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Effect of different sources and application mode of zinc on growth, yield attributing characters and yield of rice variety Pusa basmati 1121 in sandy loam soil

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Abstract

The kharif season experiment comprised of twelve treatments in randomized block design with three replications consisting four levels of zinc sources (Zinc Sulphate, Mono Zinc sulphate, Chelated Zinc and micronutrient mixture) with two mode of application (soil and foliar) with recommended NPK @120:60:60 and vermicompost @ 3t ha⁻¹+ RDF thus, making 36 treatment combinations. The experimental soil was low in organic carbon and available nitrogen and medium in phosphorus and higher in potassium with slightly alkaline in pH.

In present study, growth parameters, yield attributing characters, grain and straw yield of rice crop varied significantly due to application of different treatments during both years. Plant height increased as the use of different sources of zinc with the soil and foliar application at all the stages of crop growth. Maximum number of tillers per meter row length at 30 (47 and 49) and 60 (69 and 73) DAT during 2011 and 2012, respectively in T₁₂ were found statistically at par to T₃ (61 and 64) and T₁₁ (64 and 69) and significantly higher than the rest of the treatments. Grain yield in among treatments was significantly increased by 31.52 to 52.07 and 23.99 to 62.31 per cent during 2011 and 2012, respectively except the control. Maximum grain yield 43.50 q/ha during 2012 recorded in T₁₂ was found statistically at par to T₃, T₁₁ and significantly higher than the rest of the treatments. Results showed that soil and foliar application of Zn produced significant impact on the growth parameter, grain yield and its components i.e., panicle length, number of grains per spike and test weight as compare to NPK alone.

Keywords: Zinc, yield, RDF, rice, vermicompost, plant height and dry matter accumulation

Introduction

Rice (*Oryza sativa* L.) is the staple food for 65% of India's population and contributes 20-25% of the agricultural GDP (Singh 2001) [1]. In India, rice is grown over an area of 43 million hectares with total production of 95 million tones amounting to 40% of the total food production (Fertilizer Statistics 2010-11).

India is one of the world's largest producers of white rice and brown rice, accounting for 20% of all world rice production. Rice is India's prominent crop, and is the staple food of the people of eastern and southern parts of the country. India could achieve a record rice production of 100 million tonnes in 2010-11 crop year on the back of better monsoon this year. The India's rice production reached to a record high of 104.32 million tonnes in 2011-2012 crop year (July-June). Rice is the basic food crop and being a tropical plant, it flourishes comfortably in hot and humid climate. Rice is mainly grown in rain fed areas that receive heavy annual rainfall. That is why it is fundamentally a kharif crop in India. It demands temperature of around 25 degree Celsius and above and rainfall of more than 100 cm. Rice is also grown through irrigation in those areas that receives comparatively less rainfall. (Anonymous).

Zinc is one of the most important micronutrient essential for plant growth especially for rice grown under submerged condition. Zinc deficiency is prevalent worldwide in temperate and tropical climates (Fageria *et al.*, 2003 Slaton *et al.*, 2005). Forty seven percent of Indian soils (Takkar, 1996) are deficient in zinc. Zinc is a major component and activator of several enzymes involved in metabolic activities (Klug and Rhodes, 1987).

Zinc deficiency continues to be one of the key factors in determining rice production in several parts of the country (Chaudhary *et al.*, 2007). Rice is the staple food for more than half of the world population and it provides 21% and 15% per capita of dietary energy and protein, respectively (Maclean *et al.*, 2002). Zinc deficiency in rice has been reported in lowland rice of India (Mandal *et al.*, 2000) and Brazil (Fageria *et al.*, 2011). Zinc deficiency in plant is noticed when the supply of zinc to the rice plant is inadequate. Among the many factors which influence zinc supply to the plants, pH, concentration of zinc, iron, manganese and phosphorus in soil solution are very important. Brar and Sekon (1976) stated that decrease in availability of zinc in submerged soils are due to the formation of insoluble franklinite ($ZnFe_2O_4$) compound (submerged soil), insoluble ZnS (intense reduced condition), insoluble $ZnCO_3$ (partial pressure of CO_2 coupled with decomposition of OM) and insoluble $Zn(OH)_2$ (alkaline pH). Zinc deficiency is usually corrected by application of zinc sulfate. Khan *et al.* (2003) observed that the methods were used, i.e., nursery root dipping in 1.0% $ZnSO_4$, 0.20% $ZnSO_4$ solution spray after transplanting, and 10 kg Zn ha⁻¹ by field broadcast method. Zinc content of soil before flowering and after harvest was significantly increased for all the methods. The yield and yield parameters also increased significantly by the application of Zn by any method. Among the methods used the effect of Zn was significant on yield components like tillers m⁻², spikelets panicle⁻¹, % filled grains, 1000-grain weight and straw yield. However, soil application of Zn at 10 kg ha⁻¹ was rated superior because it produced significantly higher paddy yield. Singh and Singh (2004) reported that the soil application of 10 kg Zn/ha was adequate in partially reclaimed alkali soil with initial pH 10.3, exchangeable sodium percentage of 85 and electrical conductivity of soil solution (1:2) 2.1 dS/m. Zinc sulfate was the superior source of zinc compared to zinc frits. Zinc application increased chlorophyll and increased the tissue concentration of Zn, Ca, Mg, K and P, whereas Na content decreased. Zinc modified the elemental composition of plant tissues favorably and thereby accelerated plant growth and yield. Chakeralhossein *et al.* (2009) studied that Soil application and foliar spraying of $ZnSO_4$ and root exposure to 2% Zn suspension. Design was in a completely randomized block (RCBD) with three replication. The results showed that in first year, zinc application increased yield significantly at 5% probability level. The highest yield was 7508 kg/ha with application of 40 kg Zn sulfate/ha in addition to foliar spraying $ZnSO_4$ with 0.003 concentrations. In the second year, fertilizer application increased yield significantly at 1% probability level. Grain yield was 3988 kg/ha in control, which increased to 6366 kg/ha with application of 40 kg Zn/ha soil application in addition to foliar spraying of $ZnSO_4$. Results showed that soil application of 40 kg $ZnSO_4$ /ha plus foliar spraying of 3/1000 $ZnSO_4$ increases the rice yield. Keeping in view the importance of zinc nutrition and its use efficiency in rice, a field experiment was conducted to study the effect of Zn fertilization on growth and productivity of rice.

Materials and Methods

The experiment was conducted at the Crop Research Center, Chirodi of Sardar Vallabhbhai Patel University of Agriculture & Technology (SVPUAT), Meerut (U.P.) during *kharif* 2011 and 2012 which is located at a latitude of 29° 40' North and longitude of 77° 42' East and at an altitude of 237 meter above mean sea level (MSL). Meerut lies in the heart of western Uttar Pradesh and has semi arid to sub-tropical climate.

The region enjoys semi-arid and subtropical climate with extremes of hot weather in summer and cold in winter season. The area does have 3 distinct seasons viz- *kharif*, *rabi* and *spring*. There is gradual decrease in mean daily temperature from October reaching as low as 2-4 °C in January and further a gradual increase is registered from February reaching as high as 43-45 °C in May. The rains are predominantly caused by south-west monsoon which sets in the last week of June, reaches its peak in July-August and withdraws by the end of September. The area receives 862 mm of rains annually on an average, of which 90% is confined to rainy season (July - September). The soil of experimental site was sandy loam in texture having 53.54, 27.6, and 18.86 % sand, silt and clay, respectively; pH 8.35, Electrical conductivity (EC) 0.189 dSm⁻¹, Organic Carbon 0.42% (4.2 g Kg⁻¹) low, alkaline $KMnO_4$ - N 206.30 Kg ha⁻¹, Olson -P 18.60 Kg ha⁻¹ ammonium acetate extractable K 278.70 Kg ha⁻¹ and DTPA extractable Zn 1.23 mg Kg⁻¹, Fe 14.85 mg Kg⁻¹, Cu 2.43 mg Kg⁻¹, Mn 10.91 mg Kg⁻¹. The treatments comprised of 4 sources of Zn (zinc sulphate heptahydrate, mono zinc sulphate, chelated zinc and micronutrient mixture) and vermicompost with the combination of RDF (NPK @ 120:60:60) in different mode of application (soil application and foliar spray). There were 12 treatments combinations replicated thrice in a factorial randomized block design. The vermicompost @ 3 t ha⁻¹ were applied before transplanting with the combination of RDF during 2011 and 2012. While the graded level of Zn were applied at the time of transplanting, tillering and panicle initiation. A uniform dose of urea, Diammonium Phosphate (DAP), (MOP), Zinc Sulphate, Mono Zinc sulphate, Chelated Zinc, micronutrient mixture and Vermicompost were used to provide N, P, K, Zn, Cu, Fe, Mn as per treatments in T₂-T₁₂. Whereas in T₁ no fertilizers were used. A basal dose of 60 Kg N, 30 Kg P and 30 Kg K ha⁻¹ and 5 Kg Zn ha⁻¹ and full dose of vermicompost was applied at the time of transplanting while remaining half dose of N were applied at the time of tillering and panicle initiation. Rice variety (Pusa Basmati 1121) was sown @ 12-14 Kg ha⁻¹ for transplanting. The seedlings of rice variety Pusa basmati 1121 raised in nursery plot by "Wet bed method". The nursery beds were irrigated one day before seedling uprooting to make the soil soft and about 29 days old seedlings were uprooted by holding at the base and pulling them up one by one and their roots were washed to remove the soil. Transplanting was done manually as per treatments keeping two seedlings hill⁻¹ at the spacing of 20 cm x 15 cm of row to row and plant to plant. Two hand weeding were done at 20 days interval after transplanting of rice. Four irrigations were applied at maximum tillering, flowering, dough and seed formation stages, respectively of rice during both the years. Growth observations were recorded at 30 and 60 day after transplanting (DAT) and at harvesting of the crop. Yield attributes were recorded at harvest and grain and straw yield was recorded plot wise after threshing of produce. After cleaning and drying the grains, the grain yield was recorded in kg per plot. The moisture percentage in 100 g samples drawn from each treatment was determined with the help of moisture meter and grains yield per plot was adjusted to 14 percent moisture. The yield of net plot, thus converted to qha⁻¹. Dry weight of straw collected from net plot was recorded after sun drying for 5-6 days and expressed in qha⁻¹. The total biological yield was recorded on dry basis after sun drying from net plots and expressed in qha⁻¹. The entire data was analyzed statistically by using ANOVA. Chemical analysis for plant and soil was done by using standard

methods in the Department of Soil Science, College of Agriculture, SVPUAT, Meerut (U.P.), India.

Results and Discussion

Growth parameters of rice at different stages

Plant Height

The perusal of pooled mean data of two consecutive years (Table 1) showed that the plant height was measured at three successive stages. The data related to plant height recorded at 30, 60 DAT, and at harvest as influenced by various sources of Zinc and application mode are presented in table 1. It is clear from the table that measured plant height was affected significantly by different treatments at all the observation interval during both the years. Plant height increased at faster rate till 60 DAT while after that the increment in plant height was slower. The plant height measured at 30 DAT ranged from 66.33 to 85.87 and 72.30 to 90.94 cm during 2011 and 2012, respectively under different treatments. With exception of T₁₀ rest of the fertilized treatments resulted in taller plant than T₂ where no zinc was applied along with recommended dose of fertilizer (RDF) during both the years. At 30 DAT stage maximum plant height of 85.87 and 90.94 cm was obtained in treatment where 3 t/ha vermicompost was applied with recommended NPK that was statistically at par with treatment receiving soil application of micronutrient mixture 25kg ha⁻¹ with recommended NPK and significantly higher

than the rest of the treatments during both the years. Plant height was slightly lower in the treatments receiving zinc nutrition through foliar than soil application with every source. At 60 DAT stage plant height ranged from 83.68 to 105.21 and 87.35 to 109.78 cm during 2011 and 2012, respectively under different treatments and varied significantly. Plant height increased by 19.02 to 26.16 and 20.71 to 20.82 per cent from the height recorded at 30 DAT under different treatments during both the years respectively. At this stage the maximum plant height (105.21 and 109.78 cm) was recorded in T₁₂ where 3 t ha⁻¹ vermicompost was applied with recommended NPK in both the years followed by T₁₁ (103.98 to 106.64 cm) where micronutrient mixture was applied with recommended NPK. At this stage also comparatively lower plant height was recorded with foliar than soil application. The same trend was observed at harvest growth stages of crop. Plant height increased significantly due to basal application of different zinc sources with recommended NPK may be due to better utilization of applied zinc with developed rooting system which contributed to accelerate the enzymatic activity and auxin metabolism in plants that may increase the overall growth of the plant. Similar results were also reported by Jana, *et al.* (2009)^[7]. They reported that the application of 30 to 40 kg ZnSO₄/ha gave significantly higher plant height. Khan *et al.* (2007)^[8] also found the similar results.

Table 1: Effect of zinc sources and application mode on plant height (cm), Number of tillers per meter row length and dry matter accumulation (q ha⁻¹) of rice at different stages

Treatments	Plant height (cm)						Number of tillers per meter row length						Dry matter accumulation (q ha ⁻¹)			
	30 DAT		60 DAT		At harvest		30 DAT		60 DAT		At harvest		30 DAT		60DAT	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
T ₁	66.33	72.30	83.68	87.35	86.87	89.34	19	22	32	36	29	33	17.44	19.83	33.43	39.47
T ₂	74.97	75.75	94.98	99.37	98.95	101.88	23	25	37	41	36	38	19.59	22.10	38.32	44.16
T ₃	82.07	85.94	101.92	105.65	105.88	108.37	41	44	61	64	59	62	28.45	31.35	52.88	58.71
T ₄	82.07	84.54	101.55	105.12	105.67	107.42	35	38	54	58	52	55	25.08	28.95	52.02	57.85
T ₅	80.16	82.23	100.97	104.54	104.76	107.23	33	35	50	54	48	51	24.44	26.90	49.73	55.60
T ₆	79.40	82.23	100.85	104.47	104.67	107.10	32	33	47	51	45	48	23.87	26.40	47.57	53.41
T ₇	79.33	81.96	99.62	104.20	104.57	106.97	31	32	44	48	42	45	22.53	25.06	46.27	52.10
T ₈	78.73	80.82	98.15	101.57	102.12	105.31	28	30	43	46	40	43	22.23	24.37	44.78	50.55
T ₉	76.46	80.81	97.08	100.12	101.52	102.46	27	29	41	45	38	42	21.45	23.47	42.68	48.94
T ₁₀	75.00	79.47	96.99	99.97	100.96	102.13	25	27	40	44	37	40	20.58	22.36	39.04	44.72
T ₁₁	84.40	87.87	103.98	106.64	107.18	108.93	44	46	64	69	62	65	30.75	33.78	56.55	62.81
T ₁₂	85.87	90.94	105.21	109.78	109.75	111.52	47	49	69	73	68	71	33.58	36.48	61.74	66.02
SE (m)	1.17	1.63	2.24	1.95	1.88	1.58	2.38	2.24	2.99	3.96	3.77	3.62	2.01	2.41	2.23	2.34
CD(p=0.05)	3.46	4.81	6.61	5.76	5.55	4.66	7.03	6.62	8.84	11.69	11.15	10.70	5.93	7.11	6.60	6.93

Number of tillers per meter row length

It is clear from the table that measured number of tillers per meter row length were affected significantly by different treatments at all observation interval during both the years. Number of tillers increased at faster rate till 60 DAT and there after a slight decline in number of tillers per meter row length was noticed. The number of tillers per meter row length counted at 30 and 60 DAT varied from 19 to 47 and 22 to 49 and 32 to 69 and 36 to 73 during 2011 and 2012, respectively. Maximum number of tillers at 30 and 60 DAT 47 and 49 and 69 and 73 during 2011 and 2012, respectively in T₁₂ were found statistically at par to T₃ (61 and 64), T₁₁ (64 and 69) and significantly higher than the rest of the treatments. Number of tillers per meter row length increased significantly due to basal application of different zinc sources with recommended NPK which may be due to better utilization of applied zinc owing to developed root system. With the sufficient nutrition of zinc growth promoting substance like auxin in plant is produced and that may increase the overall growth of the

plant. Similar results were also recorded by Cheema *et al.* (2006)^[2] who advocated that the final plant height, number of tillers/hill, panicle bearing tillers, number of primary and secondary spikelet's panicle size, 1000-grain weight, paddy and straw yield and harvest index showed positive correlation with the increase in ZnSO₄ levels from 2.5 to 10 kg/ha. Ghatak *et al.* (2005)^[4] revealed that zinc fertilizer application significantly increased the plant height, effective tillers, panicle length, grains per panicle, grain and straw yields, uptake of Zn, N and K by plant. Application of 30 kg ZnSO₄/ha recorded the highest values of yield attributes, yield, uptake of Zn, N and K by plant. Murali and Setty (2000)^[11] also revealed that application of 150:75:75 NPK kg ha⁻¹ recorded significantly higher growth, yield attributes and yield (5261 kg ha⁻¹) compared to lower NPK rates. Scented rice cv. Pusa Basmati-1 responded significantly to manure. Application of vermicompost at 5 t/ha resulted in significantly higher yield (4889 kg ha⁻¹) compared to no vermicompost application.

Dry matter accumulation ($q\ ha^{-1}$)

Maximum dry matter accumulation at 30 DAT 33.58 and 36.48 qha^{-1} during 2011 and 2012, respectively recorded in T₁₂ that was found statistically at par to T₃, T₁₁ and significantly higher than the rest of the treatments. Same trend was recorded at 60 DAT. At this stage highest dry matter accumulation was recorded in T₁₂ (61.74 and 66.02 qha^{-1}) where 3t/ha vermicompost was applied with recommended NPK and found statistically at par with T₁₁ (56.55 and 62.81 qha^{-1}) and T₃ (58.71 qha^{-1}) where micronutrient mixture and ZnSO₄@ 25kg ha^{-1} was applied with recommended NPK respectively during both the years. At 60 DAT dry matter accumulation increased by 83.85 to 91.68 and 80.97 to 99.04 per cent from the dry matter accumulation recorded at previous stage under different treatments during 2011 and 2012, respectively. All the stages comparatively lower dry

matter accumulation was recorded with foliar than soil application. The effect of treatments consisting foliar application of zinc on dry matter accumulation was more or less similar. This finding may be due to basal application of different zinc sources with recommended NPK may increase the leaf area and photosynthetic rate and auxin metabolism in plant that may increase the overall dry matter accumulation of the plant. Similar results was also reported by Prado *et al.* (2008) [12] who noted zinc sulphate provided greater production of total the highest yield of 14 818 and 8732 kg ha^{-1} , respectively were obtained from NPK + Zn + Cu + Fe + Mn. dry matter in rice seedlings in relation to zinc oxide. The application of 3.92 g Zn/kg of seed, using the zinc sulphate source provided the greatest increment in dry matter with values 48% higher than the control.

Table 2: Effect of zinc sources and application mode on yield attributing and characters and yield ($q\ ha^{-1}$) of rice

Treatment	Panicle length (cm)		Grains panicle ⁻¹		Test weight (g)		Biological yield		Grain yield		Straw yield	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
T ₁	23.61	23.99	94.01	104.70	18.95	19.35	65.17	67.82	24.33	26.80	40.80	40.99
T ₂	24.79	25.13	106.93	112.38	19.28	20.24	83.80	87.07	32.00	33.23	51.63	53.83
T ₃	26.71	27.06	123.83	130.18	22.85	23.28	90.10	97.02	36.17	39.60	54.77	57.81
T ₄	26.16	26.44	122.40	128.75	21.69	22.36	89.90	95.11	35.33	37.30	54.73	57.44
T ₅	26.05	26.44	118.56	124.26	20.95	21.49	89.80	93.98	34.67	36.93	54.40	57.42
T ₆	25.75	26.18	115.42	122.87	20.74	21.35	87.73	93.44	34.33	36.17	53.87	56.96
T ₇	25.57	26.01	112.39	121.95	20.58	21.26	87.63	92.94	34.00	35.77	53.15	56.78
T ₈	25.48	25.98	110.48	120.30	19.89	20.78	87.40	92.02	33.83	35.47	52.97	56.51
T ₉	25.23	25.89	108.65	118.25	19.68	20.66	86.40	90.13	33.00	35.10	52.90	54.36
T ₁₀	25.04	25.63	107.93	117.03	19.52	20.38	85.70	88.70	33.00	34.60	51.80	54.10
T ₁₁	27.31	27.73	125.35	132.10	23.88	24.56	90.87	97.60	36.67	40.17	56.03	58.52
T ₁₂	28.16	28.47	128.59	135.40	24.55	26.38	92.20	109.79	37.00	43.50	57.03	66.29
SE (m)	.56	.52	1.15	.69	1.84	1.72	4.65	3.33	1.73	1.37	2.67	2.33
CD(p=0.05)	1.65	1.55	3.39	2.03	N.S.	N.S.	13.73	9.85	5.12	4.05	7.90	6.89

Yield and yield attributing characters**Panicle length**

It is clear from the table 2 that measured panicle length was affected significantly by different treatments during both the years. Panicle length varied from 23.61 to 28.16 cm and 23.99 to 28.47 cm and increment in panicle length from 19.27 to 18.67 per cent in comparison to control was noticed during 2011 and 2012 respectively. Maximum panicle length (28.16 and 28.47 cm) during 2011 and 2012, respectively recorded in T₁₂ were found statistically at par to T₁₁, T₃ and significantly higher than the rest of treatments. Result reveals that application of ZnSO₄@25 $kg\ ha^{-1}$ was equally good to the application of micronutrient mixture (T₁₁) or vermicompost (T₁₂). Foliar application of zinc through either source was found significantly inferior to the soil application of zinc sulphate @25 $kg\ ha^{-1}$. This effect may be supposed due to better nutrition of crop plant with the application of micronutrient zinc or vermicompost which may also improve the availability of native zinc. Panicle length was slightly lower in the treatments receiving zinc nutrition through foliar than soil application with every source which may be due to lower zinc assimilation under foliar application treatments. Similar results was also recorded by Channabasavanna *et al.* (2001) [1] who reported that the application of 25 kg ZnSO₄/ha resulted in the highest seed yield and panicles per hill. Interaction effect indicate that an application of poultry manure or farmyard manure with 25 kg ZnSO₄/ha was optimum. Similar results were also reported by Gurmani *et al.* (2003) [5].

Number of grain per panicle

It is clear from the table-2 that counted number of grains per panicle was affected significantly by different treatments during both the years. Number of grains per panicle 24.33 to 36.78 per cent higher were recorded in comparison to control during 2011 and 2012, respectively. The highest number of grains per panicle (128.59 and 135.4) counted in T₁₂ were statistically at par with T₁₁ (125.35 and 132.10) during both the years. Number of grains per panicle recorded in T₃ (123.83 and 130.18) varied significantly from T₁₂ and found statistically at par with T₁₁ during 2011 and 2012. This effect may be explained due to better leaf area index and leaf area duration with the adequate and balanced plant nutrition. Better leaf area index and duration will affect the photosynthetic activity and transformation of photosynthates to grain. Similar results were also recorded by Kulandaivel *et al.* (2003) [9] that the yield attributes of rice, namely number of panicles/m², and number and weight of grains per panicle were higher due to the incubated mode of application of ZnSO₄.

Test weight (g)

It is clear from the table-2 that measured test weight were affected non significantly by different treatments during both the years. The highest test weight was recorded in T₁₂ where 3t/ha⁻¹ vermicompost followed by T₁₁ and T₃ where micronutrient and zinc sulphate were applied with RDF while lowest test weight was found in T₁. Similar results were also recorded by Kulandaivel *et al.* (2003) [9] that the yield

attributes of rice, namely number of panicles/m², and number and weight of grains per panicle were higher due to the incubated mode of application of ZnSO₄. Similar results were also reported by Haq *et al.* (2005)^[6].

Grain yield (qh⁻¹)

The data regarding application effect of different sources of zinc in different mode and vermicompost (VC) along with RDF on grain yield of rice during 2011-12 and 2012-13 are shown in Table-2. During 2011 grain yield recorded in T₂ to T₁₂ did not varied significantly with the application of zinc through different source, grain yield did not responded to the foliar application of either source of zinc while differ significantly from T₁. Whereas during 2012 with exception of T₁₁ and T₃ the rice grain yield recorded in T₁₂ (RDF+ VC) was significantly higher than the rest of the treatments. Grain yield increased by 31.52 to 52.07 and 23.99 to 62.31 per cent in rest of the treatments comparison to control during 2011 and 2012, respectively. Rice grain yield was slightly lower in the treatments receiving zinc nutrition through foliar than soil application with every source. Maximum grain yield 43.50 qha⁻¹ during 2012 recorded in T₁₂ was found statistically at par to T₃, T₁₁ and significantly higher than the rest of the treatments. Result reveal that application of ZnSO₄@ 25kg ha⁻¹ was equally good to the application of micronutrient mixture or vermicompost.

Similar results were also reported by Mustafa *et al.* (2011) observed that Zinc application methods and timing had significantly pronounced effect on paddy yield. Maximum paddy yield (5.21 t ha⁻¹) was achieved in treatment Zn2 (Basal application at the rate of 25 kg ha⁻¹ 21% ZnSO₄) and minimum paddy yield (4.17 t ha⁻¹) was noted in Zn7 (foliar application at 75 DAT @ 0.5% Zn solution).

Biological yield (qha⁻¹)

The data regarding application effect of various sources of zinc in different mode and vermicompost along with RDF on biological yield of rice during 2012 are shown in table-2. It is clear from the table that measured biological yield was affected significantly by different treatments during both the years. The biological yield of rice varied from 65.17 to 92.20 and 67.82 to 109.79q ha⁻¹ during 2011 and 2012, respectively under the different treatments. Maximum biological yield during 2011 was recorded in T₁₂ where 3t ha⁻¹ vermicompost was applied with recommended NPK.. With exception of T₁ rest of the fertilized treatment were non significant in respect of biological yield in 2011 but significantly differ in 2012.

Straw yield (qha⁻¹)

The straw yield of rice varied from 40.80 to 57.03 and 40.99 to 60.29 q ha⁻¹ during both the years. Straw yield increased by 26.54 to 39.77 and 31.32 to 61.72 per cent in rest of the treatments comparison to control during 2011 and 2012, respectively. Maximum straw yield (57.03 and 60.29qha⁻¹) during 2011 and 2012, respectively recorded in T₁₂ was found statistically at par to rest of the treatments with exception of T₁. Same result was found in straw yield. It may be due to more translocation of photosynthates from straw to grain in vermicompost and zinc treated plots as evidenced by comparatively higher plant height, number of tillers per meter square, panicle length and higher test weight in comparison to T₂ during both the years. Similar results were also recorded by Jana *et al.* (2009)^[7] reported that zinc application produced significantly greater yield attributes, higher grain and straw yields of rice. Application of 30 to 40 kg ZnSO₄/ha

gave significantly higher values of plant height, number of effective tillers, panicle length, grain number per panicle, grain and straw yields. Kumar and Kumar (2009)^[10] reported that a significant increase in the yield and yield attributes of rice was noted with the application of 45 kg ZnSO₄/ha.

Conclusion

On the basis of the results obtained from two year experimentation it is concluded that the application of organic source in rice can supplement the zinc nutrition. The cost of cultivation with the use of organic may be comparatively higher but to some extent it will also replenish the deficit nutrients and therefore the soil health will be maintained. Although the zinc sulphate at the rate 25 kg ha⁻¹ is commonly recommended for transplanted rice but the study shows that the application of micronutrient mixture is equally good and effective. Among the different zinc sources zinc sulphate is the best source. The soil application of zinc was found best method for application than foliar.

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