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Integrated Nutrient Management Strategies for Maximizing Yield Of Greengram and Nutrient Availability in Coastal Soil

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ABSTRACT
A field experiment was conducted in a farmer's field at Mandabam coastal village, near Chidambaram, Cuddalore District of Tamilnadu during January –March 2019. To find out the influence of integrated nutrient management strategies for maximizing yield of greengram and soil nutrient availability in coastal soil. Texturally, the experimental soil was sandy loam with initial soil characteristics (0-15 cm layer) of the experimental site were, pH–8.37 and EC–4.05 dSm^{-1}. The soil registered low organic carbon status of 2.31 g kg^{-1}, 131.47 kg ha^{-1} of alkaline $KMnO_4$–N; 9.28 kg ha^{-1} of Olsen–P and 154.87 kg ha^{-1} of NH_4OAc-K, respectively. The available Zn (DTPA extractable Zn) content (0.71mg kg^{-1}) was also low in soil. The various INM treatments imposed in the study included T_1–Control (100% NPK/ RDF alone), T_2–100% NPK + FYM @ 12.5 t ha^{-1}, T_3–100% NPK + Composted coirpith (CCP) @ 12.5 t ha^{-1}, T_4–100% NPK + FYM @ 12.5 t ha^{-1} + Rhizobium @ 2.0 kg ha^{-1}(BF), T_5–100% NPK + CCP @ 12.5 t ha^{-1}+ Rhizobium (BF), T_6–100% NPK + FYM @ 12.5 t ha^{-1} + BF + $ZnSO_4$ @ 25 kg ha^{-1}, T_7–100% NPK + CCP @ 12.5 t ha^{-1} + BF + $ZnSO_4$ @ 25 kg ha^{-1} , T_8–100% NPK + ZnEFYM @ 6.25 t ha^{-1} + BF + Pink Pigmented Facultative Methylotrophs (PPFM) @ 1.0 % Foliar spray and T_9–100% NPK + ZnECCP @ 6.25 t ha^{-1} + BF + PPFM @ 1.0 % Foliar spray twice at pre flowering stage and flowering stage. The study included the above treatments which were arranged in a Randomized Block Design (RBD) with three replications, using greengram var. ADT 5. The results of the study indicated that the combined application of 100% recommeded dose of NPK + BF + PPFM @ 1.0 % Foliar spray twice along with Zn enriched composted coirpith (ZnECCP) @ 6.25 t ha^{-1} was significantly superior in increasing the soil nutrient availability and yield characters and yield of greengram.
Key words: *INM, Coastal Saline Soil, Greengram Yield and Nutrient Availability.*

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INTRODUCTION

Rice based production system is a common feature of the coastal areas especially rice–blackgram/greengram sequence. Most of the coastal farmers of Cuddalore district are following rice-pulses cropping system. A glimpse of the pulses production in India *vis-à-vis* other countries in the world shows that it occupies 36.6 per cent of area and 25.7 per cent production. India ranks first in area (29%) and production (19%) with respect to pulses. Though the country ranks first in area, the productivity is very low, which is around 1.0 t ha^{-1} [2] as compared to other countries. Pulses are the important sources of proteins, vitamins and minerals and are popularly known as "Poor man's meat" and "rich man's vegetables" contribute significantly to the nutritional security of the country. Among the pulses, greengram (or) *Vigna radiata* L. is the third important pulse crop after chickpea and red gram, cultivated throughout India for its multipurpose uses as vegetables, pulse, fodder and green manure crop. The seeds are more palatable, nutritive, digestible and non-flatulent than other pulses grown in country. It occupies as good position due to its high seed protein content (25%), ability to store the soil fertility through symbiotic nitrogen fixation. It is grown usually as rainfed as well as rice fallow and being a photo-sensitive and short-duration crop, can also be grown during summer season. Greengram accounts for 10-12% of total pulse production in the country. In Tamilnadu, the area under greengram is 1.8 L ha, with production of 1.2 L t and productivity of 642 kg ha^{-1} [20]. The area under salt affected soils in India and Tamilnadu are 6.74 m ha and 3.68 m ha. Productivity of most of the crops in salt affected soil is low due to salt stress. Greengram is important pulse crop that is grown in saline soil. However, the productivity of greengram in coastal saline soil is very low, because of less availability and uptake of nutrients and poor organic matter [6]. Hence, use of amendments and application of farmyard manure and other organics reduces the effects of salt stress. Improper use of inorganic fertilizer depletes the soil fertility and productivity besides the reduction of nutritional quality of pulses. Thus the integration of inorganic fertilizer and organic manures resulted in better growth, yield and nutrient uptake. Being leguminous crop, greengram has ability to fix atmospheric nitrogen in soil but it is adversely affected in coastal salt affected soils. Therefore application of bio-fertilizer is needed to ensure nodulation and nitrogen fixation [10]. In this context, the productivity of this crop is very low because of their cultivation on marginal and sub marginal lands of low soil fertility where little attention is paid to adequate fertilization.

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, the reasons being, 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 as well as highier leaching losses 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 micronutrients is becomes an established nutrient supplementation technique in crop production to increase the greengram 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 increase the cost of 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 is essential to sustain soil health and crop productivity in coastal saline soil. Therefore, the present investigation was carried out to study the effect of integrated nutrient management for maximizing yield of greengram and nutrient availability in coastal saline soil.

MATERIAL AND METHODS

A field experiment was carried out in a farmer's field during January – March, 2019 at Mandabam coastal village, to find out the effect of integrated nutrient management strategies for maximizing yield of greengram and soil nutrient availability in coastal soil. The various INM treatments included were, T_1– Control (100% NPK/ RDF alone), T_2 –100% NPK + FYM @ 12.5 t ha^{-1}, T_3 –100% NPK + Composted coirpith (CCP) @ 12.5 t ha^{-1}, T_4–100% NPK + FYM @ 12.5 t ha^{-1} + Rhizobium @ 2.0 kg ha^{-1}(BF), T_5 –100% NPK + CCP @ 12.5 t ha^{-1}+ Rhizobium (BF), T_6–100% NPK + FYM @ 12.5 t ha^{-1} + BF + $ZnSO_4$ @ 25 kg ha^{-1}, T_7–100% NPK + CCP @ 12.5 t ha^{-1} + BF + $ZnSO_4$ @ 25 kg ha^{-1}, T_8–100% NPK + ZnEFYM @ 6.25 t ha^{-1} + BF + Pink Pigmented Facultative Methylotrophs (PPFM) @ 1.0 % Foliar spray and T_9 –100% NPK + ZnECCP @ 6.25 t ha^{-1} + BF + PPFM @ 1.0 % Foliar spray twice at pre flowering stage and flowering stage. The experimental plots were arranged in a Randomized Block Design (RBD), with three replications, using greengram variety ADT 5. The experimental soil had sandy loam texture with pH- 8.37; EC- 4.05 dSm^{-1}; organic carbon- 2.31 g kg^{-1}, and DTPA-Zn 0.71 mg kg^{-1}. The alkaline $KMnO_4$–N; Olsen-P and NH_4OAc-K, were low, low and medium status, respectively. Calculated amount of inorganic fertilizer doses of Nitrogen (25kgNha^{-1}), Phosphorus (50 kg P_2O_5 ha^{-1}) and Potassium (25 kg K_2O 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 coirpith as per the treatment schedule were incorporated into the soil. Enriched organic manures like zinc enriched FYM (ZnEFYM) and zinc enriched composted coirpith (ZnECCP) @ 6.25 t ha^{-1} were applied basally and well incorporated into the soil as per the treatment schedule. Required quantities of $ZnSO_4$ were also applied through 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 namely *Rhizobium* @2.0 kg ha^{-1} were incorporated as per the treatment schedule. The soil samples were collected at flowering stage (FS), pod formation (PFS) and harvest stages (HS) and analyzed for major (N, P and K) and micronutrients (Zn) status of soil were also estimated using the standard procedure as outlined by Jackson [8]. At harvest stage, seed and haulm yield were also recorded.

RESULTS AND DISCUSSION

EFFECT OF INM ON THE YIELD CHARACTERS OF GREENGRAM (Table 1)

The integrated nutrient application either through organic, inorganic, biofertilizer along with Zn-enriched organics significantly and positively influenced the yield 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. Among the various IPNS treatments, combined application of recommended dose of NPK + zinc enriched composted coirpith @ 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 (5.97 cm) 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 (5.64 cm) 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 4.96 cm) and number of seeds pod^{-1} (7.88 and 9.21), 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 (3.31 cm) 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 [7]. 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 [5]. Further, the addition of organic manure namely Zn enriched composted coirpith 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 [3]. With Zn enriched organic manures the higher yield attributes could be explained by the supply of zinc and N upto harvest stage and larger supply of mineralized N to the plants. [1, 15]. Zinc also has an important role for the increase in photosynthate, which translocate and produced higher number of pods and consequently increase in number of seeds [12]. The beneficial effect of INM in increasing the yield attributes of greengram were already reported by earlier investigators [23, 28, 11]. 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 [16] and Jaganathan *et al*. [9]. The beneficial effect of INM in increasing the yield attributes of greengram was already reported by several investigators [19, 10, 27].

EFFECT OF INM ON THE GREEN GRAM YIELD (Table 1)

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.

The yield realised under the nutrient poverished 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 IPNS treatments, the treatment (T_9), 100% recommended dose of NPK + Zn enriched composted coirpith @ 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 overall improvement in yield attributing characters of tomato was obtained with the application of recommended dose of NPK + Rhizobium + Zn enriched composted coirpith @ 6.25 t ha^{-1} through soil application and foliar application of PPFM @ 1.0 per centtwice at pre flowering and flowering stage.

Application of NPK + biofertilizer and Zn enriched organic manures helped in the slow and steady rate of nutrient release into soil solution to match the absorption pattern of greengram thereby increased the yield. Further, the favourable effect of Zn and NPK nutrients on seed and haulm yield was also could be attributed to their effect in maintaining soil available nutrients in balanced proportions Singaravel *et al.* [24]. Foliar application of pink pigmented facultative methylotorphs (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 Sivakumar *et al*. [25]. Under present study, the overall improvement in increased growth and yield attributes in terms of number of pods plant^{-1}, number of seeds pod^{-1} and 100 seed weight resulted in increased yield of greengram with INM application. A plethora of evidences are available for the beneficial effect of INM on greengram with earlier reported by Marimuthu and Surendran, [14].

EFFECT OF INM ON THE AVAILABLE MAJOR NUTRIENTS (Table 2)

Alkaline $KMnO_4$-N

The availability of nitrogen in coastal saline soils are very low due to poor crop residues and microbial activity and leaching of nutrients associated with poor structure and low use efficiency of applied nutrients. The influence of various INM treatments in significantly increasing the availability of nitrogen in soil was well evidenced. Among the various INM treatments, application of recommended dose of fertilizer (RDF) + BF (Rhizobium) @ 2 kg ha^{-1} along with Zn enriched composted coirpith (ZnECCP) @ 6.25 t ha^{-1} through soil and foliar spray of PPFM @ 1.0% twice (T_9) recorded the highest alkaline $KMnO_4$ –N content of 157.74, 148.64 and 139.53 mg kg^{-1} at FS, PFS and harvest stage, respectively. This was followed by the treatment T_8, which received RDF + BF + ZnEFYM @ 6.25 t ha^{-1} + PPFM @ 1.0% through foliar application. This treatment recorded149.71, 141.09 and 132.51 mg kg^{-1} of alkaline $KMnO_4$–N at flowering, pod formation and harvest stage, respectively. The treatments T_7 (RDF + CCP @ 12.5 t ha^{-1} + BF + $ZnSO_4$ @ 25 kg ha^{-1}) and T_6 (RDF + FYM @ 12.5 t ha^{-1} + BF +$ZnSO_4$ @ 25 kg ha^{-1}) which recorded a lowest alkaline $KMnO_4$ –N content 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. At all the growth stages, control registered the lowest alkaline $KMnO_4$-N content in the soil.

The betterment increase in available nitrogen in soil due to incorporation of organic materials might be also attributed to the enhanced multiplication of microbes by the incorporation of enriched organics and composted organics or crop residues for the conversion of organically bound N to inorganic form. Further, the favorable soil conditions under zinc enriched composted coirpith might have helped in the mineralization of soil N leading to the buildup of higher available N reported by Selvi [21].

Olsen-P

The effect due to the application of INM treatments in enhancing the available P content of soil was significant at all the critical stages like flowering, pod formation and at harvest stages of greengram. The treatment 100 per cent recommended dose of fertilizer (RDF) + BF +ZnECCP @ 6.25 t ha^{-1} through soil and foliar application of PPFM @1.0 per cent twice(T_9)recorded the highest available P content of 14.93 kg ha^{-1} at FS, 12.79 kg ha^{-1} at PFS and 10.75 kg ha^{-1}at harvest stage, respectively. This was followed by the next best treatment registered with T_8 which received RDF + BF + ZnEFYM @ 6.25 t ha^{-1}along with foliar application of PPFM@ 1.0% twice. This was followed by the treatments T_7, application of RDF + CCP @ 12.5 t ha^{-1} + BF + $ZnSO_4$ @ 25 kg ha^{-1} and treatment T_6, application of RDF +FYM @ 12.5 t ha^{-1} + BF along with $ZnSO_4$ @ 25 kg ha^{-1}which recorded a Olsen-P content of 10.17, 9.55 and 8.96 kg ha^{-1} at harvest stage, respectively. This was followed by the treatments arranged in the descending order viz., T_5> T_4> T_3 and T_2. These treatments were also statistically significant with each other. The control treatment T_1, recorded the lowest Olsen-P content of 5.92 kg ha^{-1} at harvest.

Larger build up in available P with organics may be attributed to the influence of organic manure in increasing the labile P in soil through complexation of cations like Ca^{2+} and Mg^{2+} which are mainly responsible for the fixation of phosphorus in soil. Further, the increased phosphatase activity with INM treatment might have played a signifying release of more organic bound P as reported by Chalwade *et al*. [4]. Incorporation of FYM and composted coirpith along with inorganic fertilizers and biofertilizer increase the availability of P and this is attributable to reduction in fixation of water soluble P, increased mineralization of organic P due to microbial action and enhanced mobility of P. These results are in conformity with the findings of Ramalakshmi *et al.* [18].

Table 1. Effect of integrated nutrient management practices on the yield characters and yield of greengram

Treatments	Yield characters				Yield	
	Number of pods plant^{-1}	Pod length (cm)	Number of seeds pod^{-1}	100 seed weight (g)	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
T$_1$ – Control (RDF/100% NPK alone)	18.04	3.31	5.78	3.35	440	960
T$_2$ – RDF+ FYM @ 12.5 t ha^{-1}	19.87	3.65	6.47	3.37	619	1236
T$_3$ – RDF+ CCP @ 12.5 t ha^{-1}	21.48	3.93	7.21	3.36	672	1345
T$_4$ – RDF+ FYM + Biofertilizer (Rhizobium)	23.51	4.29	7.79	3.40	721	1460
T$_5$ – RDF+ CCP + Biofertilizer	25.33	4.62	8.56	3.55	773	1603
T$_6$ – RDF+ FYM + Biofertilizer + $ZnSO_4$ @ 25 kg ha^{-1}	27.06	4.96	9.21	3.51	824	1721
T$_7$ – RDF+ CCP + Biofertilizer + $ZnSO_4$ @ 25 kg ha^{-1}	28.79	5.29	9.88	3.59	875	1858
T$_8$ – RDF+ Zn E FYM @ 6.25 t ha^{-1} + BF + PPFM @ 1% FS	30.48	5.64	10.47	3.57	929	1972
T$_9$ – RDF + Zn E CCP @ 6.25 t ha^{-1} + BF + PPFM @ 1% FS	32.95	5.97	11.10	3.60	982	2079
SE$_D$	0.74	0.13	0.25	0.08	22.47	47.54
CD (p=0.05)	1.58	0.28	0.54	NS	48.10	101.75

Table 2. Effect of integrated nutrient management practices on the nutrients availability in coastal soil

Treatments	Alkaline $KMnO_4$-N (kg ha^{-1})			Olsen-P (kg ha^{-1})			NH_4OAc-K (kg ha^{-1})			DTPA-Zn (mg kg^{-1})		
	FS	PFS	HS	FS	PFS	HS	FS	PFS	HS	FS	PFS	HS
T$_1$	93.29	87.88	82.94	8.97	7.30	5.92	107.07	103.78	100.91	1.17	0.66	0.47
T$_2$	101.41	95.46	90.07	9.76	8.03	6.48	116.19	112.62	109.39	1.32	0.82	0.56
T$_3$	109.37	103.12	97.12	10.57	8.68	7.12	125.23	121.37	117.76	1.48	0.97	0.62
T$_4$	117.32	110.71	104.0	11.32	9.33	7.67	134.30	130.21	126.13	1.63	1.12	0.69
T$_5$	125.49	118.24	111.35	12.20	10.08	8.34	143.38	138.97	134.59	1.76	1.24	0.75
T$_6$	133.66	125.88	118.41	12.44	10.73	8.96	152.37	147.82	143.04	1.91	1.35	0.84
T$_7$	141.72	133.55	125.43	13.39	11.46	9.55	161.36	156.70	151.51	2.05	1.46	0.92
T$_8$	149.71	141.09	132.51	14.06	12.13	10.17	170.43	165.53	159.95	2.21	1.58	1.03
T$_9$	157.74	148.64	139.53	14.93	12.79	10.75	179.45	174.38	168.31	2.34	1.68	1.09
SE$_D$	3.66	3.46	3.23	0.34	0.28	0.25	4.18	4.07	3.88	0.05	0.03	0.02
CD (p=0.05)	7.84	7.41	6.96	0.73	0.62	0.53	8.94	8.70	8.32	0.11	0.08	0.05

NH_4OAc-K

The positive influence of various IPNS treatments through inorganic fertilizers, biofertilizer along with Zn enriched organics was also significantly increased the NH_4OAc-K content of the soil in the present investigation. Of all the treatments, application of recommended dose of NPK + BF + Zn enriched composted coirpith (ZnECCP) @ 6.25 t ha^{-1} by soil along with foliar spray of PPFM @ 1.0 per cent twice (T$_9$) registered the highest NH_4OAc-K content of 179.45, 174.38 and 168.31 kg ha^{-1} at FS, PFS and at the harvest stages, respectively. This was followed by the treatment (T$_8$) which received RDF + BF + Zn enriched FYM

(ZnEFYM) @ 6.25 t ha^{-1}through soil and foliar spray of PPFM @ 1.0% recorded a value of K availability at flowering (170.43kg ha^{-1}), at pod formation(165.53 kg ha^{-1}) and at harvest (159.95 kg ha^{-1}) stage, respectively. This was followed by the treatment T_7,(RDF + CCP @ 12.5 t ha^{-1} + BF + $ZnSO_4$ @ 25 kg ha^{-1}) and treatment T_6,(RDF + FYM @ 12.5 t ha^{-1} + BF + $ZnSO_4$ @ 25 kg ha^{-1}) which recorded a lowest NH_4OAc-K (151.51 and 143.04 kg ha^{-1})content at harvest stage as compared to above said treatments. This was followed by the treatments arranged in the descending order as $T_5>T_4>T_3$ andT_2. These treatments were also statistically significant. The control treatment recorded the lowest soil K availability at all the critical stages of greengram.

The addition of organics along with recommended dose of NPK fertilizers reduced the K fixation and release of K due to the interaction of organic matter with clay besides the direct addition of potassium to available pool of the soil contributed for increased K availability. Organics also minimized the leaching loss of K by retaining K ions on exchange sites of the decomposition products. Similar results were also reported by [13]. Earlier findings of Senthilvalavan and Ravichandran [22] also reported increased availability of potassium in rice-pulse cropping system of soil with INM practices.

DTPA-Zn

Coastal soil is known for the restricted availability of zinc in soil due to poor organic matter, high leaching, prevailing high pH and salinity. The profound influence of various INM treatments in increasing in DTPA–Zn content of soil was well established in present study. The availability of DTPA-Zn content in the soil significantly increased at all the growth stages of greengram with the application of different INM treatments. The highest available zinc status at flowering (2.34 mg kg^{-1}),pod formation (1.68 mg kg^{-1}) and at harvest stage (1.09 mg kg^{-1}) was recorded with the combined application of 100 per cent recommended dose of NPK + BF @ 2 kg ha^{-1} + ZnECCP @ 6.25 t ha^{-1} through soil and foliar spray of PPFM @ 1.0% twice at pre flowering and flowering stage (T_9). This was followed by the treatment which received RDF + BF + ZnEFYM @ 6.25 t ha^{-1} through soil along with foliar spray of PPFM @ 1.0% twice (T_8) which recorded 1.03 mg kg^{-1} of DTPA-Zn content of soil at harvest stage. This treatment was followed by recommended NPK + BF + CCP @ 12.5 t ha^{-1} along with $ZnSO_4$ @ 25 kg ha^{-1}(T_7) and treatment T_6 which received NPK + BF + FYM @ 12.5 t ha^{-1} along with $ZnSO_4$ @ 25 kg ha^{-1}(T_6) which recorded a DTPA-Zinc content (0.92 and 0.84 mg kg^{-1}) of soil at harvest stage. This was followed by the treatments significantly arranged in the descending order as $T_5 > T_4 > T_3$ and T_2. The control treatment (RDF alone) registered the lowest DTPA-Zn availability of 0.47 mg kg^{-1} at harvest stage.

The highest DTPA-Zn content was recorded with the treatment RDF + Rhizobium along with ZnECCP application. The increased use efficiency of applied micronutrient fertilizer and their availability with the addition of micronutrients along with organics in complexing and mobilizing property might have increased the DTPA-Zinc content of the soil. Earlier findings support the present findings. In general, most of the saline soils, including the coastal region are well supplied with micronutrients with exception of Zn. The deficiency of micronutrients is induced in saline soils due to the reduction of sulphate salts to sulphides and subsequent precipitation of the micronutrients [26]. The increased zinc availability might be attributed to the direct addition of these nutrients by fertilizer and enriched organic manures, which maintain maximum available Zn and other micronutrients status in post harvest soil. Further the complexation of micronutrients with applied organics might have mobilized and increased the availability of Zn in soil. These findings are accordance with Patel *et al.* [17].

CONCLUSION

The present investigation clearly established the beneficial role of integrated nutrient management (INM) approaches to improve the soil properties and sustain the yield of greengram in coastal saline soil. Application of 100% recommended dose of NPK + biofertilizer (Rhizobium) @ 2.0 kg ha^{-1} along with Zn enriched composted coirpith (ZnECCP) @ 6.25 t ha^{-1} through soil application and foliar spray of pink pigmented facultative methylotrophs (PPFM) @ 1.0% twice at critical stages *viz.,* pre flowering and flowering stage was identified as best treatment combination to restore the soil fertility status and to realize the maximum profit in greengram cultivation in coastal saline soil.

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