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Effect of split application of vermicompost and zinc sources on yield and nutrient uptake of greengram [*Vigna radiata* (L.) Wilczek] in semi-arid eastern plain of Rajasthan

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Abstract

Zinc deficiency and poor nutrient management are major constraints in arid and semi-arid region. For efficient nutrient management strategies involving vermicompost and zinc fertilization are required to improve soil fertility and crop yield. So the experiment was conducted during *Kharif* season of 2024 at S. K. N. College of Agriculture, Jobner, Jaipur (Rajasthan). The experiment consisting of four treatments of split application of vermicompost (Control, 100% RDV at sowing, 75% RDV at sowing + 25% RDV at 15 DAS and 50% RDV at sowing + 50% RDV at 15 DAS) and four sources of zinc application (Control, 5 kg Zn ha^{-1} through Zn-EDTA as soil application, 5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$ as soil application and 2.5 kg Zn ha^{-1} through Zn-EDTA as soil application + 2.5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$ as soil application). The experiment was laid in a factorial randomized block design with three replications. The split application of vermicompost @ 75% RDV at sowing + 25% RDV at 15 DAS and zinc sources@5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$ as soil application, increased significantly (P=0.05) the grain yield, stover yield and biological yield, nutrient content and uptake in grain and stover of greengram. The interactive effect of N, P, K and Zn uptake in grain was significantly higher with combined application @ 50% RDV at sowing + 50% RDV at 15 DAS and 5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$ as soil application compared to other treatments. However, the increase was significant upto 75% RDV at sowing + 25% RDV at 15 DAS and 5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$ as soil application (VC_2Zn_2) which was found to be statistically at par with VC_3Zn_2 (50% RDV at sowing + 50% RDV at 15 DAS and 5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$ as soil application (VC_3Zn_2). We concluded on the basis of experimental findings that the combined application of 75% RDV at sowing + 25% RDV at 15 DAS + 5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$ as soil application with recommended dose of fertilizer.

Key words: Pulse crop, crop productivity, micronutrient efficiency, organic amendments.

Introduction

Pulses are an essential part of the Indian diet as they are a major source of protein. India has been identified as a major contributor to global research output. Apparently, it is the largest producer (26%), the consumer (27%), and importer (15%) of the pulses (Bhat *et al.*, 2022). Pulses are a good source of dietary protein and have unique ability of maintaining and restoring soil fertility through biological nitrogen fixation as well as addition of ample amount of residues to the soil and mushrooming the soil microbial population in the soil. In total pulse production, chickpea stands first with 48%, followed by redgram with 17%, blackgram with 10%, and greengram with 7%. The remaining quantity is contributed by other pulses (Marimuthu *et al.*, 2024). The grains

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contain approximately 25-28% protein, 1.0-1.5% oil, 3.5-4.5% fibre, 4.5-5.5% ash content and 62-65% carbohydrates on dry weight basis. It is considered as dual-purpose crop which can be used for seeds as well as for forage (Davies and Stewart, 1987).

Vermicompost considered a valuable organic fertilizer as it supplies nutrients for the crop which results in saving cost of chemical fertilizers (Erhart *et al*., 2005). Besides, it provides all the essential macro and micro nutrients in readily available forms, enhances uptake of these nutrients by the plants and play a major role in improving growth and yield of crops (Vukovic *et al*., 2021). Vermicompost also acts as a niche for microbes and enriches the soil with a variety of the indigenous micro-flora and fauna (Paul, 2007). Micronutrients are essential for crop production and their deficiency affects growth and metabolism especially during reproductive phase of the plant and also in animals and human beings. Among the micronutrients, zinc deficiency in both the plant and soil has been reported across the world (Alloway, 2008). The critical limit of available zinc in the soil suitable for growth is 0.6 mg kg^{-1}. The available zinc in the Indian soils extracted with DTPA is less than 1 per cent of the total zinc content (Takkar and Mann, 1975). Shukla *et al*. (2021) reported that 36.5, 23.2, 13, 12.8, 7.1 and 4.2% soils of India are deficient in zinc, boron, molybdenum, iron, manganese and copper, respectively. Zinc is one of the essential micronutrient and plays an important role in various enzymatic and physiological activities of the plant. It is also essential for photosynthesis and nitrogen metabolism and important for the stability of cytoplasmic ribosome's, cell division, as co factor to enzymes like dehydrogenase, proteinase and peptidase in the synthesis of tryptophan, a component of some proteins and a compound needed for production of growth hormones (auxin) such as indole acetic acid. Most of the soils of Rajasthan have been found deficient in zinc and assigned low availability of zinc in coarse textured soils with low organic carbon content (Singh and Singh, 1981). Therefore, if the soil is in short supply with respect to zinc, crop yields are further adversely affected. Hence, it becomes necessary to pay serious attention to the application and utilization of zinc. Hence, looking to the above facts the present investigation was carried out to study the effect of split application of vermicompost and zinc sources on crop productivity and nutrient uptake of greengram [*Vigna radiata* (L.) Wilczek] in semi-arid eastern plain of Rajasthan. It was hypothesized that split application of vermicompost combined with suitable zinc sources would enhance nutrient availability, improve nutrient uptake, and ultimately increase crop productivity compared to conventional application practices.

Materials and Methods

Experimental details: The experiment was conducted during *kharif* season of 2024 at the Instructional Farm (Agronomy), S.K.N. College of Agriculture, Jobner (Rajasthan) situated at an altitude of 427 m above mean sea level and at $26^0 06'$ North latitude and $75^0 28'$ East longitude. The region falls under agro-climatic zone-III-A (Semi-Arid Eastern Plain) of Rajasthan. Soil of the experiment was loamy sand in texture, saline in reaction (8.39±0.14), normal in electrical conductivity (0.748±0.01dS m^{-1}), low in organic carbon (0.236±0.01%), available N (128.26±5.15 kg ha^{-1}), medium in available P (18.32±0.25 kg ha^{-1}), medium in available K (162.57±6.20 kg ha^{-1}) and low in available zinc (0.439±0.011 mg kg^{-1}). The experiment was laid out in factorial randomized block design and replicated thrice in the plot size of 4.0 m x 3.0 m (12 m^2). The treatments consisting of four split application of vermicompost (Control, 100% RDV at sowing, 75% RDV at sowing + 25% RDV at 15 DAS and 50% RDV at sowing + 50% RDV at 15 DAS) (RDV = Recommended Dose of Vermicompost) and four sources of zinc application (Control, 5 kg Zn ha^{-1} through Zn-EDTA as soil application, 5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$ as soil application and 2.5 kg Zn ha^{-1} through Zn-EDTA as soil application + 2.5 kg Zn ha^{-1} through $ZnSO_{4.}7H_2O$ as soil application). The greengram var. RMG-492 was sown in lines at 30 cm apart. As per the treatments, the application of vermicompost @2 t ha^{-1} applied in the field as per treatments mixed at the time of sowing and 15 days stage of crop. The recommended dose of nitrogen (15 kg ha^{-1}) was applied in two equal splits, the half as basal and the remaining half was top dressed at the time of first irrigation. The basal dose was applied through urea after adjusting the quantity supplied through diammonium phosphate. The whole quantity of phosphorus (35 kg ha^{-1}) through diammonium phosphate and zinc through $ZnSO_4.7H_2O$ and Zn-EDTA was drilled as basal at 8-10 cm depth along with half nitrogen prior to sowing. The seeds obtained from the produce of individual plot were recorded as seed yield kg $plot^{-1}$ and later it was converted into kg ha^{-1}.

Nutrient uptake: The content of the nutrients were analyzed using standard methods and the concentration of nitrogen, phosphorus and potassium were expressed in per cent whereas concentration of zinc as ppm. The uptake of these nutrients were calculated using following methods and nitrogen, phosphorus, and potassium uptake expressed in kg ha^{-1} whereas zinc in g ha^{-1}.

$$\text{N, P, K uptake (kg ha}^{-1}) = \frac{\text{Nutrient content (\%) in grain} \times \text{Grain yield (kg ha}^{-1}) + \text{Nutrient content (\%) in stover} \times \text{Stover yield(\%) (kg ha}^{-1})}{100}$$

$$\text{Zn uptake (g ha}^{-1}) = \frac{\text{Nutrient content (ppm) in grain} \times \text{Grain yield (kg ha}^{-1}) + \text{Nutrient content (ppm) in stover} \times \text{Stover yield (kg ha}^{-1})}{1000}$$

Statistical analysis: The data recorded for different parameters were analyzed with the help of analysis of variance (ANOVA) technique as outlined by Panse and Sukhatme (1985) for a factorial randomized block design. The results are presented at 5% level of significance (P=0.05).

Results and Discussion

Yield

Effect of split application of vermicompost: Data presented in Table 1 revealed that yields of greengram ware significantly increased with the split application of vermicompost. The highest grain yield, stover yield and biological yield (1130.53, 2322.71 & 3453.24 kg ha^{-1}) was recorded under the treatment 50% RDV at sowing + 50% RDV at 15 DAS (VC_3) followed by 75% RDV at sowing + 25% RDV at 15 DAS (VC_2) and 100% RDV at sowing (VC_1) treatments as compared to control (VC_0). The lowest grain yield (886.22, 1922.30 & 2808.52kg ha^{-1}) was recorded under control (VC_0). It was hypothesized that split application of vermicompost along with zinc sources would enhance yield and nutrient uptake of greengram. The recommended practice for greengram in the region was considered that (35:15:00 kg ha^{-1} N, P_2O_5, K along with zinc sources). However, the increase was significant upto VC_2 which was found to be statistically at par with VC_3. The increase in grain yield, stover yield and biological yield was obtained to the extent of 27.57, 20.83 and 22.96 per cent with the split application of vermicompost @ 50% RDV at sowing + 50% RDV at 15 DAS, respectively as compared to control (VC_0), respectively. The beneficial response of vermicompost to yield attributes and yield might also be attributed to the

Table 1. Effect of split application of vermicompost and zinc sources on yield of greengram

Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})
Split application of vermicompost (t ha^{-1})			
Control (VC_0)	886.22	1922.30	2808.52
100% RDV at sowing (VC_1)	982.03	2092.17	3074.20
75% RDV at sowing + 25% RDV at 15 DAS (VC_2)	1102.62	2273.64	3376.26
50% RDV at sowing + 50% RDV at 15 DAS (VC_3)	1130.53	2322.71	3453.24
S.Em±	13.57	34.94	51.65
CD (P=0.05)	39.19	100.90	149.18
Zinc sources (kg ha^{-1})			
Control (Zn_0)	860.37	1918.22	2778.59
5 kg Zn ha^{-1} through Zn-EDTA as SA (Zn_1)	1036.88	2144.41	3181.29
5 kg Zn ha^{-1} through $ZnSO_4$ $7H_2O$ as SA (Zn_2)	1155.70	2325.43	3481.13
2.5 kg Zn ha^{-1} through Zn-EDTA as SA+ 2.5 kg Zn ha^{-1} through $ZnSO_47H_2O$ as SA (Zn_3)	1048.44	2222.77	3271.21
S.Em ±	13.57	34.94	51.65
CD (P=0.05)	39.19	100.90	149.18

availability of sufficient amounts of plant nutrients throughout the growth period and especially at critical growth periods of crops resulting in better uptake, plant vigour and superior yield attributes. The incorporation of vermicompost in the soil ensures successive and almost continuous supply of macro and micro nutrients to the greengram over the entire crop growth period (Biswas, 2011). The possible reason could be ascribed to the favourable effect on soil properties due to formation of more humus colloidal complex coupled with higher nutrient content of compost and it contributes directly to the nutrients pool of the soil (Biswas, 2011). Similar, findings were also reported by Akande *et al.* (2008) and Chahar *et al.* (2023).

Effect of zinc sources: Data presented in Table 1 indicated that the application of zinc sources significantly increased the yield over control (Zn_0). The highest grain yield, stover yield and biological yield was recorded under Zn_2 (1155.70, 2222.77 & 3271.21kg ha^{-1}) followed by Zn_3 and Zn_1 treatments as compared to control (Zn_0), respectively. However, the difference between Zn_1& Zn_3 treatments was also found to be statistically at par. The treatment 5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$ as soil application (Zn_2) increased the grain yield, stover yield and biological yield to the extent of 34.33, 21.23 and 25.28 per cent, respectively as compared to control (Zn_0), respectively. The favourable influence of applied zinc on grain, stover and biological yield may be due to catalytic or stimulatory effect of zinc on most of the physiological and metabolic processes of plants. The increase in grain, stover and biological yield with zinc fertilizer application might be due to the fact that zinc plays an important role in biosynthesis of indole acetic acid (IAA) and initiation of primordial for reproductive part which have favored the metabolic reaction within plant. The increase in the yield due to zinc application may be attributed to the fact that the initial status of available zinc in the experimental soil was low. The increase in yield attributes may be due to increased supply of available zinc to plants by way of its addition to soil which resulted in proper growth and development. These findings are also supported by Kumar *et al*. (2019) and Jat *et al.* (2021) in various crops.

Nutrient content and uptake

Effect of split application of vermicompost

The significantly highest N, P, K and Zn content (3.49 & 1.58%, 0.400 & 0.131%, 1.005 & 1.43% and 45.40 &38.65 mg kg^{-1}) and uptake (39.67 & 36.90 kg ha^{-1}, 4.50 & 3.04 kg ha^{-1},1 1.45 & 33.45 kg ha^{-1} and 51.58 & 89.93 g ha^{-1}) in grain and stover was obtained under the treatment VC_3 (50% RDV at sowing + 50% RDV at 15 DAS) followed by 75%

Table 2. Effect of split application of vermicompost and zinc sources on nitrogen, phosphorus, potassium and zinc content in grain and stover of greengram

Treatments	N content (%)		P content (%)		K content (%)		Zn content (mg kg^{-1})	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
Split application of vermicompost (t ha^{-1})								
Control (VC_0)	3.07	1.42	0.342	0.112	0.862	1.26	41.13	36.04
100% RDV at sowing (VC_1)	3.28	1.51	0.370	0.119	0.936	1.32	42.24	37.19
75% RDV at sowing + 25% RDV at 15 DAS (VC_2)	3.47	1.57	0.392	0.128	0.989	1.42	44.22	38.32
50% RDV at sowing + 50% RDV at 15 DAS (VC_3)	3.49	1.58	0.400	0.131	1.005	1.43	45.40	38.65
S.Em$\pm$	0.03	0.01	0.004	0.001	0.015	0.02	0.44	0.36
CD (P=0.05)	0.10	0.04	0.011	0.004	0.043	0.06	1.26	1.05
Zinc sources (kg ha^{-1})								
Control (Zn_0)	3.11	1.43	0.399	0.131	0.863	1.25	41.08	36.10
5 kg Zn ha^{-1} through Zn-EDTA as SA (Zn_1)	3.29	1.52	0.380	0.124	0.949	1.35	42.82	37.31
5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$ as SA (Zn_2)	3.52	1.58	0.365	0.120	1.007	1.45	45.25	38.93
2.5 kg Zn ha^{-1} through Zn-EDTA as SA+ 2.5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$ as SA (Zn_3)	3.39	1.55	0.360	0.116	0.973	1.38	43.84	37.85
S.Em$\pm$	0.03	0.01	0.004	0.001	0.015	0.02	0.44	0.36
CD (P=0.05)	0.10	0.04	0.011	0.004	0.043	0.06	1.26	1.05

RDV at sowing + 25% RDV at 15 DAS(VC_2) and VC_1 (100% RDV at sowing) and lowest N,P,K and Zn content (3.07&1.42%, 0.342&0.112%, 0.862&1.26%, 41.13&36.06 mg kg^{-1}) and uptake (27.31&27.28 kg ha^{-1}, 3.02&2.15 kg ha^{-1}, 7.68&24.22kg ha^{-1}, 36.56&69.40 g ha^{-1}) in grain and stover was obtained under the treatment control (VC_0) (Table 2, 3). However, the difference between VC_3 & VC_2 treatment in N, P, K and Zn content and uptake in grain and stover were found to be statistically at par. Similarly, phosphorus and zinc uptake in stover also showed no significant difference between VC_2 and VC_3 treatments. The vermicompost increased N, P, K and Zn content and uptake in grain and stover might be due to the better macro and micro nutrient availability released which are converted during vermicomposting into more plant-available forms. These results are in agreement with the findings of Todawat *et al.* (2018). Due to the acidifying properties of organic acids pH decreases, Manivannan *et al.* (2009) shown that lowering pH to between 6.0 and 7.0 can encourage nutrient availability to plants and thereby improve nutrient uptake by crop. It was observed that humic acid released from decomposition of compost can influence nutrient uptake by influencing the synthesis and activity of membrane proteins, particularly proton pumps that heighten the electrochemical proton gradient across the plasma membrane (Jat *et al*., 2015). Sims (1987) suggested that the vermicompost applied plot's showed higher N uptake may be attributed to the highest N content, the mineralization of N from organic matter, and the mineralization influence on native nitrogen. It might be because N and K ions have comparable ionic radii. Due to the synergistic relationship between N and P, higher N levels would have promoted P content in grain and straw. This closely echoes the findings of Bi *et al.* (2012). Vermicompost application may have improved the availability of native micronutrient cations, which may have contributed to the rise in Zn and Fe content. This is because applying micronutrients increased their content and converted their solid phase form into soluble metal-complexes. The findings of the current investigation closely match those of Sharma *et al*. (2017).

Effect of zinc sources

The maximum nutrient content (N 3.52 & 1.58%, K 1.007 & 1.45% and Zn 45.25 & 38.93 mg kg^{-1}) and uptake (N 40.90 & 36.86 kg ha^{-1}, P 4.24 & 2.80 kg ha^{-1}, K 11.71 & 33.86 kg ha^{-1} and Zn 52.51 & 90.71 g ha^{-1}) in grain and stover was recorded under the treatment Zn_2 (5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$ as soil application) as compared to control (Zn_0), respectively (Table 2, 3). However,

Table 3. Effect of split application of vermicompost and zinc sources on nitrogen, phosphorus, potassium and zinc uptake by grain and stover of greengram

Treatments	Nitrogen (kg ha^{-1})		Phosphorus (kg ha^{-1})		Potassium (kg ha^{-1})		Zinc (g ha^{-1})	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
Split application of vermicompost (t ha^{-1})								
Control (VC_0)		27.31	27.28	3.02	2.15	7.68	24.22	36.56
69.40								
100% RDV at sowing (VC_1)	32.32	31.57	3.62	2.49	9.22	27.62	41.55	77.95
75% RDV at sowing + 25% RDV at 15 DAS (VC_2)	38.44	35.90	4.31	2.91	10.96	32.51	48.92	87.28
50% RDV at sowing + 50% RDV at 15 DAS (VC_3)	39.67	36.90	4.50	3.04	11.45	33.45	51.58	89.93
S.Em±	0.52	0.66	0.06	0.05	0.18	0.59	0.72	1.62
CD (P=0.05)	1.52	1.90	0.16	0.15	0.51	1.69	2.08	4.68
Zinc sources (kg ha^{-1})								
Control (Zn_0)	26.86	27.52	3.45	2.52	7.45	24.07	35.44	69.39
5 kg Zn ha^{-1} through Zn-EDTA as SA (Zn_1)	34.27	32.70	3.96	2.67	9.90	29.07	44.57	80.17
5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$ as SA (Zn_2)	40.90	36.86	4.24	2.80	11.71	33.86	52.51	90.71
2.5 kg Zn ha^{-1} through Zn-EDTA as SA + 2.5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$ as SA (Zn_3)	35.71	34.57	3.79	2.59	10.26	30.80	46.10	84.30
S.Em±	0.52	0.66	0.06	0.05	0.18	0.59	0.72	1.62
CD (P=0.05)	1.52	1.90	0.16	0.15	0.51	1.69	2.08	4.68

the difference between Zn_1& Zn_3 treatments in case of N, K and Zn content and uptake in grain and stover were found to be statistically at par. Whereas, the application of zinc significantly decreased the phosphorus content in grain and stover as compared to control. The increase in nutrient uptake due to application of 5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$ as soil application were in order of N 52.30&33.94%, P 23.16&11.05%, K 57.28&40.63% and Zn 48.18&30.73% in grain and stover of greengram, respectively as compared to control (Zn_0) (Table 2, 3). Zn application appeared to have a synergistic effect on N, K, and Zn content, but an antagonistic effect on P content. The higher nitrogen content in grain and stover could be due to role of zinc in synthesis of DNA and RNA and metabolisms that result in the formation of lipids, carbohydrates, and proteins. Also Zn significantly influences chlorophyll synthesis, which ultimately leads to greater biomass yield and nitrogen uptake (Hussain *et al*., 2019). The results are in agreement with the findings observed by Jat *et al*. (2021). K and Zn work together synergistically, applied zinc aids in the synthesis and translocation of enzymes and metabolic processes of plant which might has ultimately facilitated the removal of potassium and consequently the K uptake. The results obtained get support from the finding of Shivay *et al.* (2015). Improved Zn contents of greengram could be attributed to increased absorption of it in light of greater availability in the rhizosphere and greater translocation due to increased metabolic activity of plant as a result of Zn fertilization. This is because soil application of Zn in extremely deficient soil increased its availability (Imran and Rehim, 2017). Higher uptake of Zn was the outcome of higher Zn concentrations and higher dry matter production. Instead, the negative impact of Zn treatment on P content could be attributed to impeded P translocation caused by increased Zn availability, which interfered with the absorption and/or translocation of phosphorus absorbed by the roots. However, the rise in P uptake by seed and straw of greengram may be due to higher grain and stover yields, which partially balance the decline in contents. Verma *et al*. (2022) reported that application of $ZnSO_4$ enhanced available zinc in soil solution which would have encouraged zinc content and uptake by wheat crop.

Table 4. Interactive effect of split application of vermicompost and zinc sources on nitrogen, phosphorus, potassium (kg ha^{-1}) and zinc uptake (g ha^{-1}) by grain of greengram

Treatments	Zn_0	Zn_1	Zn_2	Zn_3
Nitrogen uptake (kg ha^{-1})				
VC_0	21.89	26.92	32.06	28.37
VC_1	25.95	32.09	37.73	33.50
VC_2	31.08	38.06	45.40	39.20
VC_3	28.49	40.02	48.41	41.77
S.Em±	1.05			
CD (P=0.05)	3.03			
Phosphorus uptake (kg ha^{-1})				
VC_0	2.77	3.07	3.28	2.97
VC_1	3.32	3.70	3.90	3.54
VC_2	3.99	4.39	4.71	4.16
VC_3	3.71	4.70	5.09	4.49
S.Em±	0.11			
CD (P=0.05)	0.33			
Potassium uptake (kg ha^{-1})				
VC_0	5.99	7.65	9.04	8.03
VC_1	7.17	9.28	10.81	9.63
VC_2	8.63	10.98	12.98	11.25
VC_3	8.00	11.69	14.00	12.12
S.Em±	0.354			
CD (P=0.05)	1.03			
Zinc uptake (g ha^{-1})				
VC_0	29.82	36.12	42.50	37.83
VC_1	33.98	41.41	48.04	42.80
VC_2	40.22	48.56	57.22	49.69
VC_3	37.74	52.19	62.29	54.09
S.Em±	1.44			
CD (P=0.05)	4.15			

Interactive effect of split application of vermicompost and zinc levels

A significant interactive effect of split application of vermicompost and zinc sources on nitrogen uptake, phosphorus uptake, potassium uptake and zinc uptake in grain of greengram ware observed (Table 4). The maximum nitrogen (48.41kg ha^{-1}), phosphorus (5.09kg ha^{-1}), potassium (14.00 kg ha^{-1}) and zinc uptake (62.29 kg ha^{-1}) was obtained under 50% RDV at sowing + 50% RDV at 15 DAS + 5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$ as soil application (VC_3Zn_2) combination and the lowest under control (VC_0Zn_0). However, the increase was significant upto VC_2Zn_2 which was found to be statistically at par with VC_3Zn_2.This might have resulted in improved nutritional environment of rhizosphere as well as physicochemical properties of soil thereby improving the efficiency of utilization of native as well as applied nutrients (Chitdeshwari and Krishnaswami, 1998). The increase in grain yield, stover yield and biological yield might be due to the fact that vermicompost and zinc had an additive effect. Since the experimental soil was deficient in nutrients especially Zn the supplementation of Zn with vermicompost incorporation improved the availability of both nutrients as well as water by increased water and nutrient retention in the root zone by reducing infiltration and percolation. The applied vermicompost and zinc might have reacted synergistically in increasing the availability and steady supply of plant nutrients for plant metabolism and photosynthetic activity resulting into optimum growth and development which increased ultimately the grain and stover yield of maize substantially (Doodhawal, 2021). These findings are in agreement with those of Todawat *et al.* (2017) on greengram.

Conclusion

On the basis of experimental finding, it can be concluded that the combined application of 75% RDV at sowing + 25% RDV at 15 DAS + 5 kg Zn ha^{-1} through $ZnSO_4.7H_2O$ (VC_2Zn_2) as soil application along with the recommended dose of fertilizer results in significantly higher productivity and nutrient uptake of greengram in semi - arid eastern plain of Rajasthan.

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