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IMPACT OF DIFFERENT SOURCES AND APPLICATION MODES OF ZINC AND VERMICOMPOST ON N, P, K CONTENT AND UPTAKE IN SCENTED RICE CROP VARIETY PUSA 1121 IN SANDY LOAM SOIL

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ABSTRACT

A field investigation was conducted during *Kharif* season 2011 and 2012 in sandy loam soil to study the potential of vermicompost and different sources and methods of zinc application on yield, content and uptake of N, P and K in rice crop. The experiment was laid out in Randomized Block Design with 12 treatments and 3 replications. The recommended dose of NPK at the rate of 120:60:60kg ha^{-1} respectively, was applied alone and with the combination of four sources of zinc in the mode of soil and foliar application and vermicompost @ 3t ha^{-1}. The experimental soil was low in organic carbon and available nitrogen and medium in phosphorus and higher in potassium with slightly alkaline in pH. Result reveal that application of $ZnSO_4$ @ 25kg ha^{-1} with RDF was equally good to the application of micronutrient mixture and vermicompost with RDF. Nutrient assimilation at different stages by the rice crop varied significantly due to application of different treatments in the study. Maximum nitrogen content 1.43 and 1.58% at growing stage (30 DAT) and in grain (1.29 and 1.62%) during 2011 and 2012 found in T_3, where 5 Kg zinc was applied with NPK @ 120: 60: 60 were significantly higher than the rest of the treatments, while minimum N content recorded in T_1 control (without fertilizers). N content at 60 DAT (1.36 and 1.48) and in straw (0.73 and 0.87%) was found significantly higher in the treatment T_{12}, where RDF was applied with the combination of VC @ 3 t h a^{-1} and significantly higher than the rest of treatments during both the years respectively. Maximum P and K content were recorded in the treatment T_{12} at all the growing stages as well as grain and straw during both the years. Maximum N uptake at 30, 60 DAT, Grain and straw during 2011 and 2012 found in T_3 where zinc sulphate was applied with combination of RDF and which was significantly higher than the rest of the treatments while minimum uptake recorded in T_1 but the maximum P and K uptake was recorded in the treatment T12. which was due to the application of vemicompost decreases the fixation of p and k in soil and increases the soluble p and k content in soil this lends support to higher uptake of p and k. The phosphorus content in grain and straw was found to decrease with the application of zinc. It might be due to the antagonistic effect of zinc on P absorption during both the years.

Key words : Zinc, Vermicompost, Content, uptake, Nitrogen, Phosphorus, Potassium, Soil application, Foliar application.

Introduction

Rice is the stable food of more than 60 percent of the world population. About 90 percent of all rice grow in the world is produced and consumed in Asian region. In India, rice is the most important and extensively grown food crop, occupying about 44.8 million hectares of land. Rice occupies a pivotal place in Indian agriculture and is the stable food for more than 70 per cent of population and source of livelihood for about 120- 150 million rural households. It accounts for about 43 per cent of total food grain production and 55 percent of cereals production in the country. India is one of the world's largest producers of white rice and brown rice, for 20% of all world rice production. Almost all parts of India are suitable for raising rice during the summer season provided that the water is available. Thus, rice is also raised even in those parts of western Uttar Pradesh, Punjab and Haryana where low level areas are waterlogged during the summer monsoon rainy season. Shukla and Behera (2011), reported that in India, zinc (Zn) is considered as most yield limiting essential element in agricultural crops, which likely to increase from 49 to 63% by 2025. Zinc is involved in physiological functions and its inadequate supply reduces the yield of crop. Its deficiencies can affect quality of produces. It is a constituent of many enzymes and role in carbohydrate and protein synthesis, maintaining the integrity of membranes, regulating auxin synthesis and in pollen formation. Its deficiency is a common problem in food crops, causing reduction in yield and quality of produces. In India analysis of 14,863 soil samples showed that 49% of soils are deficient and in Madhya Pradesh 60.3% of 6713 soil samples analyzed indicated deficiency of Zn (Shukla and Tiwari *et al*., 2014). In this situation, the crops cultivated have low yield and produce seeds without Zn content. Zinc plays significant role in rice production but its deficiency is widespread and continues to be a limiting factor (Yilmaz *et al*., 2010). Zinc sulphate is used in the amelioration of Zn deficiency and in the enrichments of grains (Alloway, 2009). Zn influences growth, yield and quality of paddy (Patnaik *et al*., 2011). Keeping in view the important role of cereal in the economy of the tribals but limited information about this nutrient in soil, there is an urgent need for an accurate estimation of Zn in soils of central and north India. Since, it is a natural organic product which is eco-friendly, it does not leave any adverse effects either in the soil or in the environment. The C/N ratio of vermicompost is much lower (16:1) than that of FYM (30:1). 4 ton vermicompost was applied in rice at flowering and 100% NPK to wheat. Residual effect of 4 ton vermicompost application on available soil K was significant. Organic carbon (%), pH and electrical conductivity (dS m^{-1}) were not significant (Kumar *et al*., 2017). Fertilizers are the major source of nutrients for rice under intensive cultivation. The use of chemical fertilizers in rice cultivation potentially reduces soil fertility (Biswas *et al*., 2020). To improve physical, chemical and biological properties of soil, organic fertilizer can be applied (Olivares *et al*., 2020 and Montenegro *et al*., 2021). Micronutrients deficiency in crops and livestock's may cause a serious crop production or animal health problems. Micronutrients serve as constituents of prosthetic groups in metalloprotein and as activator of enzyme reactions. Iron is a structural component of porphyyrin molecules like cytochromes, hematin, ferrichrome and legheamoglobin. Manganese helps in chlorophyll formation and influence auxin levels in plants and high concentration of Mn favour the breakdown of indole acetic acid (IAA). Copper form various compound with amino acid and proteins in the plant. Copper has some indirect effect on nodule formation. It also act as electron carrier in enzyme which bring about oxidation- reduction reaction in plant. Zinc influences the formation of some growth hormones in the plant. Zinc is helpful in reproduction of certain plant and is associated with water uptake and water relation in plant. The major nutrient, deficiencies of zinc, copper, iron and manganese are frequent occurrence with major losses of crop productivity. Soil properties such as soil pH, redox potential, organic matter and moisture content exert large impact on adsorption-desorption and dissolution-precipitation reactions. Thus, soil properties regulate the amount of Zn dissolved in soil solution. Soil pH is the stronger variable affecting nutrient availability and the zinc nutrition is not far behind in this process. Increasing soil pH, especially above 6.5, results in decreased extractability and plant availability of soil Zn. Soil Zn is usually more available in soils with greater organic matter content and a relatively higher proportion of clay. Exchange positions are important in maintaining the Zn level sufficient for wet land rice and in this regard the cation exchange capacity of soils seems to play dominant role. Studied that among the different doses of NPK, application of NPK @ 125% RDF recorded significantly higher N, P and K content in plants, available in soil and uptake by plants over rest of treatments (Bairwa and Yadav, 2017). Prakash *et al.* (2019) recorded that **t**he nutrient uptake was significantly -1 influenced by application of 100% RDF + GLM @ 6.25 t ha + -1 $ZnSO_4$ @ 12.5 kg ha as basal + 1.0% foliar spray (T). Soil plus foliar application of zinc with green leaf manure results in greater nutrient availability. The conjunctive use of green leaf manures and zinc which might have helped in gradual mineralization processes and the balanced supply of nutrients are the reason for the higher uptake of nutrients (N, P, K and Zn) by the crop. Kumar and Verma (2018) concluded that conventional till-wet direct seeded rice and 6 kg Zn ha^{-1} (basal application) was found better for N, P and K content and their uptake. Keram *et al.* (2012) revealed that yield, harvest index, nutrient (N, K and Zn) uptake and quality increased significantly with the application of recommended NPK+ Zn @ 20 kg ha^{-1} by wheat as compare to NPK alone. In general, yield, harvest index, total nutrient uptake and quality increased up to highest level of Zn, except total P uptake. Similar result also found by Bora *et al.* (2018) exhibited that FYM application along with NPK and NPK +Zn enhanced concentration of nutrients as well as their uptake and that increased significantly with the application of N, P, K Zn and FYM applied in balanced combination. The highest values of nitrogen, phosphorus and potassium content uptake in rice were obtained under N120P40K40 + Znf + FYMr and N120P40K40 + FYMr treatments.

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.

The area receives 862 mm of rain 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, cheated 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), Muriate of Potash (MOP), Zinc sulphate, Mono zinc suphate, Chelated zinc, micronutrient mixture and vermicompost were used to provide N, P, K, Zn, Cu, Fe, Mn as per treatments in T_2-T_{12}. Whereas, in T_1 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. 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 to 14 per cent moisture. The yield of net plot, thus converted to q ha^{-1}.Dry weight of straw collected from net plot was recorded after sun grains; the grain yield was recorded in kg per plot. Plant sample were analyzed for total N, P, K, Zn, Cu, Fe and Mn. The total N content was estimated through Automatic N analyzer using 0.2 gm grounded samples. For P and K analysis, plant samples were wet digested in di-acid mixture. P was determined by Vanadomolybidosphosphoric yellow color method (Jackson, 1973), K by Flame Photometer (Jackson, 1973), Zn, Cu, Fe and Mn by atomic absorption spectrophotometer. 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

To study the effect of zinc sources and application mode on major nutrient content and uptake of rice

The plant as well as grain samples of rice were analyzed for different elements to work out their removal from the soil and data regarding the content of different nutrients in plant samples at different stages as affected by different treatments are shown in different Tables 1-3.

Effect on nitrogen content (%) and uptake of rice at different stages

Data presented in Table 1 that N content and uptake by rice biomass at 30 and 60 DAT and rice grain and straw at harvesting was significantly affected by different treatments during both the years. Nitrogen content of rice plant at 30 DAT ranges from 0.75 to 1.43 and 0.89 to 1.58% and uptake ranges from 13.08 to 44.32 and 17.65 to 66.10 kg ha^{-1} during 2011 and 2012. Maximum nitrogen content 1.43 and 1.58% during 2011 and 2012 found in T_3 with application of recommended NPK + soil application of zinc @ 5 kg ha^{-1} maximum nitrogen uptake 44.32 $kgha^{-1}$ during 2011 recorded in T_{12} and 60.10 kg ha^{-1} during 2012 in T_3. Nitrogen content of rice plant at 60 DAT ranges from 0.60 to 1.36 and 0.74 to 1.48% during 2011 and 2012, respectively. Maximum N content 1.36 and 1.48 and uptake 96.35 and 108.27 $kgha^{-1}$ during 2011 and 2012 respectively found in T_{12}, where recommended NPK was applied with vermicompost @ 3 t ha^{-1}, while minimum N content and uptake was observed in T_1 control during both the years. The nitrogen content and uptake of plant sample in T_{11} and T_3 where RDF was used with micronutrient mixture and zinc sulphate respectively was also higher but not to the level of nitrogen content and uptake recorded in T_{12}. The highest N content 1.29 and 1.62% and uptake 46.65 and 64.15 $kgha^{-1}$ in rice grain during 2011 and 2012 found in T_3 was significantly higher than the rest of the treatments while minimum N content and uptake recorded in T_1

Table 1 : Effect of zinc sources and application mode on nitrogen content (%) and uptake (kg ha^{-1}) in rice at different stages.

Treatments	30 DAT		60DAT		Grain		Straw		30 DAT		60DAT		Grain		Straw	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
T_1	0.75	0.89	0.60	0.74	0.77	1.11	0.27	0.38	13.08	17.65	20.05	29.20	18.73	29.74	11.01	15.57
T_2	1.40	1.42	1.20	1.14	0.94	1.28	0.39	0.46	27.42	31.38	45.98	50.34	30.08	42.53	20.13	24.76
T_3	1.43	1.58	1.25	1.37	1.29	1.62	0.63	0.69	40.68	66.10	66.12	80.44	46.65	64.15	34.50	39.88
T_4	1.37	1.52	1.20	1.28	1.24	1.58	0.55	0.62	34.34	44.57	62.45	74.05	43.80	58.93	30.10	35.61
T_5	1.34	1.51	1.17	1.20	1.23	1.57	0.50	0.57	32.71	40.61	58.24	66.71	42.64	57.98	27.20	32.72
T_6	1.30	1.47	1.09	1.14	1.20	1.54	0.46	0.53	31.03	38.83	51.89	61.22	41.19	55.70	24.78	30.18
T_7	1.17	1.34	0.98	1.05	1.11	1.44	0.45	0.52	26.34	33.54	45.32	54.74	37.74	51.51	23.92	29.52
T_8	1.15	1.32	0.87	0.96	1.09	1.43	0.43	0.50	25.59	32.16	38.94	48.51	36.92	50.72	22.77	28.25
T_9	1.15	1.20	0.96	0.95	1.00	1.34	.0.42	0.48	24.66	28.17	40.97	46.49	33.00	47.09	22.22	26.09
T_{10}	1.13	1.17	0.83	0.92	0.98	1.32	0.41	0.47	23.25	26.18	32.40	41.14	32.34	45.67	21.23	25.42
T_{11}	1.38	1.15	1.38	1.42	1.26	1.33	0.68	0.80	42.23	38.84	78.02	89.19	46.20	53.42	38.10	46.81
T_{12}	1.37	1.52	1.36	1.48	1.21	1.18	0.73	0.87	46.00	55.44	83.96	97.70	44.77	51.33	41.63	57.67
SE (m).	*.018*	*.016*	*.017*	*.017*	*0.01*	*0.02*	*0.01*	*0.02*	*1.09*	*.45*	*1.24*	*1.44*	*2.57*	*2.76*	*1.74*	*2.49*
CD(p=0.05)	*0.05*	*0.04*	*0.05*	*0.05*	*0.04*	*0.06*	*0.04*	*0.05*	*3.22*	*1.33*	*3.66*	*4.26*	*5.71*	*6.13*	*3.86*	*5.52*

where any sources of element was not applied. The N content and uptake of grain sample was higher in these treatments, where zinc in either source was applied as basal as foliar. The N content of grain in T_{11} and T_{12} was also higher but not to the level of N content recorded in T_3. Among the treated plots minimum plant N content was recorded in T_{10} followed by T_9. With exception of T_{11} during 2012 generally the nitrogen uptake of grain was higher in those treatments where zinc through either source was applied basal than foliar during both the years. Maximum N content 0.73 and 0.87% and uptake 41.63 and 57.67 kgha^{-1} by rice straw during 2011 and 2012 found in the treatment T_{12} was superior but significantly at with the treatments T_{11} and T_3, where RDF was applied with micronutrients mixture and zinc sulphate @ 20 Kg ha^{-1}, while minimum N content recorded in T_1 was significantly lower than the rest of the treatments during both the years. In general the N content and uptake of straw was higher in those treatments where zinc in either source was applied as basal as foliar. Nitrogen, phosphorus and potassium content of rice plant decline with the advancement in crop growth in different treatments which is obvious due to dilution effect. Maximum nitrogen content during 2011 and 2012 found in T_3 was significantly higher than the rest of the treatments while minimum N content recorded in T_1 was significantly lower than the rest of the treatments during both the years. The application of recommended NPK with zinc sulphate @25 kg ha^{-1} recorded higher nitrogen content in T_3 followed by T_2, T_{11} and T_{12} higher N content in T_3, T_{11} and T_{12} may be supposed due to better plant growth with the supplementation of zinc. Better plant growth as evidenced by dry matter production will extract more nitrogen from soil therefore plant N content may be higher. In case of T_2 plant growth was poor in absence of zinc and since recommended dose of N was applied therefore absorbed N was not diluted and plant N content was higher. Plant N content estimated at 60 DAT, grain and straw N content was also affected significantly by different treatments. At 60 DAT, plant N content was higher in T_{12}, T_{11} and T_3. More N content in T_{12} than T_3 may be explained due to more N availability with the addition application of VC over RDF. Similar results were also recorded by Jana *et al*. (2009) that the application of 30 to 40 kg $ZnSO_4$/ha gave significantly higher values of plant height, number of effective tillers, panicle length, grain number per panicle, grain and straw yields and higher uptake of N, P, K and Zn in grain and straw of rice. Dixit *et al*. (2012) reported that nitrogen, phosphorus and potassium uptake in crop increased significantly with sulphur and zinc application. Ranjitha *et al.* (2013) also

Table 2 : Effect of zinc sources and application mode on phosphorus content (%) and uptake (kg ha^{-1}) of rice at different stages.

Treatments	Content (%)								Uptake (kg ha^{-1})							
	30DAT		60DAT		Grain		Straw		30DAT		60DAT		Grain		Straw	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
T_1	0.086	0.090	0.066	0.070	0.081	0.084	0.049	0.058	1.50	1.79	2.21	2.77	1.95	2.25	1.98	2.38
T_2	0.127	0.130	0.085	0.090	0.121	0.124	0.061	0.065	2.48	2.87	3.26	3.95	3.87	4.12	3.31	3.70
T_3	0.227	0.230	0.167	0.190	0.221	0.224	0.122	0.126	6.46	7.20	8.83	11.20	7.99	8.87	6.48	7.24
T_4	0.208	0.210	0.148	0.170	0.204	0.208	0.114	0.117	5.22	6.12	7.70	9.81	7.21	7.76	6.39	6.77
T_5	0.196	0.200	0.136	0.150	0.191	0.194	0.094	0.098	4.79	5.37	6.77	8.35	6.62	7.17	5.36	5.73
T_6	0.189	0.190	0.125	0.140	0.182	0.183	0.091	0.094	4.52	4.99	5.95	7.48	6.27	6.62	4.83	5.31
T_7	0.178	0.180	0.107	0.130	0.172	0.176	0.085	0.089	4.01	4.50	4.95	6.79	5.84	6.29	4.40	4.79
T_8	0.165	0.160	0.098	0.120	0.155	0.158	0.078	0.082	3.66	3.92	4.38	6.11	5.24	5.60	4.21	4.65
T_9	0.146	0.150	0.094	0.110	0.139	0.142	0.072	0.074	3.13	3.54	4.01	5.36	4.59	4.98	3.72	4.02
T_{10}	0.138	0.140	0.091	0.100	0.132	0.133	0.065	0.068	2.84	3.13	3.55	4.49	4.35	4.60	3.55	3.90
T_{11}	0.237	0.240	0.198	0.207	0.223	0.231	0.124	0.128	7.30	8.09	11.19	12.95	8.17	9.27	6.56	7.35
T_{12}	0.256	0.270	0.216	0.240	0.246	0.263	0.141	0.149	8.60	9.84	13.34	15.84	9.10	11.44	7.71	9.88
SE (m).	*0.0020*	*0.016*	*0.002*	*0.014*	*0.002*	*0.002*	*0.002*	*0.002*	*0.14*	*0.42*	*0.16*	*.81*	*.32*	*0.30*	*0.25*	*0.27*
CD(p=0.05)	*0.006*	*0.046*	*.006*	*0.042*	*.006*	*.006*	*.005*	*.005*	*.44*	*1.24*	*0.48*	*2.40*	*0.97*	*0.89*	*0.76*	*0.80*

disclosed that significantly maximum NPK uptake by rice @ 157.9-30.7- 166.0 kg ha^{-1} was obtained in treatments receiving 50% inorganic nitrogen source (root dipping) and 50% organic nitrogen source through vermicompost (root dipping) as compared to 100% inorganic N source alone (136.5-23.2- 125.6 kg ha^{-1}) and control (58.7-6.9-61.6 kg ha^{-1}).

Phosphorus content (%) and uptake of rice at different stages

It is clear from the Table 2 that measured phosphorus content was affected significantly by different treatments during both the years. P content of rice at 30 DAT, 60 DAT and rice grain and straw at harvesting was significantly affected by different treatments during both the years. P content of rice plant at 30 DAT ranges from 0.086 to 0.256 and 0.090 to 0.270 percent and uptake 1.50 to 8.60 and 1.79 to 9.84 kgha^{-1} during 2011 and 2012, respectively. The maximum P content 0.256 and 0.270% and uptake 8.60 and 9.84 kgha^{-1} both during 2011 and 2012 found in T_{12}, while minimum P content and uptake was recorded in T_1 during both the years. In general the P content of plant sample at this stage was higher in those treatments where zinc in either source was applied as basal as foliar in optimum level. The P content and uptake of plant sample in T_{11} and T_3 was also higher but not to the level of P content recorded in T_{12}. The similar trend in P content and uptake was recorded at 60 DAT. The maximum P content 0.246 and 0.263% and uptake 9.10 and 11.44 kg ha^{-1} in grain during 2011 and 2012 found in T_{12} was significantly higher than the rest of the treatments while minimum P content and uptake of rice grain was recorded in T_1 significantly lower than the rest of the treatments during both the years. P content and uptake of rice grain was higher in those treatments where zinc by either source was applied basal than foliar. The response of T_{11} and T_3 in respect of grain P content and uptake was also higher but not to the level of P content recorded in T_{12}. The highest P content 0.141 and 0.149% and uptake 7.71 and 9.98 kgha^{-1} in straw during 2011 and 2012 found in T_{12} was significantly higher than the rest of the treatments, while minimum P content of rice straw recorded in T_1 was significantly lower than the rest of the treatments. The P content of straw sample was higher in those treatment where zinc in either source was applied in basal than foliar. The straw zinc content in treatments (T_{11}) receiving micronutrient mixture +RDF and T_3, where $ZnSO_4$ @ 25kg ha^{-1} + RDF was also higher, but not reach to the level of P content recorded in T_{12} where vermicompost @ 3tone ha^{-1} was used with RDF. Among the treated plots minimum P content and uptake in rice straw was recorded in T_2 followed by T_{10} and T_9. Phosphorus content of the rice at 30, 60, grain and straw stage was significantly affected by different treatments during both the years. During all the stages the highest P content found in T_{12} was significantly higher than the rest of the treatments while minimum P content recorded in T_1 was significantly lower than the rest of the treatments during both the years. The P content was higher in those treatment where zinc in either source was applied in basal than foliar. The crop growth was better with balanced and adequate nutrition. Rooting system will also be better with adequate and balanced plant nutrition. Since roots are directly related to P absorption higher P content in those treatments is well expected. Addition of vermicompost will increase P well benefit the standing crops. Rana and Kashif (2014) reported that lowest P concentrations for paddy and straw were recoded under absolute control (T_1). When compared with Z-control (T_2) different sources of Zn application resulted in decreased P content in paddy and straw (except Zn-EDTA application, both soil and foliar). Maximum value of P content in paddy (2.11%) and straw (1.09%) were obtained in T_5 (Zn-EDTA applied @ 10.00 kg ha^{-1} in soil) followed by T_2. Among the Zn treatments, T_6 (ZnO applied @ 5.00 kg ha^{-1} in soil) recorded lower P contents in paddy (1.72 %) and straw (0.77 %). Ram *et al*. (2020) also reported thatthe content of nitrogen (N) of grain and straw of summer rice was maximum in the treatments with 75% RDN+25% N through Vermicompost (T_2) and it was closely followed by the treatment 75% RDN+25% RDN through FYM (T_3) and 100% RDN (T_1). The N content in straw of the treatment T_3 (75% RDN+25% RDN through FYM) was further significantly superior to 50% RDN+50% N through Vermicompost (T_4). Kumar *et al.* (2023) the content of phosphorus (P) in grain and straw of rice was at par with all nutrient management treatments except control (T_8) was significantly inferior to others. When compared to control and other treatments, the application of 125% RDF + Vermicompost @ 6 t ha^{-1} + 2% Zinc Solubilizing bacteria (T_8) resulted in significantly higher values for NPK uptake in grain and straw. This is because the concentration of nutrients in the soil was raised by using vermicompost in conjunction with chemical fertilizers. Similar result also found by Biswas *et al.* (2020) the highest nitrogen and potassium content by rice grain and straw were recorded with the application of 75% RDF + 25% N through vermicompost. The phosphorus content in grain was highest with 100% RDF + S40 Zn5 B 1.5 kg ha^{-1} while in straw it was maximum with customized fertilizer. The higher K content in grain and straw were noticed in 75% RDF + 25% N through sewage sludge.

Potassium content (%) and uptake (Kg/ha) of rice at different stages

It is clear from Table 3 that measured potassium content and uptake was affected significantly by different treatments during both the years. Potassium content and rice biomass at 30 and 60 DAT and rice grain and straw at harvesting were significantly affected by different treatments during both the years. Maximum K content 1.81 and 1.85% and uptake 60.81 and 67.47 kg ha^{-1} during 2011 and 2012 found in T_{12} was significantly higher than the rest of the treatments, while minimum K content recorded in T_1 was significantly lower than the rest of the treatments during both the years. In general, the K content of rice plant at this stage was higher in those treatments where zinc in either source was applied basal than foliar. The K content and uptake of rice plant sample in T_{11} and T_3 was also higher but not to the level of K content recorded in T_{12}. Among the treated plots minimum plant K content and uptake was recorded in T_2 followed by T_{10}. A similar trend in Potassium content and uptake was observed in rice plants at 60 DAT. The maximum range of Potassium content from 0.250 to 0.523 and 0.280 to 0.550% and uptake from 6.13 to 19.34 and 7.54 to 23.93 $kgha^{-1}$ of grain during 2011 and 2012, respectively. The highest K content 0.523 and 0.550% and uptake 19.34 and 23.93 $kgha^{-1}$ during 2011 and 2012 found in T_{12} was significantly higher than the rest of the treatments while minimum K content and uptake recorded in T_1 was significantly lower than the rest of the treatments. The K content and uptake of grain sample was higher in those treatments, where zinc in either source was applied as basal as foliar. The K content of grain in T_{11} and T_3 was also higher but not to the level of K content recorded in T_{12} among the treated plots minimum plant K content was recorded in T_2 followed by T_{10}. The potassium content of straw ranges from 1.21 to 1.55 and 1.24 to 1.58 % and uptake ranges from 49.25 to 84.82 and 50.76 to 104.67 kg ha^{-1} during 2011 and 2012, respectively. The highest K content 1.55 and 1.58% and uptake 84.82 and 104.67 kg ha^{-1} during 2011 and 2012 found in T_{12} was significantly higher than the rest of the treatments while minimum K content and uptake recorded in T_1 was significantly lower than the rest of the treatments. The K content and uptake of straw was higher in those treatments, where zinc in either source was applied basal than foliar. The K content and uptake of plant sample in T_{11} and T_3 was also higher but not to the level of K content recorded in T_{12}. Among the treated plots minimum

Table 3 : Effect of zinc sources and application mode on potassium content (%) and uptake (kg ha^{-1}) of rice at different stages.

Treatments	Content (%)								Uptake (kg ha^{-1})							
	30DAT		60DAT		Grain		Straw		30DAT		60DAT		Grain		Straw	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
T_1	1.33	1.38	.98	1.04	.25	.28	1.21	1.24	23.19	27.77	32.81	41.07	6.13	7.54	49.25	50.76
T_2	1.40	1.44	1.04	1.08	.29	.32	1.25	1.28	27.44	31.82	39.87	47.70	9.28	10.62	68.04	68.86
T_3	1.65	1.68	1.32	1.35	.45	.48	1.48	1.51	46.92	52.68	69.82	79.29	16.29	19.04	79.35	87.33
T_4	1.58	1.63	1.28	1.31	.43	.46	1.42	1.46	39.64	47.17	66.56	75.80	15.18	17.16	77.50	83.86
T_5	1.54	1.59	1.21	1.25	.40	.43	1.39	1.43	37.61	42.79	60.23	69.51	13.93	15.95	75.92	82.12
T_6	1.52	1.56	1.18	1.21	.38	.41	1.36	1.41	36.30	41.20	56.16	64.60	13.09	14.84	72.01	81.01
T_7	1.50	1.53	1.15	1.18	.35	.38	1.34	1.39	33.80	38.32	53.22	61.46	11.94	13.54	71.71	79.19
T_8	1.45	1.50	1.14	1.16	.33	.36	1.33	1.36	32.25	36.57	51.07	58.66	11.17	12.74	70.64	77.19
T_9	1.44	1.48	1.10	1.14	.32	.35	1.31	1.33	30.87	34.74	46.97	55.77	10.59	12.28	69.41	75.28
T_{10}	1.42	1.46	1.08	1.11	.30	.33	1.29	1.31	29.25	32.66	42.15	49.66	9.88	11.40	67.60	71.18
T_{11}	1.73	1.78	1.38	1.42	.48	.51	1.51	1.54	53.19	60.10	78.05	89.19	17.58	20.47	80.58	90.11
T_{12}	1.81	1.85	1.45	1.49	.52	.55	1.55	1.58	60.81	67.47	89.51	98.34	19.34	23.93	84.82	104.67
SE (m).	*0.015*	*0.018*	*0.017*	*0.014*	*0.014*	*0.014*	*0.013*	*0.017*	*1.251*	*.617*	*1.50*	*1.47*	*.937*	*.88*	*3.53*	*3.44*
CD (p=0.05)	*0.044*	*0.052*	*0.049*	*0.042*	*.041*	*.042*	*0.038*	*0.051*	*3.693*	*1.82*	*4.43*	*4.33*	*2.76*	*2.61*	*10.42*	*10.17*

plant K content was recorded in T_2 followed by T_{10}. Potassium content of the rice at 30, 60, grain and straw stage was affected significantly by different treatments during both the years. During all the stages the highest K content found T_{12} was significantly higher than the rest of the treatments while minimum K content of rice in T_1 was significantly lower than the rest of the treatments during both the years. The K content was higher in those treatments where zinc through either source was applied in basal than foliar. Grain and straw K content is affected significantly by the application of 3 tha^{-1} vermicompost + NPK (T_{12}), it may be due to more availability of K with the release of K from minerals owing to acidulation (Kumar *et al.*, 2023). When compared to control and other treatments, the application of 125% RDF + Vermicompost at 6 tha^{-1} + 2% Zinc Solubilizing bacteria (T8) resulted in higher values for NPK content in grain and straw. Grain and straw nitrogen and phosphorus concentration was recorded significantly higher in T_8. Potassium concentration in grain is significantly higher in T8 while straw potassium concentration is comparable to T7. The application of vermicompost, which is a rich source of nutrients and enhances the availability of macronutrients in soil, is responsible for the increase in nutritional content. Similar outcomes were discovered by Taheri Rahimabadi *et al.* (2017) and Papia Biswas *et al.* (2020). The control plots were found to have the lowest NPK concentration in grain and straw. Similar result was also recorded by Khan *et al.* (2003) recorded that a significant increase in Zn content of rice leaf before and after flowering and a significant decrease in P content of straw and paddy and starch content of paddy was recorded for all the methods. Nitrogen, K and Zn of paddy and straw and Zn contents of roots increased significantly with the application of zinc irrespective of the methods over control. The soil application of Zn was rated superior because it gave significantly higher content of N in rice paddy. Apoorva *et al.* (2017) reported that the K content was found to increase with the application of zinc. This might be due to the synergistic interaction between zinc and potassium. The highest uptake of potassium in grain (26.0 kg ha^{-1}) and straw (109.7 kg ha^{-1}) was seen in the treatment receiving RDF + soil application of bio zinc @30 kg ha^{-1}. The lowest uptake was recorded in control grain (6.5 kg ha^{-1}), straw (59.2 kg ha^{-1}).

Conclusion

Based on the experimental findings, it could be concluded that vermicompost is a best organic source of carbon and mineral nutrients which is a product of decomposition process using various species of earthworms and increase the availability of macro and micronutrients in soil. The application of 100% RDF + Vermicompost at 3 t ha^{-1} in T_{12} recorded higher values in NPK content and uptake over the other treatments. But the content and uptake of NPK in treatments (T_{11}) receiving micronutrient mixture +RDF and T_3 where $ZnSO_4$ @ 25kg ha^{-1} + RDF was also higher and equally good like treatment T_{12}.

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