Studies on the macro- nutrient concentration and up- take of rice as effected by different levels and sources of zinc under temperate conditions.

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Name of the Authors:

Syed Talib Hussain[1],
Showket Ahmed Dar[2]

[1] Mountain Research Centre for Field Crops, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Khudwani Campus J & K 192 102

[2] Division of Entomology , SKUAST- Kashmir, Shalimar, Srinagar-190025. India

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I. INTRODUCTION

Rice (*Oryza sativa* L.) is the premier food crop of India and therefore, national food security system largely depends on the productivity of rice ecosystems. Among the rice growing countries India ranks first in area (43.8 M ha) and second in production (105.0 MT), next only to China However, the average productivity of rice in India is only 3.2 t ha^{-1} against the global average of 4.0 t ha^{-1} (FAO, 2010). Increasing productivity and production are essential to meet the food requirement of the burgeoning population.

In Jammu and Kashmir State the rice crop is cultivated over an area of 274.0 thousand hectares with a production of around 904.4 thousand tonnes. However, in Kashmir valley the area under rice is 158.0 thousand hectares with a production of 576 thousand tones and productivity of 3.64 t ha^{-1} (DES, 2013-14). The Kashmir valley with temperate climate has a unique set of varieties suited to its agro-climatic situation. The abundant sunshine with nearly pest free environment makes this region suitable for good rice yields. In spite of this fact the average yields (3.24 t ha^{-1}) are far below the potential yields (7 t ha^{-1}) owing to the several constraints, the main among them being poor soil fertility status, weed infestation and poor adoption of recommended package of practices etc. The use of only major nutrients has resulted in mining of secondary and micronutrients.

Zinc deficiency is prevalent worldwide both in temperate and tropical climate (Marschner, 1995; Fageria *et al.,* 2003). It is especially widespread in high pH calcareous soils (Liu *et al.,* 1983). Zinc deficiency is a well documented problem in food crops, causing decreased crop yields and nutritional quality. Increasing incidences of Zn deficiency over the past several years have been due to various reasons. These include increased crop demand on soils ability to supply Zn fast enough as a result of improved cultivars and management, use of urea in place of acid fertilizer ammonium sulphate, increased use of phosphate fertilizers and the resulting P induced Zn deficiency; and the use of alkaline irrigation water without proper drainage. It is anticipated that further increase in incidences with the advent of rice with Zn dense grains for human nutrition which will have greater Zn requirement (Welch and Graham, 1999). An analysis of 2, 33,003 soil samples taken from different states showed that 47 per cent of Indian soils are deficient in Zn (Takkar, 1996). Analysis of 25,000 plant samples collected from different states in India showed that 44% of the plant samples contained inadequate Zn (Singh, 2007). These values indicate that Zn deficiency in soils represents a particular constraint to crop yield and a major reason for the low dietary intake of Zn.

Application of Zn fertilizers or Zn- enriched NPK fertilizers (agronomic biofortification) offers a rapid solution to the problem. In India, zinc deficiency is more widespread in the rice-wheat cropping system belt of north western India, which has high pH calcareous soils (Prasad, 2005; Prasad, 2006). Soil application of Zn increased grain Zn concentrations in various cereal crops by a factor of two to three, depending on species (Moraghan, 1994) and crop genotype (Singh, 1992). Soil type also influences the extent of increase in Zn concentration in grain as consequence of soil Zn fertilization. Soil low in CEC (Rengel and Graham, 1995) does not bind Zn well, leaving a relatively greater proportion of fertilizer Zn in the plant available form, thus allowing for a considerable increase in grain Zn concentration with an increase in Zn fertilization to 3.2 mg Zn kg^{-1} soil (up to 145 mg Zn kg^{-1} grain).

Response of rice to zinc has been reported by several workers in India (Singh and Abrol, 1986; Shivay *et al.,* 2008 a, b, c). The general recommendation for rice-wheat system in India is soil application of 10 to 25 kg ha^{-1} zinc sulphate heptahydrate (Takkar, 1996). Zn deficiency in cereal plants is a well-known problem that causes reduced agricultural productivity all over the world (Cakmak *et al*., 1999; Fageria *et al*., 2002).

Zinc is essential for several biochemical processes in the rice plant, such as cytochrome and nucleotide synthesis, auxin metabolism, chlorophyll production, enzyme activation and membrane integrity (Dobermann and Fairhurst, 2000). Although, a large number of studies are available on the role of soil and foliar applied Zn fertilizers in corrrection of Zn deficiency and increasing plant growth and yield (Mortvedt and Gilkes 1993; Rengel *et al*. 1999). Zinc can be directly applied to soil as both organic and inorganic compounds. Zinc sulfate ($ZnSO_4$) is the most widely applied inorganic source of Zn due to its high solubility and low cost. Zinc can also be applied to soils in form of ZnO, Zn-EDTA and Zn-oxysulfate. Keeping in view the importance of zinc fertilization, a field experiment was conducted to study the nutrient up-take of rice as effected by different levels and sources of zinc under Kashmir valley conditions.

II. MATERIALS AND METHODS

A field experiment was conducted at Mountain Research Centre for Field Crops, Khudwani of Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir. The experimental site is situated in temperate zone of Jammu and Kashmir State between 34° N latitude and 74° E longitude at an altitude of 1560 m above mean sea level. Climatologically the experimental site was in mid altitude temperate zone characterized by hot summers and very cold winters with an average annual precipitation of 812 mm (average of past 20 years) most of which is received from December to April in the form of snow and rains. The experiment was conducted during kharif 2011 and 2012 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}) .The rainfall received during crop- growing season, extending from May to October for 2011 and 2012 was 32mm and 60mm, respectively. The experiment comprised of two factors viz. 3 levels of zinc(3,6 and 9kg Zn ha^{-1}) and 5 sources of zinc(Zinc sulphate ,Zinc oxide, Zinc enriched urea, Zinc FYM incubated and Zn-EDTA and one absolute control (*i.e.* no zinc) was laid out in a Randomized Complete Block Design with three replications. Transplanting was carried out during 1st week of June; during both the years with three robust seedlings of 30 days old per hill were transplanted at a spacing of 15x15 cm. Marked ropes at equal distances were used to achieve square planting. Well decomposed farm yard manure (FYM) @ 10 t ha^{-1} was applied to experimental sites at the time of lay out of the field. Full recommended dose of phosphorus and muriate of potash at the rate of 60 and 30 kg P_2O_5 and K_2O ha^{-1}, respectively was uniformly applied to each plot as basal dose before transplanting the seedlings. Nitrogen @ 120 kg ha^{-1} was applied through urea with half as basal and remaining half in two equal splits i.e. tillering and panicle initiation stages. As per the treatments wherever zinc was to supplied through Zn enriched urea, the entire dose of N and Zn was supplied through the same. In the rest of the plots the N was supplied through urea. In the plots wherever the Zn was supplied through Zn incubated FYM, the recommended dose of FYM and Zn as per the treatments was applied through Zn incubated FYM. Recommended dose of FYM was applied in rest of the plots. As per treatment 5 cm depth of water was maintained upto semi dough stage. Irrigation was withheld for 5 days at pre- heading stage and before harvesting. Two hand weddings were done at 25 and 40 days after transplanting (DAT) for removal of weeds. Butachlor was applied @1.5 kg *a.i* ha^{-1}, 5 days after transplanting. Harvesting of crop was done immediately after physiological maturity i.e. at 20 per cent grain moisture content, leaving border and penultimate rows from all the sides of each plot. After recording the dry weight of pant samples(qha^{-1}) collected from each plot, oven dried samples were grounded in Wileys mill and passed through 32 mesh sieve, both of grain and straw were grounded and subsequently used for chemical analysis. The data were statistically analysed for critical difference as per method described by Cochran and Cox (1963).

III. RESULTS AND DISCUSSION

Nutrient concentration and up-take by grain and straw of rice : The pooled data (Table 1) on N concentration of grain and straw of rice revealed that N concentration increased significantly with increase in zinc levels over control both in grain as well as in straw. Highest N concentration was obtained with 9kg Zn ha^{-1} while least N concentration was recorded in control. Different Zn sources were equally effective in improving the nitrogen content both in grain and straw and therefore did not effect N content significantly. Nitrogen is reported to have a positive interaction with zinc. These findings corroborate the findings of Pooniya and Shivay (2011).

Table 1: Effect of levels and sources of zinc on N, P and K content (%) in grain and straw of rice at harvest (Average of two years)

Treatment	NPK concentration (%)					
	Grain			Straw		
	N	P	K	N	P	K
Zinc levels (kg ha^{-1})						
3	1.09	0.20	0.19	0.54	0.13	1.36
6	1.14	0.19	0.21	0.60	0.12	1.41
9	1.15	0.18	0.21	0.65	0.11	1.42
SEm±	0.02	0.01	0.012	0.015	0.005	0.015
C.D (p≤0.05)	**0.035**	**NS**	**NS**	**0.03**	**NS**	**0.03**
Zinc sources						
Zinc sulphate	1.12	0.19	0.20	0.58	0.13	1.38
Zinc oxide	1.12	0.19	0.20	0.62	0.12	1.39
Zinc enriched urea	1.14	0.20	0.20	0.64	0.12	1.40
Zinc-FYM incubated	1.12	0.19	0.21	0.60	0.13	1.39
Zn-EDTA	1.13	0.20	0.21	0.62	0.12	1.40
SEm±	0.02	0.02	0.01	0.025	0.01	0.02
C.D (p≤0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Control	0.97	0.02	0.16	0.43	0.14	1.29
SEm±	0.03	0.02	0.015	0.03	0.01	0.03
C.D (Control vs Zn)	0.065	NS	0.03	0.065	NS	0.055

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With increase in the Zn levels from 0 to 9kg Zn ha^{-1} a progressive decline in P concentration was recorded both in grain as well as straw. Different Zn sources also resulted in non-significant change in P content in grain and straw. Antagonistic effects of Zn and phosphorous has been reported by several workers (Chaudhry *et al*., 1992; Yaseen *et al*., 1999).

The data revealed that Zn application significantly influenced K content in straw but displayed a non significant effect on K content in grain .Different Zn sources failed to produce any significant difference with respect to K content in grain and straw of rice. These results are in accordance with Rehman (1991)

Nutrient-uptake

The pooled data (Table 2) on N up-take of grain and straw revealed that Zn levels significantly increased N uptake in grain and straw over control. 6kg Zn ha^{-1} increased N uptake over 3kg Zn ha^{-1} and control though at par with 9kg Zn ha^{-1} .Zinc sources recorded a significant difference with respect to nitrogen uptake in grain as well as straw. Zn-EDTA recorded highest N uptake though it was at par with zinc enriched urea and Zn-FYM incubated but significantly higher than ZnO and $ZnSO_4$. Since Zn application stimulated vegetative growth which in turn increased the grain and straw yield .Enhanced N content in combination with straw and grain yield resulted, increase in total N uptake. The results are in line with Swami and Shekhawat (2009).

Table 2: Effect of levels and sources of zinc on NPK uptake (Kg ha-1) in grain and straw of rice at harvest (Average of two years)

Treatment	NPK uptake (kg ha^{-1}) Grain			Straw		
	N	P	K	N	P	K
Zinc levels (kg ha^{-1})						
3	78.20	14.72	13.76	46.62	11.47	117.5
6	86.20	14.88	16.40	55.51	11.73	128.7
9	87.00	14.21	16.75	57.28	11.87	129.2
SEm±	1.66	0.62	0.63	2.14	0.49	3.55
C.D ($p \leq 0.05$)	**3.35**	**1.21**	**1.28**	**4.38**	**NS**	**7.24**
Zinc sources						
Zinc sulphate	81.05	13.87	14.61	48.33	11.23	119.9
Zinc oxide	79.95	13.25	14.18	50.85	10.95	120.2
Zinc enriched urea	86.11	14.54	15.92	53.67	11.99	127.8
Zinc-FYM incubated	85.81	14.26	16.32	55.75	12.13	126.9
Zn-EDTA	86.83	14.62	16.69	53.27	12.81	130.0
SEm±	2.14	0.8	0.80	2.77	0.63	4.58
C.D ($p \leq 0.05$)	**4.37**	**1.33**	**1.65**	**5.65**	**NS**	**9.36**
Control	62.54	13.52	10.65	36.65	11.25	99.17
SEm±	2.87	1.07	1.08	3.71	0.15	6.14
C.D (Control vs Zn)	**5.87**	**1.36**	**2.22**	**7.59**	**NS**	**12.55**

In spite of the fact that P content in grain and straw got decreased due to the increasing Zn levels but P uptake increased over control due to overwhelming effect of increase in grain and straw yield. These findings confirm the findings of Darade and Bankar (2009); Shivay *et al*. (2008b).

Zn-EDTA recorded highest P uptake though it was at par with zinc enriched urea and Zn-FYM incubated but significantly higher than ZnO and $ZnSO_4$.

The Zn levels significantly increased potassium uptake over control. As a result of increase in yield and K content in grain and straw there was corresponding increase in total K uptake. A positive impact on Zn application on K uptake has been reported by many researchers. Fageria *et al*., 2011; Ghatak *et al*., 2005). Zn-EDTA, Zn enriched urea and Zn-FYM incubated were more efficient in increasing the K uptake than the ZnO and $ZnSO_4$. Zn-EDTA has been reported to posses highest “zinc-mobilization efficiency” compared to the other zinc sources Srivastava *et al*. (1999).

IV. CONCLUSION

From this it is concluded that 6 kg Zn ha^{-1} significantly increase N and k up-take in grain and straw over 3kg Zn ha^{-1} and control. The highest uptake was recorded with 9 kg Zn ha^{-1} .However, P up-take was significant only upto 3kg Zn ha^{-1} beyond which it started decreasing significantly upto 9 kg Zn ha^{-1} . Among different zinc sources Zn-EDTA recorded the highest macronutrient uptake in grain as well as straw though at par with Zn enriched urea and Zn-incubated FYM.

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