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EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH, YIELD AND NUTREINT UPTAKE BY GREENGRAM (*VIGNA RADIATA* L.) IN COASTAL SALINE SOIL

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Abstract

An experiment was conducted in the farmer's field at Mandabam coastal village, near Chidambaram in Cuddalore District, Tamilnadu during January-April, 2019 to study the effect of integrated nutrient management practices on growth, yield and nutrient uptake of greengram using greengram variety ADT-5 as test crop. The treatments imposed in the study includes T_1– Control (RDF alone/100% NPK), T_2–RDF + FYM @ 12.5 t ha^{-1}, T_3–RDF + Composted coirpith (CCP) @ 12.5 t ha^{-1}, T_4–RDF + FYM @ 12.5 t ha^{-1} + Rhizobium @ 2.0 kg ha^{-1}(BF), T_5–RDF + CCP @ 12.5 t ha^{-1}+ Rhizobium (BF), T_6–RDF + FYM @ 12.5 t ha^{-1} + BF + $ZnSO_4$ @ 25 kg ha^{-1}, T_7–RDF + CCP @ 12.5 t ha^{-1} + BF + $ZnSO_4$ @ 25 kg ha^{-1}, T_8–RDF + ZnEFYM @ 6.25 t ha^{-1} + BF + Pink Pigmented Facultative Methylotrophs (PPFM) @ 1.0 % Foliar spray and T_9–RDF + ZnECCP @ 6.25 t ha^{-1} + BF + PPFM @ 1.0 % Foliar spray twice at pre flowering stage and flowering stage. The experiment was carried out in a Randomized Block Design (RBD) with three replications. The results of the study clearly indicated that the integrated application of recommended dose of NPK + Zn enriched composted coir pith (ZnECCP) @ 6.25 t ha^{-1} along with Rhizobium @ 2.0 kg ha^{-1} through soil and foliar spray of pink pigmented facultative methylotrophs (PPFM) 1.0 per cent twice at pre flowering and flowering stage enhanced the growth and yield and nutrient uptake of greengram.

Key words : INM, ZnECCP, ZnEFYM, Growth, Yield, Nutrient Uptake, Greengram, Coastal Saline Soil.

Introduction

Coastal saline soils have specific soil constraints *viz.,* light texture, poor exchange property, low nutrient and water retention capacity, low status of organic carbon and deficiency of macro and micronutrients. These problems severely affect the productivity of crops in this region. Even the applied nutrients are leached to the lower layers due to poor physical properties, poor nutrient retention and low organic carbon content, which further aggravates the problem of nutrient deficiency. The coastal farmers are cultivating the lands by adopting traditional management practices and realizing very low yield of crops as compared to other regions (Karthika, 2019).

Coastal salt affected soils are most commonly suffered due to zinc deficiency. Boron, Iron, Manganese and Copper are also deficient in some locations. The Zinc plays a vital role to improve production and quality of greengram. Zinc is also recognized as a key element for protein synthesis, biological nitrogen fixation and also plays an important role in various enzymatic activities in the growth and development of plants. It is now established that micronutrient deficiency is the prime factor responsible for that low productivity of greengram in coastal areas. $ZnSO_4$ is most common and widely used source of Zn fertilizer by the farmers due to easy water solubility and high Zn content (20-25%). However, it is easily leachable in coastal sandy/sandy loam soils due to poor organic matter which resulted in low availability or use efficiency of Zn in crop plants. In this context, now a day's enriched or fortified organic manures with

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micronutrients are becomes an established nutrient supplementation technique in crop production to increase the yield and quality of crops. In addition to that some part of water soluble Zn may be converted to insoluble $ZnCO_3$ and Zn $(OH)_2$. However, other than Zinc sources like Zn EDTA is costlier than zinc enriched composted coir pith and FYM (ZnECCP/ZnEFYM), therefore it is not affordable to farmers and to increase production. Hence, inclusion of recommended dose of NPK fertilizer, micronutrient fertilizer like Zinc along with Zn enriched / fortified manures techniques becomes an imperative need to improve the yield of pulse production. It is more vivid that applications of NPK, micronutrients along with organic manures are essential to sustain soil health and crop productivity in coastal saline soil (Chaudhary *et al.,* 2016). Therefore, the present investigation was carried out to study the effect of integrated plant nutrient system for maximizing yield and nutrient uptake by greengram.

Materials and Methods

A field experiment was conducted at farmer's field in Mandabam coastal village near Chidambaram from January to April- 2019. The soil (0-15 cm) had the following characteristics viz., organic carbon- 0.27%, pH - 8.37, EC- 4.05 dS m^{-1}, available alkaline $KMnO_4$-N 131.47 kg ha^{-1}, Olsen P- 9.28 kg ha^{-1} and NH_4OAC-K 154.874 kg ha^{-1}. The available Zn (DTPA extractable Zn) content (0.71mg kg^{-1}) was also low in soil. The treatments consisted of T_1–Control (RDF alone/100% NPK), T_2 –RDF + FYM @ 12.5 t ha^{-1}, T_3 –RDF + Composted coirpith (CCP) @ 12.5 t ha^{-1}, T_4 –RDF + FYM @ 12.5 t ha^{-1} + Rhizobium @ 2.0 kg ha^{-1}(BF), T_5 – RDF + CCP @ 12.5 t ha^{-1}+ Rhizobium (BF), T_6 –RDF + FYM @ 12.5 t ha^{-1} + BF + $ZnSO_4$ @ 25 kg ha^{-1}, T_7 – RDF + CCP @ 12.5 t ha^{-1} + BF + $ZnSO_4$ @ 25 kg ha^{-1}, T_8–RDF + ZnEFYM @ 6.25 t ha^{-1} + BF + Pink Pigmented Facultative Methylotrophs (PPFM) @ 1.0 % Foliar spray and T_9 –RDF + ZnECCP @ 6.25 t ha^{-1} + BF + PPFM @ 1.0 % Foliar spray twice at pre flowering stage and flowering stage. The treatments were replicated thrice in a Randomised Block Design (RBD). The test crop used in this study was greengram var. ADT 5. N (25 kg N ha^{-1}), P (50 kg P_2O_5 ha^{-1}) and K (25 kg K_20 ha^{-1}) were applied through Urea, DAP and Muriate of potash respectively. Half of the N and entire P_2O_5 and K_2O were applied as basal and the remaining half dose of N was applied in two splits at flowering and pod formation stage. Required quantities of different organics *viz*., Farm yard manure and composted coir pith as per the treatment schedule were incorporated into the soil. Enriched organic manures like Zinc enriched FYM (ZnEFYM) and Zinc enriched composted coir pith (ZnECCP) @ 6.25 t ha^{-1} were applied basally and well incorporated into the soil as per the treatment schedule. Foliar spray of Pink Pigmented Facultative Methylotrophs (PPFM) @ 2.0 per cent twice at Pre Flowering Stage (PFS) and at Flowering Stage (FS) was applied as per the treatment. The biofertilizer - *Rhizobium* @ 2.0 kg ha^{-1} was incorporated as per the treatment schedule. Seed and haulm yield at maturity stage were recorded. The seed and haulm samples were collected at harvest, dried at 70°C, powdered and diacid extract was prepared. The concentrations of nutrients viz., N, P, K and micronutrients namely and Zn were estimated using the standard procedure as outlined by Jackson (1973) and uptake were calculated.

Results and Discussion

Growth characters

The application of Zinc enriched organics + biofertilizer along with inorganic NPK fertilizers was significantly and positively influenced the growth characters *viz.,* plant height, number of branches per plant, LAI and dry matter production at different growth stages of greengram (Table 1). With INM treatments, the application of recommended dose of fertilizer (RDF) + ZnECCP @ 6.25 t ha^{-1} + Rhizobium @ 2 kg ha^{-1} through soil application + foliar spray of PPFM @ 1.0 per cent twice at pre flowering stage and at flowering stage (T_9) recorded the highest plant height (45.47cm), number of branches $plant^{-1}$(15.72), LAI (2.28) and dry matter production (3309 kg ha^{-1}) at the harvest stages of greengram, respectively. This was followed by the treatments T_8 (RDF + ZnEFYM @ 6.25 t ha^{-1} along with BF @ 2.0 kg ha^{-1} through soil + foliar spray of PPFM @ 1.0% twice at pre flowering and flowering stage), T_7 (RDF + CCP @ 12.5 t ha^{-1} + BF along with $ZnSO_4$ @ 25 kg ha^{-1}) and treatment T_6 (RDF + FYM @ 12.5 t ha^{-1} + BF along with $ZnSO_4$ @ @ 25 kg ha^{-1}) which recorded a mean growth characters like plant height (43.13, 40.74 and38.36 cm), number of branches $plant^{-1}$ (14.84, 13.99 and 13.17), LAI (2.16, 2.05 and 1.92) and dry matter production (3158, 2994 and 2818 kg ha^{-1}) of greengram at harvest stage, respectively. This was followed by the application of organics and biofertilizer alone or organics alone and without micronutrients treatments. The treatment T_5 (application of RDF + CCP @ 12.5 t ha^{-1} + BF), T_4 (application of RDF + FYM @ 12.5 t ha^{-1} + BF), T_3 (RDF + CCP @ 12.5 t ha^{-1}) and T_2 (RDF + FYM @ 12.5 t ha^{-1}) recorded the lowest growth components as compared to INM treatments (organics + BF and inorganic). The control treatment T_1, application of 100% recommended dose of NPK alone (without micronutrient and organics) produced the shortest plants and lowest

Table 1: Effect of integrated nutrient management on the growth characters of greengram.

Treatments	Plant height (cm)			Leaf area index (LAI)			Number of branches Plant $^{-1}$			Dry matter production (kg ha^{-1})		
	FS	PFS	HS	FS	PFS	HS	FS	PFS	HS	FS	PFS	HS
T_1	15.49	20.85	25.69	1.32	1.24	1.19	5.89	7.16	8.96	998	1216	1759
T_2	16.84	22.74	28.18	1.45	1.36	1.33	6.47	7.79	9.85	1092	1330	1917
T_3	18.31	24.57	30.77	1.59	1.51	1.48	6.98	8.44	10.70	1197	1434	2082
T_4	19.69	26.56	33.25	1.75	1.64	1.61	7.52	9.16	11.52	1296	1549	2261
T_5	21.03	28.49	36.00	1.92	1.81	1.79	8.03	9.85	12.38	1420	1657	2593
T_6	22.54	30.41	38.36	2.06	1.95	1.92	8.54	10.52	13.17	1521	1764	2818
T_7	24.38	32.23	40.74	2.24	2.09	2.05	9.09	11.13	13.99	1633	1892	2994
T_8	25.36	34.07	43.13	2.39	2.24	2.16	9.66	11.79	14.84	1734	2005	3158
T_9	26.75	35.84	45.47	2.54	2.37	2.28	10.18	12.43	15.72	1832	2109	3309
SE_D	0.59	0.81	1.04	0.06	0.05	0.04	0.23	0.28	0.35	45.07	48.48	67.45
CD (p=0.05)	1.27	1.73	2.23	0.12	0.11	0.10	0.49	0.60	0.75	96.45	103.75	144.35

number of branches pant^{-1}, LAI and dry matter production of greengram over all other INM treatments.

In coastal saline soil, greengram responded well to the integrated nutrient application. Among the various INM treatments, integrated application of recommended dose of NPK fertilizers + *Rhizobium* along with ZnECCP @ 6.25 t ha^{-1} and foliar spray of pink PPFM @ 1.0% twice recommended dose of NPK fertilizers were better than NPK alone. This might be due to application of Zn through $ZnSO_4$ or enriched Zn organics along with biofertilizer, which enhanced plant growth, increased plant metabolites and encouraged the growth of microorganisms as well as organic matter. Further, the presence of organic manure may be tended to slow and steady supplement nutrients continuously to the growing plants. These results are in conformity with Veeranagappa *et al*., (2010) and Kodeeswarn, (2015). In addition, foliar application of PPFM might have improved the fundamental cell processes like photosynthesis and respiration. The presence of micronutrients in chloroplasts, cell organelles was considered for the possible causes of increased growth characters of plants. Further, microbes harbouring rhizosphere of crops provide benefits to crops through better nutrient availability by way of atmospheric N_2 fixation or solubilizing fixed mineral form of nutrients. In addition to that close relations between microorganism growth and activity to organic matter content in the soil provided carbon and energy sources for the growth of microorganism which led to an increase in various plant metabolites responsible for cell division and elongation. Similar findings were reported by Mohana Keerthi *et al*. (2015) and Sivakumar *et al.,* 2017).

Yield characters

The integrated nutrient application either through organic, inorganic, biofertilizer along with Zn-enriched organics significantly and positively influenced the yield

Table 2: Effect of integrated nutrient management on the yield characters and yield of greengram.

Treatments	Yield components				Yield	
	No. of pods plant^{-1}	Number of seeds pod^{-1}	Pod length (cm)	100 seed weight (g)	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
T_1	18.04	3.31	5.78	3.35	566	1103
T_2	19.87	3.65	6.47	3.37	619	1236
T_3	21.48	3.93	7.21	3.36	672	1345
T_4	23.51	4.29	7.79	3.40	721	1460
T_5	25.33	4.62	8.56	3.55	773	1603
T_6	27.06	4.96	9.21	3.51	824	1721
T_7	28.79	5.29	9.88	3.59	875	1858
T_8	30.48	5.64	10.47	3.57	929	1972
T_9	32.95	5.97	11.10	3.60	982	2079
SE_D	0.74	0.13	0.25	NS	22.47	47.54
CD (p=0.05)	1.58	0.28	0.54	NS	48.10	101.75

characters *viz*., number of pods plant^{-1}, pod length and number of seeds pod$^{-1.}$ Whereas, the 100 seed weight of greengram was not statistically significant (Table 2). Among the various INM treatments, combined application of recommended dose of NPK + zinc enriched composted coir pith @ 6.25 t ha^{-1} +biofertilizer (BF) @ 2.0 kg ha^{-1} through soil application and foliar spray of pink pigmented methylotrophic bacteria (PPFM) @ 1.0 per cent twice at pre flowering and flowering stage (T_9) recorded the highest number of pods plant^{-1} (32.95), pod length (5.97cm) and number of seeds pod^{-1} (11.10), respectively. This was followed by the next best treatment T_8, which received RDF + zinc enriched FYM @ 6.25 t ha^{-1} +BF @ 2.0 kg ha^{-1} through soil application along with foliar spray of PPFM @ 1.0% which recorded a mean number of pods plant^{-1} (30.48), pod length (5.64cm) and number of seeds pod^{-1} (10.47), respectively. This was followed by the treatment T_7, which received with RDF + CCP @ 12.5 t ha^{-1} + BF + $ZnSO_4$ @ 25 kg ha^{-1} and treatment T_6, which received with RDF + FYM @ 12.5 t ha^{-1} + BF + $ZnSO_4$ @ 25 kg ha^{-1} which recorded the lowest number of pods plant^{-1} (28.79 and 27.06), pod length (5.29 and 4.96cm) and number of seeds pod^{-1}, respectively as compared to above said treatments. This was followed by the treatments arranged in the descending order like $T_5 > T_4 > T_3$ and T_2 (without BF and micronutrient). The lowest number of pods plant^{-1} (18.04), pod length (3.31cm) and number of seeds pod^{-1} (5.78) was recorded in the treatment T_1, (RDF alone).

The increase in yield attributes of greengram might be due to sustained release of nutrients from conjunctive use of NPK along with micronutrients and organics sources of nutrient (Gupta *et al.,* 2002). In addition, response of greengram to micronutrient application either through $ZnSO_4$/ZnECCP through soil and foliar spray of PPFM along with RDF significantly increased the yield attributes may be ascribed to better nutrient availability of soils (Debele *et al.,* 2000). Further, the addition of organic manure namely Zn enriched composted coir pith in these treatments and their subsequent decomposition in soil released the plant nutrients slowly throughout the crop growth and thus improved all the yield characters of greengram. Similar findings were also reported by Basvaraj and Manjunthaiah, (2003). Further, higher yield characters of greengram might also be attributed to enhanced metabolic activity, dry matter accumulation in the reproductive parts and formation of higher sink capacity with the addition of NPK + Rhizobium along with organics. Integrated supply of nutrients through Zn-enriched organics + NPK + biofertilizer not only increase the amount of nutrients present in soil but also increasing use efficiency and their availability in meeting out needs of crop at critical growth stages, resulted in increased plant growth and yield characters. These results are in agreement with Naveen savior and Stalin, (2013).

Greengram yield

The greengram responded well for the integrated plant nutrients application. The significant influence of recommended NPK, biofertilizer along with Zn enriched organics in increasing the grain and haulm yield of greengram was well documented in the present study (Table 2).

The yield realised under the nutrient impoverished coastal saline soil, the highest seed yield (982 kg ha^{-1}) and haulm yield (2079 kg ha^{-1}) was recorded with combined application of recommended dose of fertilizer (RDF) + *Rhizobium* @ 2 kg ha^{-1} + ZnECCP @ 6.25 t ha^{-1} through soil along with foliar spray of PPFM @ 1.0 per cent twice at pre flowering and flowering stage (T_9). This was followed by the treatments T_8, (RDF + BF + ZnEFYM @ 6.25 t ha^{-1} through soil application and foliar application of PPFM @ 1.0%), T_7 (RDF + CCP @ 12.5 t ha^{-1} + BF + $ZnSO_4$ @ 25 kg ha^{-1}) and T_6 (RDF + CCP @ 12.5 t ha^{-1} + BF + $ZnSO_4$ @ 25 kg ha^{-1}) which recorded the seed (929,875 and 824 kg ha^{-1}) and haulm (1972,1858 and 1721kg ha^{-1}) yield of greengram, respectively. This was followed by the application of organics and biofertilizer alone or without micronutrient treatments T_5, (RDF + CCP @ 12.5 t ha^{-1} + BF), T_4 (RDF+FYM @ 12.5 t ha^{-1} + BF), T_3 (RDF + CCP @ 12.5 t ha^{-1}) and T_2 (RDF +FYM @ 12.5 t ha^{-1}) which recorded the lowest seed and haulm yield as compared to above said INM treatments (organic, inorganic and BF). Among the various INM treatments, the treatment (T_9), 100% recommended dose of NPK + Zn enriched composted coir pith @ 6.25 t ha^{-1} along with Rhizobium @ 2 kg ha^{-1} and foliar spray of PPFM @ 1.0% twice recorded a seed and haulm yield of 982 and 2079 kg ha^{-1} which was 42.36 and 46.94 per cent increase over control or 100 per cent NPK alone (without micronutrients, BF and organics). The control treatment T_1, 100 per cent NPK alone recorded a lower seed (566 kg ha^{-1}) and haulm (1103 kg ha^{-1}) yield of greengram, respectively.

The constraint of high pH and salinity coupled with poor availability of nutrients causes' problem for the productivity of crops in coastal saline soil. Under such conditions, the imposition of organic manures and biofertilizer plays a crucial role in improving the physico chemical properties, nutrient availability and yield of crops. In the present investigation, keeping this in review the Integrated Nutrient Management methodology was

adopted with a prime aim to improve to yield of greengram. As expected the imposition of the various INM treatments exerted significant effect in increasing the yield of greengram. The application of recommended dose of NPK + Rhizobium + ZnECCP through soil and foliar spray of PPFM twice increased yield to 42.36 and 46.94 per cent of seed and haulm, respectively over NPK alone/control treatment. This could be due to combined effect of nutrients supply synergism and physical and biological properties of soil (Mohana Keerthi *et al.,* 2015). The application of NPK as chemical fertilizer supplied nutrients initially required for greengram growth and resulted in higher growth and yield characters leading to increased seed and haulm yield as earlier reported by Usman *et al.,* (2014) and Ramalakshmi *et al.,* (2015).

Foliar application of PPFM at pre flowering and flowering stages of crop growth were effectively absorbed in the plant system and translocated into sink which resulted in more number of pods plant^{-1} and more number of seeds pod^{-1}. Further, increased in photosynthesis during growth stages might be contributed for greater assimilates supply to the pods which resulting in better seed setting and also betterment of higher seed yield of greengram. PPFMs excrete auxins and cytokinins plant growth hormones that influence more number of flowering, pod filling and play critical roles in a plant's response to water/ saline stress condition. The results are in conformity with Jeyajothi *et al*., (2014).

Nutrients uptake (NPK)

The NPK uptake of greengram at all the critical stages of crop growth and in seed and haulm was significantly increased with the various INM treatments (Table 3). Integrated application of recommended NPK and Zn enriched organics along with biofertilizer through soil and foliar spray of PPFM significantly increased the uptake of major nutrients by greengram. Among the various INM treatments evaluated, the treatment T_9 (RDF + Rhizobium @ 2 kg ha^{-1} + ZnECCP @ 6.25 t ha^{-1} through soil and foliar spray of PPFM @ 1.0 %) registered the highest N (33.48 and 39.31kg ha^{-1}) P (6.58 and 5.41kg ha^{-1}) and K (9.65 and 15.01 kg ha^{-1}) by seed and haulm, respectively. This was followed by T_8, application of RDF + BF + Zn enriched FYM @ 6.25 t ha^{-1} through soil and foliar spray of PPFM @ 1.0 per cent, T_7 application of RDF + CCP @ 12.5 t ha^{-1} + BF along with $ZnSO_4$ @ 25 kg ha^{-1} and T_6 application of RDF + FYM @ 12.5 t ha^{-1} + BF along with + $ZnSO_4$ @ 25 kg ha^{-1} which recorded a lowest NPK uptake as compared to above said INM treatments. This was followed by the treatments arranged in the descending order like $T_5 > T_4 > T_3$ and T_2 (without BF and micronutrients). These treatments were also statistically significant. The lowest NPK uptake was registered in control (100% NPK alone).

The combined application of RDF + Rhizobium along with ZnECCP @ 6.25 t ha^{-1} through soil and foliar application of PPFM @ 1.0% twice at pre flowering stage and flowering stage (T_9) accounted for a highest NPK uptake at different stages in plants and in seed and haulm as compared to other treatments. The increased NPK uptake by greengram with application of Zn enriched organics along with biofertilizer and PPFM foliar spray may be due improvement of the soil environment which encouraged proliferation of roots resulting in more absorption of water and nutrients from larger rhizosphere. Moreover, Zn enriched organic manures during decomposition release nutrients which became available to the plants and thus increased NPK concentration. Further, integrated application of plant nutrients results in

Table 3: Effect of integrated nutrient management on the major nutrients uptake by greengram.

Treatments	Nitrogen uptake				Phosphorus uptake				Potassium uptake			
	FS	FFS	HS		FS	FFS	HS		FS	FFS	HS	
			Seed	Haulm			Seed	Haulm			Seed	Haulm
T_1	17.68	22.35	19.60	22.17	3.25	3.89	3.28	2.49	3.57	5.83	5.26	8.33
T_2	19.34	24.58	21.71	24.59	3.64	4.32	3.73	2.93	3.94	6.41	5.97	9.21
T_3	20.92	26.60	23.36	26.65	4.02	4.69	4.07	3.41	4.30	6.92	6.52	9.99
T_4	22.53	28.54	24.64	28.76	4.38	5.13	4.63	3.76	4.63	7.48	7.06	10.83
T_5	24.16	30.75	26.58	31.00	4.73	5.59	4.99	4.14	4.99	8.09	7.54	11.71
T_6	25.72	32.72	28.32	33.04	5.09	5.95	5.46	4.49	5.31	8.63	8.12	12.57
T_7	27.24	34.86	30.01	35.18	5.42	6.43	5.81	4.78	5.66	9.24	8.66	13.36
T_8	28.78	36.99	31.76	37.27	5.76	6.89	6.22	5.12	6.02	9.78	9.15	14.18
T_9	30.35	38.94	33.48	39.31	6.71	7.31	6.58	5.41	6.37	10.35	9.65	15.01
SE_D	0.69	0.87	0.76	0.83	0.14	0.16	0.15	0.12	0.14	0.23	0.21	0.35
CD (p=0.05)	1.49	1.88	1.63	1.78	0.29	0.35	0.32	0.26	0.31	0.50	0.47	0.75

Table 4: Effect of integrated nutrient management on the zinc uptake by greengram.

Treatments	Zinc uptake (g ha^{-1})			
	FS	FFS	HS	
			Seed	Haulm
T_1	17.66	37.95	19.16	38.06
T_2	19.39	41.80	21.15	42.30
T_3	21.01	45.29	23.01	46.43
T_4	22.58	48.72	24.73	49.95
T_5	24.23	52.20	26.68	53.86
T_6	25.75	55.76	28.37	57.48
T_7	27.36	59.22	30.18	61.12
T_8	28.94	62.58	31.96	64.71
T_9	30.48	65.53	33.72	68.19
SE_D	0.70	1.51	0.78	1.58
CD (p=0.05)	1.50	3.24	1.68	3.39

more uptakes of them as compared to sole use of organic or inorganic or biofertilizer alone and control. This may be due to the fact that the balanced and combined use of various plant nutrient sources results in proper absorption, translocation and assimilation of those nutrients, ultimately increasing the dry matter accumulation and nutrient contents of plant and thus showing more uptake of NPK nutrients. Similar findings were reported by Tyagi *et al*., (2014) and Kalaiyarasi *et al*., (2019).

Zinc uptake

The effect due to the integrated application of RDF + Biofertilizer along with Zn enriched organic manures and PPFM foliar spray had significant influence on zinc uptake by greengram at all the critical stages viz., flowering, pod formation and at harvest in grain and haulm (Table 4). Among the various INM treatments, the highest Zn uptake by seed (19.16 g ha^{-1}) and haulm (38.06 g ha^{-1}) was recorded with the application of RDF + BF + ZnECCP @ 6.25 t ha^{-1} and foliar spray of PPFM @ 1.0 per cent twice (T_{-9}). This was followed by application of 100% NPK (RDF) + BF + ZnEFYM @ 6.25 t ha^{-1} through soil and foliar application of PPFM @ 1.0 per cent (T_8), application of 100% NPK + CCP @ 12.5 t ha^{-1} + BF along with $ZnSO_4$ @ 25 kg ha^{-1} (T_7) and application of 100% NPK + FYM @ 12.5 t ha^{-1} + BF along with $ZnSO_4$ @ 25 kg ha^{-1} (T_6) which recorded a Zn uptake of 31.96, 30.18 and 28.37 g ha^{-1} by seed and 64.71, 61.12 and 57.48 g ha^{-1} by haulm, respectively. This was followed by the treatments which received organics and biofertilizer or organics alone along with recommended NPK (without Zn) applied treatments. The treatment T_5, (100% NPK + CCP @ 12.5 t ha^{-1} + BF) and T_4, (100% NPK + FYM @ 12.5 t ha^{-1} + BF) recorded a lowest Zn uptake of greengram as compared to above said treatments (micronutrients, Zn enriched organics and PPFM foliar spray). This was followed by the treatments T_3 and T_2. These two treatments were also statistically significant. The control (100% NPK alone) treatment recorded the lowest Zn uptake at all the critical stages of greengram.

The addition of Zn enriched organic manures resulted in higher micronutrient availability due to mineralization according to Mali *et al*., (2015). Zinc fortified organic manure application could result in release of more micronutrients in easily available form which was reflected in overall growth of the crop plants. These results are in accordance with the earlier reports of Mandal *et al*., (2007) and Mhonthy *et al*., (2015). The application of INM treatments especially Zn enriched composted coir pith was associated with relatively greater uptake of Zn by greengram at all the critical stages of crop growth. This increased uptake of Zn due to the INM treatment especially Zn-enriched organics application might be due to the decreased pH of the experimental soil which might have increased the availability of Zinc. Further, increased Zn uptake may also be attributed to the favorable condition either to increased solubility in soil solution and by possible stimulation of root absorptions as suggested by Singaravel *et al.,* (2003). Addition of organics caused higher Zn uptake mainly due to beneficial effect in mobilizing the native nutrient to increase the availability besides addition of Zn-enriched organics to the soil by naturally chelated form. This might have caused better Zn nutrition over a longer period to cause better growth (Gupta *et al.,* 2002).

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