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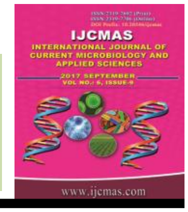

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Effect of Planting Geometry and Nutrient Levels on Yield and Zinc Concentration in Grains of High Zinc Rice (*Oryza sativa* L.)

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A B S T R A C T

A field experiment was conducted at Raipur, during *kharif* season of 2013 in factorial randomized block design with four replications to assess the effect of planting geometry on grain yield, zinc concentration, zinc yield and soil available zinc content of high zinc rice. Treatment comprised of three planting geometry *viz.*, 10cm x 10cm, 15cm x 10cm and 20cm x 10cm and three levels of nutrient *viz.*, 50%, 100% and 150% recommended dose of fertilizers (RDF). Recommended level of nutrient was 80:50:30 kg NPK/ha. Test variety was R-RHZ-1 which was short duration. The study revealed that planting geometry of 20cm x 10cm recorded higher grain yield, zinc concentration, zinc yield and zinc uptake as compared to other planting geometry. Planting geometry of 20cm x 10cm exhibited increase of 11.98 and 15.14% in grain yield, 3.37 and 4.65% in zinc concentration in grain, 6.44 and 9.98% in zinc yield and 5.79 and 9.30% in zinc uptake, however, soil available zinc was 11.98 and 15.14% lesser as compared to closer planting geometry of 15cm x 10cm and 10cm x 10cm, respectively. Among different nutrient levels, application of 150% RDF produced higher grain yield, zinc yield and zinc uptake, however, zinc concentration and soil available zinc content were higher under 50% RDF. Application of 150% RDF recorded increase of 12.81 and 7.09% in grain yield, 7.17 and 6.83% in zinc yield and 6.40 and 6.86% in zinc uptake as compared to 50% RDF and 100% RDF, respectively. Moreover, zinc concentration was 5.69 and 0.13% and available zinc content was 10.76 and 3.03% lesser with application of 150% RDF as compared to 50% RDF and 100% RDF, respectively.

Keywords

Planting geometry, Nutrient levels, Grain yield, Zinc concentration, Zinc uptake, High zinc rice.

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Introduction

Rice is most important staple food crop for half of the world population. It is cultivated in the largest area in India with acreage 45.5 m ha and productivity of 2393 kg/ha (Anonymous 2013). Chhattisgarh is main rice growing area and known as "Rice bowl" due to the highest area in the state. It is cultivated in 3.67 m ha area which is about 75% area of kharif season with productivity of 2041 kg/ha during 2013-14 (Anonymous, 2014). It is grown in different agroclimatic zones of the state and in a variety of soil with different land situations. It is the main staple food of the state and most of the dietary requirements are fulfilled by rice. The people, more particularly tribal habitats, are generally malnourished and zinc and protein deficiencies are more common. The most common reason for high Zn deficiency in human beings is inadequate dietary zinc intake, particularly in the regions where cereal based foods are the major source of calories.

WHO (2002) estimated 8 lakhs deaths worldwide each year to zinc deficiency and over 28 million healthy life lost. Zinc deficiency in human body causes undesirable consequences including growth retardation, dermatitis, impaired immune functioning, hypogonadism, delayed wound healing and poor mental development (WHO, 2002). The present high yielding varieties of rice have lesser zinc content around 12-14 ppm and as rice is the main diet in this area, the supplementation of zinc through zinc enrich rice may be one of the alternative to fight against problem of zinc deficiency in human beings. Therefore, works are going to develop high zinc rice varieties which has nearly twice zinc content (22-24 ppm) suitable to particular area so that zinc intake can be enhanced in natural way through rice feeding. However, these varieties are needed to test for agronomic potential and zinc load in grain so that it can be produced in massive way to meet enough zinc to eliminate "hidden hunger," and food requirements of over growing population ant thus, growing of high zinc rice can make the difference between illness and a healthy life for millions of people around the state, country and world, and productive life.

The yield of rice can be increased through improved agronomic manipulations such as proper planting geometry and judicious use of fertilizer (BARI, 1995). The optimum planting geometry ensures the plant to grow in their both aerial and underground parts through efficient utilization of solar radiation and nutrients (Miah *et al.,* 1990). The plant to plant and row to row distance determines the plant population per unit area which has direct effect on yield. Closer planting geometry hampers intercultural operations, more competition arises among the plants for nutrient, air and light as a result, plants become weaker and thinner and consequently, yield is reduced. However, it largely depends on varietal tillering ability. So, it is most important to determine optimum planting geometry for maximizing the yield of high zinc rice. As zinc rice is the quality rice, grain yield alone may not be criteria for production. Zinc concentration in grain and zinc yield is also important features for high zinc rice as it is the practical approach to meet out zinc requirement. It is also important to know the effect of high zinc rice on soil zinc status as its uptake is more than normal rice due to higher zinc concentration in grain and straw. Therefore, present investigation was carried out to find out effect of planting geometry and nutrient levels on grain yield, zinc concentration, zinc yield and soil available zinc content of high zinc rice.

Materials and Methods

Field experiment was conducted at Research cum Instructional farm, I.G.K.V., Raipur, during *kharif* season of 2013. The soil of the experimental soil was *Vertisols* with neutral in reaction (pH 7.6), low in organic carbon (0.37%), low in available nitrogen (187.2 kg/ha), medium in available phosphorus (19 kg/ha) and potassium content (220.1 kg/ha). The soil available zinc content was 2.3 ppm. The experiment was laid out in factorial randomized block design with four replications. The treatments consisted of three planting geometry *viz*., 10cm × 10cm (S_1), 15cm × 10cm (S_2) and 20cm × 10cm (S_3) and three levels of nutrients *viz*., 50%RDF (F_1), 100%RDF (F_2) and 150%RDF (F_3). Recommended level of nutrient was 80:50:30 kg NPK/ha (RDF). Nutrients were applied as per the treatments of the investigation. The entire amount of phosphorus and potassium and half dose of nitrogen were applied as basal and remaining half dose of nitrogen was applied in two equal splits *viz*., 25% at active tillering and 25% at panicle initiation stage. The nitrogen, phosphorus and potassium were applied in the form of urea, single super phosphate and muriate of potash, respectively. The test variety was R-RHZ-1 which was short duration. Transplanting of 2-3 seedlings/hill was done at different planting geometry as per treatments. Normal cultural practices were given to all the treatments equally. Crop was irrigated as when required to maintain water levels of 5±2 cm standing water till maturity. Twenty one day old seedlings was transplanted on 27.07.2013 and harvested on 20.10.2013. Yield attributes *viz*., number of effective tillers/m^2, panicle length, panicle weight, number of total grains/panicle, number of filled grains/ panicle and test weight were recorded at harvest from random samples. Grain and straw yield were recorded from net plot area and harvest index was calculated by dividing grain yield by total biological yield multiplied by 100. Zinc content in rice was determined using method described by Lindsay and Norvell (1978). The zinc yield was calculated by multiplying brown rice yield and zinc concentration. The uptake of zinc was calculated by multiplying grain and straw yield by respective zinc concentration in grain and straw and summing up. The soil available zinc content was analysed after harvest of crop using Atomic absorption spectrophotometer DTPA Method (Lindsay and Norvell 1978). The data were analyses statistically as suggested by Gomez and Gomez (1983) to find out significant difference and to draw valid conclusion.

Results and Discussion

Yield attributes

The yield attributing characters significantly varied due to different planting geometry (Table 1). Higher panicle length (24.9), panicle weight (4.22), number of total grains/panicle (176), number of filled grains/panicle (139) and test weight (26.04) were noticed in the 20cm x 10cm planting geometry which might be due to fact that wider planting geometry provide efficient use of nutrient and available resources with less competition (Kandil *et al.,* 2010 and Pol *et al.,* 2005). While 10cm x 10cm planting geometry gave significantly the highest number of panicle/m^2 (356) which might be due to higher plant population per unit area. Similar result was also reported by Siddiqui *et al.,* (1999). Planting geometry of 15cm x 10cm produced intermediate number of panicles/m^2 and number of total grains/panicle with significant difference to other planting geometry. The number of panicles in closer planting geometry of 10cm x 10cm was 12.9 and 47.7% higher compared to 15cm x 10cm and 20cm x 10cm, respectively. However, the number of filled grains/panicle was 1.5% higher in 15cm x 10cm and 6.92% higher in 20cm x 10cm as compared to 10cm x 10cm planting geometry. The lowest value of yield attributing characters except number of panicles/m^2 was obtained under10cm x 10cm planting geometry.

The application of 150% RDF produced significantly the highest number of panicle/m^2 (308), panicle length (25.3) and panicle weight (4.11). Number of panicle/m^2 and panicle weight was found at par with that of 100% RDF. The lowest value of panicle/m^2, panicle weight and panicle length was observed under the 50% RDF. Higher number of total grains/panicle, number of filled grains/panicle and test weight were recorded under 150% RDF which might have helped in improving the nutrient availability for a prolonged period resulting more translocation of photosynthates during crop growth and development stages, ultimately it influenced the reproductive stage and resulted in more yield attributing characters. The increase in number of panicle under application of 150% RDF was 12.82 and 7.31% over 50% and 100% RDF, respectively and number of filled grains was 13.60 and 7.58% higher compared to 50% and 100% RDF, respectively. Similar trend was observed by Pandey *et al.*, (2009). The lowest value of number of total grains/ panicle, number of filled grains/panicle and test weight were recorded under 50% RDF which was found at par with that of 100% RDF.

Grain yield, straw yield and harvest index

The grain yield and harvest index of rice increased with the increasing the planting geometry (Table 2). The planting geometry of 20cm x 10cm produced significantly higher grain yield and harvest index as compared to closer planting geometry (10cm x 10cm) which was found at par with that of 15cm x 10cm planting geometry. This result is supported by the finding of Bagayoko *et al.*, (2012). The straw yield was registered higher under 10cm x 10cm planting geometry which was also found at par with15cm x 10cm planting geometry. Higher straw yield under closer planting geometry of 10cm x10 cm may be due to higher plant population per unit area. Similar observation was also made by Borkar *et al.*, (2008). The lowest grain yield (40.0 q/ha) and harvest index was recorded under 10cm x 10cm planting geometry which was again found at par with that of 15cm x 10cm planting geometry. The increase in grain yield of rice was 15.14 and 11.98% in wider planting geometry of 20cm x 10cm as compared to 10cm x 10cm and 15cm x 10cm, respectively. The negative effect of 10cm x 10cm planting geometry on grain yield could be mainly due to poor translocation of food materials from source to sink.

Grain yield and straw yield of rice was influenced with increasing nutrient levels from 50% to 150% of RDF whereas harvest index was not affected by it. Among the different nutrient levels, application of 150% RDF recorded significantly the highest grain yield (43.50 q/ha) and straw yield (62.89q/ha). Whereas, application of 100% RDF produced intermediate grain and straw yield with significant difference compared to those of 150% and 50% RDF. The increase in grain yield under the highest level of nutrient applied (150%RDF) was 12.81 and 7.09% higher compared to 50% RDF and 100% RDF, respectively. This may be due to the luxury consumption along with continuous supply of nutrients in the treatments receiving higher dose of nutrients. Similar trend was also observed by Ganajaxi and Math (2008) and Priyanka *et al.*, (2013). The lowest grain yield (38.56 q/ha), straw yield (55.60q/ha) and harvest index was obtained with the application of 50% RDF.

Zinc concentration in rice grain

The zinc concentration was significantly varied due to planting geometry and nutrient levels (Table 3). However, interaction between planting geometry and nutrient level was found non-significant. Zinc concentration in grain was increased with decreasing plant population. Among three planting geometry, the highest zinc concentration was recorded with planting geometry of 20cm x 10cm. However, it was found at par with that of 15cm x 10cm.

The lowest zinc concentration was observed with the planting geometry of 10cm x 10cm which was also found at par with that of 15cm x 10cm. Wider planting geometry of 20cm x10 cm exhibited 3.37 and 4.65% higher in zinc concentration in grain compared to closer planting geometry of 15cm x 10 cm and 10cm x10 cm, respectively.

Regarding nutrient levels, zinc concentration in grain was decreased with increasing nutrient levels. The highest zinc concentration was recorded with the application of 50 % RDF. The lowest zinc content was recorded with the application of 150 % RDF which was found at par with that of 100 % RDF. The zinc concentration was 5.69 and 0.13% lesser with application of 150% RDF as compared to 50% RDF and 100% RDF, respectively. The lower zinc content under higher yield may be due to dilution effect as observed in higher nutrient application.

Table.1 Yield attributes of high zinc rice as influenced by planting geometry and nutrient levels

Treatment	No of panicles /m^2	Panicle length (cm)	Panicle weight (g)	No. of total grains/ panicle	No. of filled grains/ panicle	Test weight (g)
Planting geometry						
S_1 (10cm x 10cm)	356	24.1	3.77	163	130	25.81
S_2 (15cm x 10cm)	272	24.5	3.90	169	132	25.83
S_3 (20cm x 10cm)	241	24.9	4.22	176	139	26.04
CD (P=0.05)	18	0.6	0.24	4	7	NS
Nutrient levels						
N_1 (50% RDF)	273	23.9	3.81	165	125	25.68
N_2 (100% RDF)	287	24.6	3.97	169	132	25.78
N_3 (150% RDF)	308	25.3	4.11	175	142	26.22
CD (P=0.05)	18	0.6	0.24	4	7	0.43

Table.2 Grain yield, straw yield and harvest index of high zinc rice as influenced by planting geometry and fertility levels

Treatment	Grain yield (q/ha)	Straw yield (q/ha)	Harvest index (%)
Planting geometry			
S_1 (10cm x 10cm)	40.00	60.42	39.87
S_2 (15cm x 10cm)	40.80	59.44	40.76
S_3 (20cm x 10cm)	41.75	58.46	41.65
CD (P=0.05)	1.29	1.13	0.97
Nutrient levels			
N_1 (50% RDF)	38.56	55.60	40.94
N_2 (100% RDF)	40.62	59.82	40.43
N_3 (150% RDF)	43.50	62.89	40.88
CD (P=0.05)	1.29	1.13	NS

Table.3 Zinc concentration, zinc yield, zinc uptake and available zinc of soil as influenced by planting geometry and nutrient levels

Treatment	Zinc concentration (ppm)	Zinc yield, kg/ha	Zinc uptake Kg/ha	Available zinc of soil (mg/kg)
Planting geometry				
S_1 (10cm x 10cm)	22.58	6.31	9.03	2.51
S_2 (15cm x 10cm)	22.86	6.52	9.33	2.42
S_3 (20cm x 10cm)	23.63	6.94	9.87	2.13
CD (P=0.05)	0.81	0.23	NS	0.10
Nutrient levels				
N_1 (50% RDF)	23.92	6.42	9.22	2.51
N_2 (100% RDF)	22.59	6.44	9.18	2.31
N_3 (150% RDF)	22.56	6.88	9.81	2.24
CD (P=0.05)	0.81	0.23	0.03	0.10

Zinc yield

The zinc yield was significantly varied due to planting geometry and nutrient levels (Table 3). However, interaction between planting geometry and nutrient level was found non-significant. Zinc yield was increased with decreasing plant population.

Among three planting geometry, higher zinc yield was recorded with planting geometry of 20cm x 10cm with significant difference to others. The lowest zinc yield was observed with the planting geometry of 10cm x 10cm which was at par with that of 15cm x 10cm. Wider planting geometry of 20x10 cm exhibited 6.44 and 9.98% higher zinc yield as compared to 15cmx10 cm and 10cmx10cm, respectively.

Regarding nutrient levels, zinc yield was increased with increasing nutrient levels. The highest zinc yield was recorded with the application of 150% RDF with significant difference to other levels of nutrient application.

The lowest zinc yield was recorded with the application of 50 % RDF. The increase in zinc yield was 7.17 and 6.83% higher under 150% RDF compared to 50% RDF and 100% RDF, respectively. Zinc yield is the result of brown rice yield and its concentration, therefore, the higher the yield more zinc yield was observed.

Zinc uptake

Zinc uptake by rice was significantly influenced by nutrient level only (Table 3). However, planting geometry and interaction between planting geometry and nutrient level was found non-significant. Though the zinc uptake was non-significant, it exhibited 5.79 and 9.30% higher in zinc uptake under wider planting geometry of 20cm x 10cm as compared to 15cm x 10cm and 10cm x 10cm, respectively. Among the different nutrient levels, maximum zinc uptake by rice plant was observed under application of 150% RDF with the significant difference. The lowest zinc uptake was recorded under application of 50% RDF.

Zinc uptake was recorded 6.40 and 6.86% higher with application of 150% RDF as compared to 50% RDF and 100% RDF, respectively. The similar result was also reported by Pandey *et al.*, (2009).

Soil available zinc status

Data presented in table 3 showed that available zinc content in soil after harvest of rice varied significantly due to different planting geometry and nutrient levels. It was observed that available zinc content in soil was decreased with increasing planting geometry. The closer planting maintained higher soil available zinc status after harvest of the crop. Among the three planting geometry, 10cm x 10cm recorded the highest available zinc in soil with significant difference.

The lowest available zinc of soil was observed under the 20cm x 10cm planting geometry. Soil available zinc under 20x10 cm was 11.98 and 15.14% lesser as compared to closer planting geometry of 15cm x10cm and 10cm x 10cm, respectively. Regarding nutrient levels, application of lower doses of nutrients maintained higher status of soil available zinc.

Among the different nutrient levels, application of 50 % RDF recorded highest available zinc of soil. The lowest available zinc was registered with the application of 150 % RDF which was found at par with that of 100 % RDF. Soil available zinc content was 10.76 and 3.03% lesser with application of 150% RDF as compared to 50% RDF and 100% RDF, respectively.

Thus, from above finding, it can be concluded that planting geometry of 20cm x 10cm and 150% RDF recorded higher grain yield and zinc yield as compared to other treatment combinations. Planting geometry of 20cm x 10cm exhibited increase of 11.98 and 15.14% in grain yield and 3.37 and 4.65% in zinc concentration in grain as compared to 15cm x 10cm and 10cm x 10cm, respectively.

Application of 150% RDF recorded increase in grain yield of 12.81 and 7.09% however, zinc concentration in grain was decreased by 5.69 and 0.13% as compared to 50% and 100% RDF, respectively.

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