus foliar application was proven to enhance the grain Zn content i.e. to increase the quality of the final produce.

## REFERENCES

- Alloway, B.J. 2004. Zinc in Soils and Crop Nutrition. IZA Publications, International Zinc Association, Brussels, pp: 1-116.
- Bandara, W.M.J. and Silva, L.C. 2000. Rice crop response to zinc application in low humic gley soils of low country intermediate zone. *Journal of Soil Science Society Sri Lanka*, 12: 40-50.
- Cakmak, I. 2008. Enrichment of cereal grains with Zn: Agronomic or genetic biofortification? *Plant Soil*, 302: 1–17.
- Cakmak, I., Yilmaz, A., Ekiz, H., Torun, B., Erenoglu, B. and Braun, H. J. 1996. Zn deficiency as a critical nutritional problem in wheat production in Central Anatolia. *Plant Soil*, 180: 165–172.
- Dobermann, A. and Fairhurst, T. 2000. Rice: Nutrient disorders and nutrient management. IRRI, Manila, Philippines.
- Fageria, N.K. and Baligar, V.C. 2005. Growth components and Zn recovery efficiency of upland rice genotypes. *Pesq. Agropec. Bras.*, 40(12): 1211-1215.
- Fageria, N.K., Baligar, V.C. and Clark, R.B. 2002. Micronutrients in crop production. *Advanced Agronomy*, 77: 185-268.
- Goirdano, P.M. and Mortvedt, J.J. 1972. Rice response to zinc in flooded and nonflooded soil. *AgronomyJournal*, 64: 521-524.
- Graham, R.D. and Rengel, Z. 1993. Genotypic variation in Zn uptake and utilization by plants. In: Zn in Soils and Plants, Ed. A.D. Robson. Kluwer Academic Publishers, Dordrecht. pp. 107–118.
- Graham, R.D., Senadhira, D., Beebe, S.E., Iglesias, C. and Ortiz-Monasterio, I. 1999. Breeding for micronutrient density in edible portions of staple food crops: Conventional approaches. *Field Crops Research*, 60: 57-80.
- Lindsay, W.L. and Norvell, W.A. 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of American Journal*, 42: 421-428.
- Mandal, B., Chatterjee, J., Hazra, G.C. and Mandal, L.N. 1992. Effect of preflooding on transformation of applied zinc and its uptake by rice in lateritic soils. *Soil Science*, 153: 250-257.
- Page, A.L., Miller, R.H. and Keeney, D.R. 1982. Methods of Soil Analysis, Part-2, Second Edition, *Soil Science Society of American Journal*, Madison, Wisconsin, USA.
- Pal, S., Banerjee, H., Basu, B. and Maiti, S. 2008. Studies on nutrient management practice in rice-rice crop sequence under new alluvial zone of West Bengal. *Oryza*, 45(1): 125-128.
- Rahman, M.T., Jahiruddin, M., Humauan, M.R., Alam, M.J. and Khan, A.A. 2008. Effect of sulphur and zinc on growth, yield and nutrient uptake of boro rice (cv. BRRI DHAN 29). *Journal of Soil Nature*, 2(3): 10-15.
- Reddy, A.M., Shankhdhar, D., Shankhdhar, S.C. and Mani, S.C. 2010. Effect of aerobic cultivation on yield, biochemical and physiological characters of selected rice genotypes. *Oryza*, 47(1): 22-28.



- Rengel, Z., Romheld, V. and Marschner, H. 1998. Uptake of zinc and iron by wheat genotypes differing in tolerance to zinc deficiency. *Journal of Plant Physiology*, 152: 433-438.
- Senasdhira, D. and Graham, R.D. 1999. Genetic variation in iron and zinc concentrations in brown rice. *Micronutrients and Agrilculture*, 3: 4-5.
- Singh, M.V. 2009. Micronutrient nutritional problems in soils of India and improvement for human and animal health. *Indian Journal of Fertilizer*, 5(4): 11-16, 19-26 and 56.
- Vallee, B.L., Wacker, W.E.C. 1970. Metalloproteins. In H. Neurath (ed.). The proteins (2nd ed.) Vol 5. Academic Press, New York. p. 192.
- Walkley, A.J. and Black, I.A. 1934. Estimation of soil organic carbon by the chromic acid titration method. *Soil Science*, 37: 29-38.
- Yang, X.E., Chen, W.R. and Feng, Y. 2007. Improving human micronutrient nutrition through biofortification in the soil-plant system: China as a case study. *Env. Geochem. Health*, 29: 413-428.
- Zou, C.Q., Gao, X.P. and Zhang, F.S. 2007. Micronutrient deficiencies in crop production in China. In: Alloway, B. (Ed) Micronutrient Deficiencies in Global Crop Production.

**Table 1: Influence of Zn fertilization on number of tillers per hill at maximum tillering stage, plant height and panicle length of the rice cultivars at harvesting stage.**

Type of cultivar	Name of the cultivar	No. of tillers per hill			Plant height (cm)				Panicle length (cm)			
		Zn <sub>0</sub>	Zn <sub>1</sub>	Mean	Zn <sub>0</sub>	Zn <sub>1</sub>	Zn <sub>2</sub>	Mean	Zn <sub>0</sub>	Zn <sub>1</sub>	Zn <sub>2</sub>	Mean
HYV	Sabita	10.4	11.3	10.8	153.3	159.5	167.7	160.2	24.2	24.5	28.7	25.8
	IR 36	15.5	18.4	17.0	97.5	98.8	100.9	99.1	21.3	21.6	22.3	21.8
	Khitish	13.4	16.0	14.7	98.2	100.5	102.2	100.3	23.7	23.8	24.1	23.9
	Satya	17.1	18.4	17.7	94.9	97.6	102.5	98.3	21.3	21.7	21.6	21.5
	Triguna	15.9	20.0	17.9	99.7	100.9	103.8	101.4	25.3	25.7	27.7	26.2
	Bhudev	14.6	13.9	14.3	128.8	141.3	144.4	138.2	24.5	26.2	27.2	26.0
	Swarna sub1	11.4	14.1	12.8	93.6	96.4	97.5	95.8	23.2	23.4	24.5	23.7
	Samba masuri sub1	17.5	17.3	17.4	96.0	100.9	108.4	101.8	20.6	21.7	21.8	21.4
	Satabdi	20.7	22.8	21.8	102.3	105.5	108.7	105.5	26.5	27.0	30.3	27.9
	IR 64	9.7	12.9	11.3	92.9	95.3	95.8	94.7	22.0	22.5	23.2	22.5
	Samba masuri	12.5	14.1	13.3	103.4	107.2	113.3	108.0	19.8	21.7	22.3	21.3
	Lalat	14.4	16.7	15.6	120.7	122.7	124.6	122.7	27.3	29.1	31.8	29.4
	Swarna	13.9	17.2	15.6	103.7	105.5	110.5	106.6	22.5	24.8	25.8	24.4
	GB 2	13.0	14.0	13.5	126.3	128.8	130.1	128.4	25.9	27.4	28.2	27.2
	GB 1	13.4	15.7	14.6	130.9	131.4	132.8	131.7	23.9	24.7	26.2	24.9
	Rasi	11.5	16.7	14.1	113.1	114.8	118.8	115.5	24.0	25.2	25.6	24.9
	PNR 519	14.1	18.2	16.1	110.9	113.4	115.5	113.3	22.5	23.9	25.0	23.8
Hybrid	KRH 2	14.8	19.9	17.3	133.4	141.7	146.8	140.6	28.9	29.9	31.6	30.1
	PHB 71	15.4	15.5	15.5	130.3	135.0	137.2	134.2	28.8	31.4	32.3	30.8

Type of cultivar	Name of the cultivar	No. of tillers per hill			Plant height (cm)				Panicle length (cm)			
		Zn <sub>0</sub>	Zn <sub>1</sub>	Mean	Zn <sub>0</sub>	Zn <sub>1</sub>	Zn <sub>2</sub>	Mean	Zn <sub>0</sub>	Zn <sub>1</sub>	Zn <sub>2</sub>	Mean
	PA 6444	16.1	17.8	17.0	130.2	132.0	133.8	132.0	23.6	26.3	27.3	25.7
Local	FR 43B	10.9	13.6	12.3	172.0	178.3	185.9	178.7	23.5	27.1	27.0	25.9
	Kalma 222	12.4	14.3	13.4	183.4	191.5	203.1	192.7	24.2	26.4	26.7	25.8
Aromatic	Gayasur	12.3	12.7	12.5	140.9	144.6	148.6	144.7	24.0	25.3	26.3	25.2
	Gobindabhog	15.0	17.3	16.2	139.5	153.3	154.1	148.9	24.4	25.5	25.5	25.1
	Badshabhog	12.2	15.6	13.9	148.9	154.5	154.8	152.7	24.2	26.7	28.8	26.6
	PNR 546	11.7	16.4	14.0	104.9	109.4	111.3	108.5	30.3	32.3	33.7	32.1
	Mean	13.8	16.2	15.0	121.1	125.4	129.0	125.2	24.2	25.6	26.7	25.5
		SEm (±)	LSD (0.05)		SEm (±)	LSD (0.05)		SEm (±)	LSD (0.05)			
	Variety	0.49	1.38		0.48	1.35		0.16	0.46			
	Zn	0.2	0.79		0.12	0.39		0.1	0.32			
	VarietyxZn	0.77	2.17		0.62	1.74		0.3	0.85			

**Table 2: Influence of Zn fertilization on test weight (g), grain yield (q/ha) and straw yield (q/ha) of the rice cultivars.**

Type of cultivar	Name of the cultivar	Test weight (g)				Grain yield (q/ha)				Straw yield (q/ha)			
		Zn <sub>0</sub>	Zn <sub>1</sub>	Zn <sub>2</sub>	Mean	Zn <sub>0</sub>	Zn <sub>1</sub>	Zn <sub>2</sub>	Mean	Zn <sub>0</sub>	Zn <sub>1</sub>	Zn <sub>2</sub>	Mean
HYV	Sabita	283.7	291.1	293.3	289.4	35.6	41.9	42.8	40.1	117.9	125.5	131.7	125.0
	IR 36	210.7	213.5	214.4	212.9	26.2	34.2	36.5	32.3	53.5	55.2	57.9	55.5
	Khitish	203.0	213.8	214.6	210.5	34.0	41.4	41.9	39.1	52.2	57.1	57.9	55.8
	Satya	146.4	153.0	154.6	151.3	34.6	38.7	40.8	38.1	74.9	93.5	100.0	89.4
	Triguna	198.9	207.2	207.6	204.5	28.1	38.3	43.3	36.6	53.7	58.3	59.7	57.3
	Bhudev	244.2	248.8	251.5	248.2	44.0	50.8	54.4	49.8	108.5	129.0	137.2	124.9
	Swarna sub1	190.7	194.4	195.3	193.5	43.2	52.8	54.2	50.0	84.7	89.4	91.2	88.5
	Samba masuri sub1	144.4	149.5	150.9	148.3	27.8	39.3	42.5	36.5	78.1	90.4	95.1	87.9
	Satabdi	170.0	173.2	174.3	172.5	22.8	28.6	30.4	27.3	47.9	53.9	54.4	52.1
	IR 64	216.4	230.8	237.4	228.2	25.7	35.4	38.3	33.1	65.7	74.9	76.1	72.2
	Samba masuri	143.9	151.0	155.4	150.1	33.2	40.3	42.1	38.5	85.3	95.6	101.5	94.1
	Lalat	238.3	246.0	251.3	245.2	27.2	34.3	40.4	34.0	84.0	103.6	108.2	98.6
	Swarna	195.6	202.7	205.6	201.3	58.7	65.1	66.7	63.5	126.5	135.1	145.1	135.6
	GB 2	213.0	219.1	222.0	218.1	41.1	45.6	48.1	44.9	52.8	56.2	59.2	56.1
	GB 1	198.0	203.5	204.0	201.9	53.7	62.9	64.4	60.4	58.3	60.7	62.6	60.6
	Rasi	196.7	203.3	204.5	201.5	31.5	39.9	40.8	37.4	47.9	57.4	60.6	55.3
PNR 519	198.5	211.4	215.1	208.3	32.8	38.5	41.0	37.5	54.3	62.4	63.3	60.0	
Hybrid	KRH 2	210.0	220.1	225.3	218.4	33.3	43.7	47.9	41.7	61.0	66.0	76.7	67.9
	PHB 71	225.7	235.2	236.3	232.4	24.3	29.0	29.7	27.7	110.1	117.9	119.6	115.9
	PA 6444	217.5	231.4	236.0	228.3	28.4	38.5	40.8	35.9	134.9	139.9	144.2	139.6
Local	FR 43B	221.6	226.3	228.2	225.4	11.4	15.8	16.8	14.7	122.8	136.7	142.4	133.9

Type of cultivar	Name of the cultivar	Test weight (g)				Grain yield (q/ha)				Straw yield (q/ha)			
		Zn <sub>0</sub>	Zn <sub>1</sub>	Zn <sub>2</sub>	Mean	Zn <sub>0</sub>	Zn <sub>1</sub>	Zn <sub>2</sub>	Mean	Zn <sub>0</sub>	Zn <sub>1</sub>	Zn <sub>2</sub>	Mean
	Kalma 222	249.9	254.9	257.3	254.0	10.1	12.6	12.8	11.9	104.2	121.7	128.7	118.2
Aromatic	Gayasur	120.3	128.3	132.9	127.1	19.6	25.3	26.5	23.8	85.7	106.0	111.2	101.0
	Gobindabhog	100.4	107.0	109.9	105.8	22.6	26.1	27.4	25.4	98.7	111.5	115.8	108.7
	Badshabhog	95.3	99.4	100.8	98.5	24.3	27.1	28.3	26.6	116.9	124.9	129.2	123.7
	PNR 546	195.6	203.5	206.8	202.0	24.2	27.6	28.5	26.8	57.8	69.2	71.9	66.3
	Mean	193.4	200.7	203.3	199.1	30.7	37.5	39.5	35.9	82.2	92.0	96.2	90.2
		SEm (±)		LSD (0.05)		SEm (±)		LSD (0.05)		SEm (±)		LSD (0.05)	
	Variety	1.1		3.08		0.37		1.04		0.88		2.46	
	Zn	0.39		1.28		0.19		0.61		0.32		1.04	
	VarietyxZn	1.85		5.16		0.6		1.68		1.15		3.22	

**Table 3: Influence of Zn fertilization on Zn and Fe content (mg kg<sup>-1</sup>) in brown rice.**

Type of cultivar	Name of the cultivar	Zn content (mg/kg)				Fe content (mg/kg)			
		Zn <sub>0</sub>	Zn <sub>1</sub>	Zn <sub>2</sub>	Mean	Zn <sub>0</sub>	Zn <sub>1</sub>	Zn <sub>2</sub>	Mean
HYV	Sabita	21.9	27.9	36.1	28.6	59.8	55.8	51.5	55.7
	IR 36	20.6	26.5	46.1	31.1	65.6	57.9	52.9	58.8
	Khitish	17.3	26.9	46.9	30.4	56.5	54.0	49.4	53.3
	Satya	17.8	24.0	40.1	27.3	55.2	51.2	47.9	51.4
	Triguna	22.0	32.4	51.3	35.2	57.6	53.5	47.6	52.9
	Bhudev	24.8	31.8	35.9	30.8	56.4	54.5	45.5	52.1
	Swarna sub1	22.1	27.8	51.3	33.7	55.6	50.1	46.6	50.7
	Samba masuri sub1	28.8	35.1	52.7	38.9	67.0	62.8	58.2	62.7
	Satabdi	27.3	31.8	56.3	38.5	50.5	45.0	42.7	46.0
	IR 64	21.8	27.7	42.5	30.6	50.0	46.6	42.5	46.4
	Samba masuri	28.5	34.7	58.9	40.7	56.0	50.6	46.4	51.0
	Lalat	27.4	41.0	72.6	47.0	55.5	53.4	49.5	52.8
	Swarna	22.8	28.3	39.0	30.0	54.4	51.0	46.5	50.6
	GB 2	20.0	28.7	52.5	33.7	50.6	48.9	45.9	48.5
	GB 1	22.5	27.1	73.6	41.1	55.3	52.4	47.5	51.7
	Rasi	24.1	32.1	65.7	40.6	56.6	52.1	47.4	52.0
	PNR 519	20.7	33.7	75.3	43.2	55.7	50.0	45.9	50.5
Hybrid	KRH 2	23.5	29.5	55.3	36.1	52.8	46.8	42.9	47.5
	PHB 71	19.8	35.3	57.1	37.4	56.6	45.8	42.1	48.2
	PA 6444	22.7	34.1	54.1	37.0	64.7	53.6	46.7	55.0

Local	FR 43B	25.5	32.4	49.0	35.6	67.8	62.5	59.3	63.2
	Kalma 222	27.1	30.9	57.4	38.5	66.1	57.8	53.6	59.2
Aromatic	Gayasur	25.4	30.4	43.3	33.1	72.1	67.8	62.9	67.6
	Gobindabhog	25.8	27.2	43.7	32.2	72.6	57.7	51.4	60.6
	Badshabhog	27.4	28.7	43.5	33.2	69.6	58.2	53.4	60.4
	PNR 546	32.7	38.2	53.0	41.3	73.7	67.6	56.9	66.0
	Mean	23.8	30.9	52.0	35.6	59.8	54.1	49.3	54.4
		SEm ( $\pm$ )		LSD (0.05)		SEm ( $\pm$ )		LSD (0.05)	
	Variety	0.50		1.41		0.14		0.38	
	Zn	0.16		0.53		0.04		0.14	
	VarietyxZn	0.89		2.49		0.24		0.67	

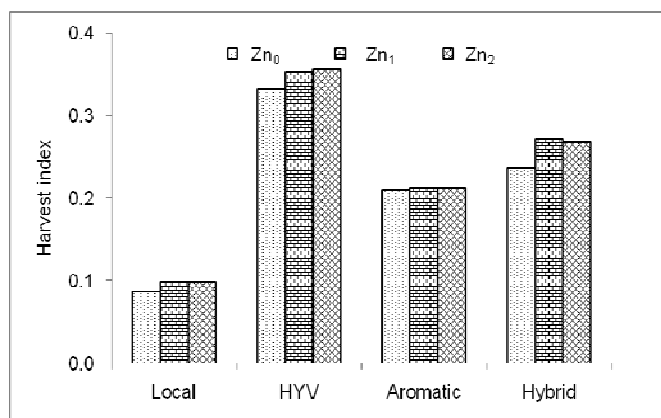


Figure 1: Variation in harvest index of the rice cultivars with different levels of Zn

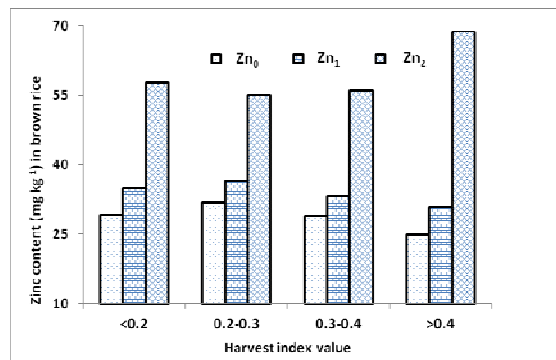


Figure 2: Relationship between harvest index and Zn content in brown rice with different levels of Zn

1. Since the Journal is for a greater audience of readers across many countries use of terms, units etc should be international.
2. Title says quality parameters but no such parameters were evaluated except grain Zn and Fe content. Hence re wording of title is suggested.
3. The LSD values given are for comparing mean effects or treatments effects. It has to be clearly indicated. The LSD value for variety is I believe can be used only to compare variety groups and not individual varieties.
4. No indication of the Figure 2 appear in the text.
5. Fe and Zn content variation in grain has to be given an important consideration as the people wanted grains having both Fe and Zn. Therefore authors should be encouraged to discuss the optimum way of having both in the grain. But he emphasize only on Zn.
6. Author has stated that he observed Brown Plant Hopper at early plant growth stage. I believe this must be thrips and not the BPH which usually attack the grown up plants with dense canopy when RH is high.