Journal of Pharmacognosy and Phytochemistry 2018; 7(1): 1555-1558

Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

J P P

Journal of Pharmacognosy and Phytochemistry

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(1): 1555-1558
Received: 12-11-2017
Accepted: 15-12-2017

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Biofortificational benefits of zinc application to rice genotypes

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Abstract

A pot experiment was conducted in the experimental farm of Mountain Research Centre for Field Crops (MRCFC), Khudwani of Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir. The experimental soil was slity clay loam, low in available N, medium in P and K and deficient in Zn with neutral pH, and was laid out in completely randomised design (CRD) with three replications to study the response of varying Zn concentrations (0, 5, 10, 15 and 20 mg Zn kg^{-1} soil) in four rice genotypes (Jhelum, SR1, China 1007 and China1039). Genotypes differed significantly in grain yield. Among the genotypes SR1 gave significantly higher grain yield over Jhelum and both out yielded the rest two genotypes. Increase in Zn concentration due to the progressive increase in Zn levels to 5, 10, 15 and 20 mg Zn kg^{-1} was 43.5, 71.5. 79.5 And 80.4% over control during the year 2011, respectively. The corresponding figures during the year 2012 were 47.8, 68.8, 74.8, 78.9%, respectively. Overall Zn concentration in brown rice, hull, straw and roots was of the order of China 1039>Jhelum>China 1007>SR1. Among the genotypes China 1039 and Jhelum gave better response to higher levels of Zn with regard to Zn content in brown rice.

Keywords: Biofortificational, zinc application, rice genotypes

Introduction

Rice (*Oryza sativa* L.) Is the premier food crop of India and therefore, national food security system largely depends on the rice productivity. The numerous studies have indicated that zinc deficiency is a serious nutritional problem for crops. An analysis of 233,003 soil samples taken from different states showed that 47% of Indian soils are deficient in Zn. The average micronutrient status of rice soils of Kashmir in general is adequate except zinc, which is marginally low (Wani *et al*., 2013) [5]. Zinc is an essential micronutrient for healthy functioning of the human body. Though present in tiny amounts, it is critical to life and its deficiency can have a variety of adverse consequences. Zinc deficiency in children results in stunting, underweight and increased risk of infections like diarrhea and pneumonia. Zinc deficiency may occur due to diets inadequate in bioavailable zinc, certain diseases like diarrhea, loss of zinc in processing foods, and poor soil deprived of zinc which can reduce the agricultural productivity and zinc content in agricultural products. The different approaches for correction of zinc deficiency include dietary intervention, supplementation, and biofortification through agronomic and genetic approaches forimproving grain Zinc concentration. Application of Zn fertilizers or Zn- enriched NPK fertilizers (agronomic biofortification) offers a rapid solution to the problem. Response of rice to zinc has been reported by several workers in India (Singh and Abrol 1986). The Zn requirement can be easily met by a genotype that is efficient in uptake and utilization in Zn deficient soils Field and pot screening studies have revealed significant genetic variation in Zn efficiency in cereal genotypes, which indicates that selection for improved Zn efficiency is possible. Keeping in view the importance of zinc fertilization, a pot experiment was conducted to study the response of rice genotypes to zinc fertilization in a zinc deficient soil.

Materials and methods

A pot experiment was conducted on slity clay loam soil, neutral in pH (6.78), low in nitrogen (215 kgha^{-1}), medium in available phosphorus (14.2kg ha^{-1}), and potassium (205kg ha^{-1}), and deficient in zinc (0.62mg kg^{-1}) Soil from the top 15 cm was collected randomly from experimental farm. The soil was mixed thoroughly to make a uniform medium in all respects and shade dried. Five kg of soil was filled in pots of 6 L capacity each. Before filling the pots Zn treatment was given in solution form. To acquire the desired Zn soil concentration of 5, 10, 15 and 20 mg kg^{-1}; 60, 120, 180 and 240 mg of $ZnSO_4.H_2O$ was dissolved in 250 ml of water. Analytical grade $ZnSO_4.H_2O$ was dissolved in water to make a uniform solution that was sprinkled on soil with constant stirring for each pot.

Each treatment was given to the pots in triplicate and the experiment was laid out in completely randomized design (CRD). The pots were given small quantity of water daily to avoid leaching of nutrients. The N, P and K fertilizer was given to each pot as the recommended dose fertilizers on soil weight basis. To determine the grain and straw yield, crops were harvested at maturity. Dried grain sample were grounded and digested in triple acid mixture and zinc concentration was determined in atomic absorption spectrometer.

Results and Discussion

Grain and straw yield

Grain and straw yield of rice responded significantly due to zinc application. (Table 1) On an average, the grain yield ranged between 49.0 to 62.2 g pot^{-1}and straw yield ranged from88.05 to 96.55g pot^{-1} due to zinc application. The highest grain yield 62.45 g pot^{-1} and straw yield 96.55 45 g pot^{-1} was noticed with 15 mg Zn kg^{-1} and minimum grain yield 49.0 and straw yield 88.05 was observed in control (no zinc). The increase in grain yield due to the application of 5 mg kg^{-1} was 23.5 per cent over control. With further increase in Zn levels, the grain yield per pot did not increase significantly. On an average the application of 10, 15 and 20 mg Zn kg^{-1} increased the grain yield by 25.8, 25.2 and 26.0 percent over control, while in straw yield percent increase with application of 5, 10 and 20 mg Zn kg^{-1} was 9.5, 9.5 and 9.3 per cent over control. Zinc application might have stimulated the metabolic and photosynthetic activity which resulted in higher vegetative growth and yield attributes. This was ultimately translated into higher grain yield. For attaining maximum grain yield soil Zn concentrations beyond the critical limits may not be necessary. That might have been the reason for a non-significant response beyond 5 mg Zn kg^{-1} soil. Khan *et al*. (2012) [3] have reported a positive impact of Zn on grain yield in Zn deficient soils. Application of Zn further enhanced the uptake of other major nutrients which might have also enhanced the vegetative growth of rice and ultimately the straw yield. The grain and straw yield differed among genotypes. SR-1 gave significantly higher grain and straw yield over Jhelum, China-1007 and China 1039. Data averaged of two years showed that highest grain yield of 67.4 g pot^{-1} straw yield 105.55 g pot^{-1} was recorded in SR-1 and lowest grain yield of 51.85 g pot $^{-1}$and straw yield138.05 g pot $^{-1}$ was recorded in China-1039. The grain yield realized in SR-1 was 7.2, 24.0 and 30.4 per cent higher as compared to Jhelum, China -1007 and China 1039, respectively. (SYED *etal*., 2016} reported that variation in the potential grain yield among rice genotypes demonstrated that genotype is an important contributor to overall variability and has to be considered in zinc fertilization management.

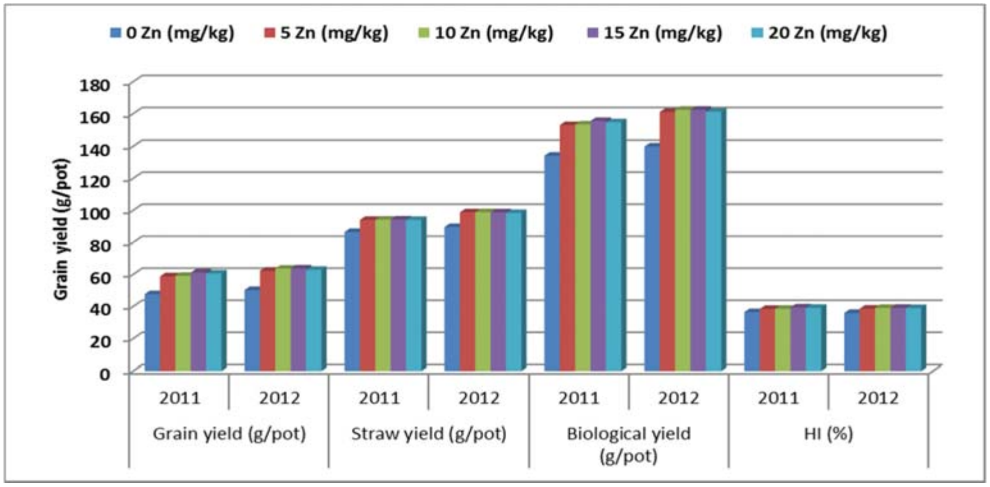

Fig 1: Effect of zinc levels on grain, straw, biological yield and harvest index of different rice genotypes.

Table 1: Effect of zinc levels on grain and straw yield of different rice genotypes

Treatment	**Grain yield (g pot^{-1})**		**Straw yield (g pot^{-1})**		**HI (%)**	
	2011	**2012**	**2011**	**2012**	**2011**	**2012**
Zinc levels (mg/kg)						
0	47.7	50.3	86.5	89.6	36.5	36.00
5	58.8	62.3	94.1	98.8	38.5	38.67
10	59.1	63.6	94.2	98.9	38.6	39.14
15	61.2	63.7	94.3	98.8	39.4	39.20
20	60.6	62.9	94.1	98.4	39.2	39.00
SEm±	2.11	2.22	2.85	2.91	1.03	1.01
C.D ($p \leq 0.05$)	4.26	4.49	5.76	5.88	NS	NS
Rice genotypes						
Jhelum	60.8	64.9	92.7	97.9	39.6	39.86
SR-1	65.6	69.2	102.8	108.3	39.0	38.99
China 1007	52.9	55.8	88.9	92.8	37.3	37.55
China 1039	50.4	53.3	86.7	89.4	36.8	37.35
SEm±	1.88	1.99	2.55	2.60	0.92	0.90
C.D ($p \leq 0.05$)	3.81	4.02	5.15	5.26	1.80	1.82
SEm±	2.24	2.17	3.29	3.17	1.10	1.07
C.D (Zn x genotypes)	NS	NS	NS	NS	NS	NS

Zn concentration

Zn concentration in brown rice

Zinc concentration in brown rice averaged over two years increased from 31.55 to 60.29 mg kg^{-1} with increase in Zn application from 5 to 20 mg Zn kg^{-1} respectively. With each level of increase in the Zn there was a corresponding increase in Zn concentration in the brown rice. However, the increase was significant only upto 15 mg Zn kg^{-1}. So, increase in Zn concentration due to the progressive increase in Zn levels to 5,10,15 and 20 mg Zn kg^{-1} was 43.5, 71.5. 79.5 And 80.4% over control during the year 2011. The corresponding figures for the year 2012 were 47.8, 68.8, 74.8, 78.9%, respectively. The increased Zn concentration in the brown rice was outcome of increased availability, absorption, translocation and deposition of Zn in brown rice. Cakmak (2015) [1] reported similar results.

Genotypes differed significantly in respect of Zn concentration in brown rice. China 1039 had Zn concentration in the brown rice which was significantly higher than all other genotypes. China-1039 recorded significantly higher zinc concentration of 57.65 and 58.1 mg kg^{-1} during the year 2011 and 2012, respectively. Jhelum ranked second in Zn concentration. Overall China 1039>Jhelum>China 1007>SR1 in respect of Zn concentration in brown rice, hull, straw and roots.

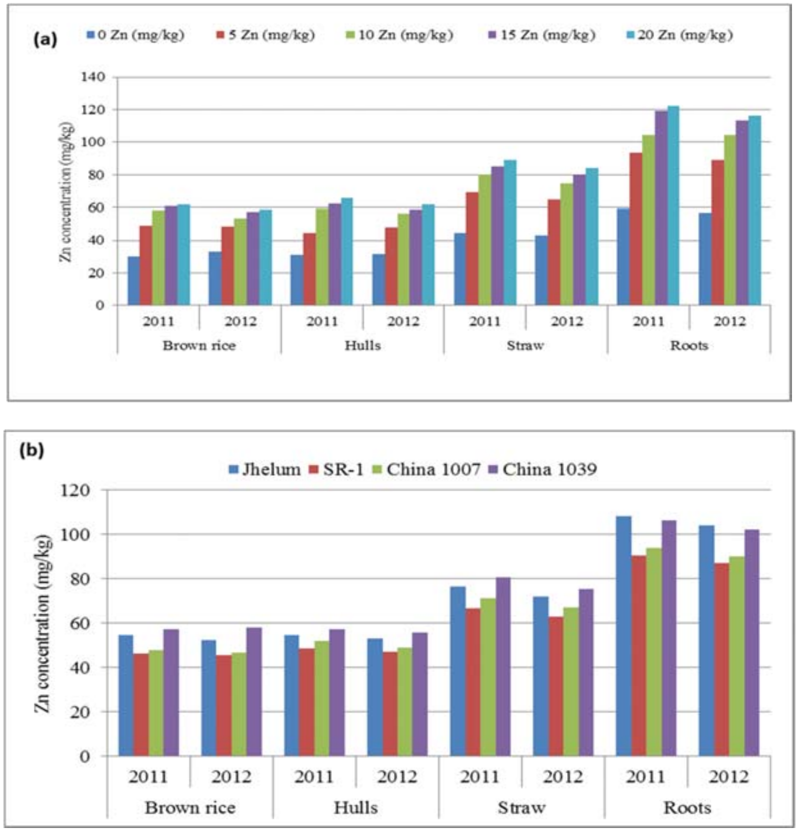

Fig 2: Effect of zinc levels (a) on Zn concentration (mg/kg) of different plant parts in rice genotypes.

Table 2: Effect of zinc levels on Zn concentration (mg kg^{-1}) of different plant parts in rice genotypes

Treatment	Brown rice		Hulls		Straw	
	2011	2012	2011	2012	2011	2012
Zinc levels (mg/kg)						
0	30.2	32.9	36.3	31.5	44.7	42.9
5	49.1	48.53	44.5	47.8	66.6	62.3
10	58.5	53.55	59.1	56.2	81.1	74.5
15	61.2	57.54	62.5	59.1	85.7	79.9
20	61.7	58.89	63.4	60.2	89.5	84.1
SEm±	1.45	1.42	1.30	1.25	1.70	1.64
C.D ($p \leq 0.05$)	2.93	2.87	2.63	2.57	3.43	3.22
Rice genotypes						
Jhelum	54.6	52.5	54.6	53.20	76.4	69.9
SR-1	46.4	45.5	48.4	47.11	66.7	62.82
China 1007	47.8	46.8	48.5	47.86	71.0	66.9
China 1039	57.2	58.1	57.3	55.70	80.5	75.4
SEm±	1.30	1.27	1.16	1.12	1.52	1.53
C.D ($p \leq 0.05$)	2.62	2.56	2.35	2.30	3.07	2.88
SEm±	1.68	1.64	1.51	1.45	1.96	1.85
C.D (Zn x genotypes)	NS	NS	5.27	5.06	6.86	6.45

Conclusion

For achieving the biofortificational benefits in rice, higher dose of Zn upto 20 mg kg^{-1}appears to be more appropriate. Among the genotypes China 1039 and Jhelum responded efficiently to the applied Zn as accumulated in brown rice.

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