ANSF APPLIED AND NATURAL SCIENCE FOUNDATION

Journal of Applied and Natural Science
13(4), 1166 - 1171 (2021)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Effect of organic fortified zinc on growth and yield of green gram (*Vigna radiata* (L). Wilczek) in *typic chromustert*

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Article Info
https://doi.org/10.31018/jans.v13i4.2933
Received: August 21, 2021
Revised: October 12, 2021
Accepted: October 21, 2021

How to Cite
Dhinagaran, M. *et al.* (2021). Effect of organic fortified zinc on growth and yield of green gram (*Vigna radiata* (L). Wilczek) in *typic chromustert*. *Journal of Applied and Natural Science*, 13(4), 1166 - 1171. https://doi.org/10.31018/jans.v13i4.2933

Abstract
Zinc is a crucial micronutrient for crop growth and enzymatic regulations. The present study was formulated to reveal the effect of organic fortified Zn composite on growth and yield parameters of green gram in *Typic chromustert* at Vellakulam village, Kalligudi block, Madurai district of Tamil Nadu. A total of eight treatments with three replications were designed to grow in Randomized Block Design (RBD). The treatments consisted of recommend dose fertilizers (25:50:25 Kg ha^{-1} N: P_2O_5: K_2O) + various sources organics applied such as vermicompost (1:5), poultry manure (1:5), biochar (1:5), FYM (1:10) incubated with $ZnSO_4$ @ 25 kg ha^{-1} and Tamil Nadu Agricultural University micronutrient mixture enriched with FYM (1:10) for 30 days. Among the treatments, application of RDF (25:50:25 Kg ha^{-1} N: P_2O_5: K_2O) + soil application of $ZnSO_4$ @ 25 kg ha^{-1} incubated with 125 kg Vermicompost (1:5) recorded maximum plant height (64 cm), leaf area index (LAI) (3.11), dry matter production (16.33 g $plant^{-1}$), pods $plant^{-1}$ (28.46), grains pod^{-1} (13.5), test weight (3.48 g), seed yield (950 kg ha^{-1}) and haulm yield (1520 kg ha^{-1}) followed by biochar and TNAU MNM shown on par results with each other. The lowest yield parameters were spotted in absolute control. A considerable increase in yield (25 %) was detected when the crop was supplemented with organically fortified Zinc than the commercial $ZnSO_4$. The study concluded that the application of biofortified Zn will deliver higher growth and yield in green gram.

Keywords: Biofortification, Green gram, Vermicompost, Yield, Zinc

INTRODUCTION

Pulses are an imperative component of a balanced vegetarian food diet, hence, known to be the 'poor man's meat'. Pulses play a vital role in soil fertility restoration through atmospheric nitrogen fixation in association with root nodule bacteria. Green gram as a proportion to fix atmospheric nitrogen (30-40 kg ha^{-1}). Green gram major dietary crop is grown over the countries, out of which 70% of the world's production comes from India (*Greengram outlook*, 2019). The nutrient profile of the charted as protein (18 - 25%), carbohydrates (50%), fat (3%), ash (4- 5%), fiber (3-4.5%), phosphorus (367 mg) and calcium (132 mg) per hundred-gram seed (Frauque *et al*., 2000).

Zn is a vital element in human, animal, and plant metabolism that takes part in the enzymatic reaction, structural constituent, regulatory cofactors of a broad range of enzymes and protein significant biochemical pathways. It is the precursor for auxin biosynthesis in plants, where its deficiency notably retards plant growth and development (Hassan *et al*., 2020).

In Indian soils, zinc deficiency is one of the abiotic stress limiting factors, with 50% of the soils lacking this essential micronutrient. When Zn is supplied as zinc sulphate, it is converted to alternate forms such as Zn (OH) and Zn $(OH)_2$ at pH 7.7 and 9.0, $ZnCO_3$ in alkali soils, zinc phosphate in high phosphorous applications, and zinc sulphide in reduced conditions (Suganya *et al*., 2020). The alternative supplementation of zinc plays a vital role in escaping the plant from zinc deficiency (Suganya *et al*., 2015). Zinc can be administrated using various sources, i.e., conventional fertilizers such as $ZnSO_4$, chelated forms as EDTA - Zn, and natural organic complex mixtures. With this background, the present study was designed to evaluate the effect of different treatments of organically biofortified Zn on green gram growth and yield.

MATERIALS AND METHODS

Experimental site

The field experiment was conducted at Vellakulam village, Kalligudi block, Madurai district of Tamil Nadu (9°67' North latitude and 77°96' East longitude) during summer (February – March), 2021. The average annual summer temperature varied from 40 to 26.3 degrees Celsius. In comparison, the average annual winter temperature ranged from 29.6 to 18 degrees Celsius, with a mean annual rainfall of 750 mm during the southwest monsoon and relative humidity of 45 to 85 percent (Karpagam *et al*., 2020).

Enrichment of organic fortified Zn

The organic sources employed in the fortification of Zn are Farmyard manure, biochar, poultry manure and vermicompost. The enrichment process included *viz.,* $ZnSO_4$ @ 25 kg ha^{-1} incubated with 250 kg FYM (1:10), $ZnSO_4$ @ 25 kg ha^{-1} incubated with 125 Kg Vermicompost (1:5), ZnSO4 @ 25 kg ha^{-1} incubated with 125 kg Biochar (1:5), $ZnSO_4$ @ 25 kg ha^{-1} incubated with 250 kg Poultry manure (1:10), Tamil Nadu Agricultural University Micronutrient Mixture @ 5 kg ha^{-1} incubated with 50 kg FYM. They were incubated for 30 days and maintained with 60 percent moisture content.

Experimental details

The field experiment was conducted in Randomized Block Design with eight treatments and three replication, each covering 20 m^2 (5 m x 4 m). The details of treatments are given in Table 1.

Table 1. Details of treatment of field experiment

T_1 - Absolute control	T_5 - SA of $ZnSO_4$ @ 25 kg ha^{-1} incubated with 125 Kg vermicompost (1:5)
T_2 - RDF (25:50:25 kg ha^{-1} $N:P_2O_5:K_2O$)	T_6 - SA of $ZnSO_4$ @ 25 kg ha^{-1} incubated with 125 kg biochar (1:5)
T_3 - SA of $ZnSO_4$ @ 25 kg ha^{-1}	T_7 - SA of $ZnSO_4$ @ 25 kg ha^{-1} incubated with 250 kg poultry manure (1:10)
T_4 - SA of $ZnSO_4$ @ 25 kg ha^{-1} incubated with 250 kg FYM (1:10)	T_8 – TNAU MNM @ 5 kg ha^{-1} incubated with 50 kg FYM (1:10).

Data collection and analysis

Before the experimentation, soil samples were collected at random places at 0-15 cm depth across the experimental site and made in to single composite. The composite soil sample was processed and used for analysis of physico-chemical characteristics viz., textural fraction (International pipette method, Piper, 1966), bulk density (Core sampler method, Gupta and Dakshinamoorthy, 1980), particle density (Core sampler method, Gupta and Dakshinamoorthy, 1980), soil reaction (pH) (Potentiometry, Jackson, 1973), electrical Conducticity (EC) (Conductometry, Jackson, 1973), soil organic carbon (Dichromate wet digestion method, Walkley and Black, 1934), available nitrogen (Alkaline permanganate method, Subbaiah and Asija, 1956), available phosphorus (Olsen method, Olsen, 1954), available potassium (Neutral normal NH4OAc method, Stanford and English, 1949), DTPA - extractable Zn, Fe, Cu, Mn (Atomic Absorption Spectrophotometer, Lindsay and Norvell, 1978). Three plants from each plot were tagged and utilized for recording biometric observations of growth attributes (plant height, Leaf Area Index (LAI), dry matter production), and yield attributes (test weight, pods $plant^{-1}$, grains pod^{-1}, grain yield and haulm yield). The data collected were statistically analysed as using AGRES and SPSS software package (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Initial properties

The various physico-chemical properties of the initial soil were analysed and the data are presented in Table 2. In this field experiment, the surface soil samples were collected from the experimental field at Vellakulam village, Madurai district. The soil texture was sandy clay in nature with a bulk density of (1.17 Mg m^{-3}) and particle density of (2.34 Mg m^{-3}). The pH of the experimental field soil was moderately alkaline (8.50) and soluble salt was very low (0.55 dS m^{-1}). The soil was low in Alkaline KMnO4 - N (184 kg ha^{-1}), medium in Olsen's - P (14.5 kg ha^{-1}), high in NH_4OAc - K (550 kg ha^{-1}) with low in organic carbon content (4.54 g kg^{-1}).

Table 2. Basic properties of the experimental soil

Soil parameters	
Texture	Sandy clay
Particle density (Mg m^{-3})	2.34
Bulk density (Mg m^{-3})	1.17
Total porosity (%)	32.37
pH	8.50
EC (dSm^{-1})	0.55
Organic carbon (g kg^{-1})	4.54
Alkaline KMnO4 - N (kg ha^{-1})	184
Olsen P (kg ha^{-1})	14.5
Neutral N NH4OAC - K (kg ha^{-1})	550
DTPA extractable Zn (mg kg^{-1})	0.42
DTPA extractable Fe (mg kg^{-1})	1.6
DTPA extractable Cu (mg kg^{-1})	0.86
DTPA extractable Mn (mg kg^{-1})	9.54

Concerning available micronutrient status, the DTPA extractable Fe was low 1.6 mg kg^{-1}, Mn (9.54 mg kg^{-1}) and Cu (0.86 mg kg^{-1}) was sufficient in the experimental soil. The soil was deficient in Zn (0.42 mg kg^{-1}). The soil was categorized as "Fine clayey montmorillonite isohyperthermic *Typic Chromustert*" by USDA soil taxonomy.

Plant height (cm)

The application of vermicompost fortified zinc sulphate exhibited positive results on the plant height. Among the various treatments, soil application of $ZnSO_4$ @ 25 kg ha^{-1} incubated with 125 kg vermicompost shown a significant increase in plant height at 30 DAS (20.51 cm), 45 DAS (41.56 cm) and at harvest (64.00 cm). Whereas irrespective of the stages, absolute control recorded the lowest plant height at 30 DAS (11.36 cm), 45 DAS (23.58 cm) and at harvest (36.67 cm) (Table 3). It is also revealed that the plants with maximum plant height considerably showed increased grain yield. The vermicompost fortified zinc supply might have contributed to an increase in enzymatic activity and auxin metabolism of plants, resulting in a considerable increase in plant height. Todawat *et al*. (2018) reported that enhanced greengram productivity was due to the combined application of vermicompost @ 5.0 t ha^{-1} and zinc @ 4 kg ha^{-1} in the Entisols of Rajasthan. Kumar *et al*. (2017) showed that RDF + Vermicompost 5 kg ha^{-1} had considerably higher growth parameters in mustard on sandy loam soils, Kanpur. Ruheentaj *et al*. (2018) revealed that vermicompost @ 1.0 t ha^{-1} + 12.5 N: 25 P_2O_5: 0 K_2O kg ha^{-1} recorded the maximum plant height of moth bean in shallow black soils of Northern Dry Zone in Karnataka. The application of RDF + 0.2 t ha^{-1} vermicompost fortified 0.75 kg Zn ha^{-1} increased plant growth attributes of green gram in loamy sand soil at Sardarkrushinagar (Chaudhary *et al*., 2019), which is well corroborated with the present study.

Leaf area index (LAI)

A steady increase in leaf area index was observed from the vegetative to pod formation stage, then gradually decreased towards the maturity stage. LAI is an indicator of photosynthesis rate and translocation activities in plants. The data presented in Table 3 showed that vermicompost fortified zinc had a steady rise in LAI at 30 DAS (1.10), 45 DAS (3.15) and at harvest (3.11), which was followed by biochar fortified zinc significantly on par with TNAU MNM. Absolute control showed the lowest LAI among all treatments. Zinc fortified vermicompost had a favourable effect on the leaf area by increasing growth hormone activity, facilitating cell development and inducing cell expansion. Better N absorption resulted in maximum leaf surface area and the same trend of increased LAI was reported in maize under *Typic Ustropepts* (Augustine and Kalyanasundaram, 2021). Application of RDF with 2 t ha^{-1} vermicompost enhanced nutrient availability, which resulted in better plant growth and development of mungbean in clay loam soils of Madhya Pradesh (Prajapati *et al*., 2016).

Dry matter production (g $plant^{-1}$)

Dry matter production is a direct correlation between yield and the growth, development of various morphological components. Table 3 revealed that SA of $ZnSO_4$ @ 25 kg ha^{-1} incubated with 125 kg Vermicompost (1:5) at sowing delivered the higher dry matter production at 30 DAS (0.84 g $plant^{-1}$), 45 DAS (9.04 g $plant^{-1}$) and at harvest (16.33 g $plant^{-1}$) followed by T_6 and T_8 statistically on par with each other. Control (T1) had the lowest dry matter output per plant at 30 DAS (0.53 g $plant^{-1}$), at 45 DAS (6.68 g $plant^{-1}$) and at harvest (8.55 g $plant^{-1}$).

Organic sources fortified zinc increased the micronutrient availability due to the chelation effect. The relationship between the leaf area index and dry matter was substantial, implying that a higher amount of radiation associated with a higher LAI contributes to increased dry matter production and photosynthetic rate. The higher plant height and DMP under fortified zinc were attributable to better nutrient uptake, which was critical for crop growth and development. Dry matter accumulation was maximum in the application of vermicompost @ 1 t ha^{-1} + RDF suggested by Ruheentaj *et al*. (2018) in moth bean on shallow black soils in Northern Dry

Zone of Karnataka. In mungbean on clay loam, Madhya Pradesh, organic manure (2 t ha^{-1} vermicompost) supplemented with inorganic (RDF) resulted in the higher dry matter at harvest (Prajapati *et al*., 2016). The same trend of results were observed in vermicompost 5 t ha^{-1} along with $ZnSO_4$ 5 kg ha^{-1} (Sharma *et al*., 2017) in Indian mustard on clay loam, Rajasthan.

Yield and yield attributes

The organic fortified zinc showed a significant impact on the number of pods $plant^{-1}$, grains pod^{-1}, test weight, grain yield, and haulm yield (Table 4). Application of $ZnSO_4$ @ 25 kg ha^{-1} incubated with 125 kg vermicompost (1:5) at planting was found to be effective in increasing pods $plant^{-1}$ (28.46), grains pod^{-1} (13.5), test weight (3.48g) followed by biochar fortified zinc significantly on par with TNAU MNM. The lowest number of pods plant (14.34), seed pod^{-1} (6.75), and test weight (3.20g) were recorded in the control. Organically fortified zinc has considerably increased the number of pods $plant^{-1}$, seed pod^{-1} and test weight compare to $ZnSO_4$ alone. Biofortified zinc application resulted in higher chlorophyll content and photosynthetic activity. Further, zinc mediated growth-promoting hormone synthesis and metabolic activities helped better the growth and yield of green gram. Vermicompost fortified Zn supply of balanced nutrition for plant growth and yield of green gram. The conjoint, application of vermicompost and zinc increased seed $pods^{-1}$ (Armin *et al.,* 2016) in mungbean on silty clay loam of inceptisols. According to Kumar *et al*. (2014), combined application organic (vermicompost 5 t ha^{-1}) and inorganic (100 percent RDF) fertilizer enhanced the 1000 grain weight (12.90 %) in rice (CV. PRH-10) grown on sandy clay loam soils of Varanasi. Combination of 2 t ha^{-1} vermicompost and 75 kg ha^{-1} of P_2O_5 resulted in higher pods $plant^{-1}$, seeds pod^{-1}, and 1000 seed weight in mungbean at Islamabad (Arsalan *et al*., 2016). Chethankumar *et al*. (2020) observed maximum pods $plant^{-1}$ in chickpea under RDF + vermicompost @ 7.5 t ha^{-1} applied plot at Latur, Maharastra.

Data in table 4 showed that grain and haulm yield in the plots that supplemented with recommended NPK and vermicompost fortified $ZnSO_4$ at sowing recorded higher grain yield (950 kg ha^{-1}) and haulm yield (1520 kg ha^{-1}) followed by biochar fortified zinc on par with TNAU MNM. The beneficial effect of Zn on raising the activity of many plant enzymes involved in glucose, protein and pollen formation. Higher yields in the integrated nutrient treatment could be attributed to the increased availability of all nutrients. Vermicompost improved nutrient status due to prolonged nutrient availability of nutrients with enhanced mineralization of soil nutrients. Combined application of zinc @ 6 kg ha^{-1} and vermicompost @ 7.5 kg ha^{-1} increased the growth and yield of green

Table 3. Effect of Organically fortified Zinc on plant height, leaf area index (LAI), dry matter production of green gram (*Vigna radiata* (L). Wilczek) in *Typic chromustert*

Treatments	Plant height (cm)			Leaf Area Index (LAI)			Dry matter production (g $plant^{-1}$)		
	30 DAS	45 DAS	At Harvest	30 DAS	45 DAS	At Harvest	30 DAS	45 DAS	At Harvest
T_1-Absolute control	11.36	23.58	36.67	0.95	2.32	1.18	0.53	6.68	8.55
T_2 - RDF (25:50:25 kg ha^{-1} N:P_2O_5:K_2O)	13.12	25.94	40.98	0.98	2.49	1.52	0.60	7.10	9.75
T_3 - SA of $ZnSO_4$ @ 25 kg ha^{-1}	15.11	30.65	45.61	1.00	2.60	1.80	0.64	7.98	10.88
T_4 - SA of $ZnSO_4$ @ 25 kg ha^{-1} incubated with 250 kg FYM (1:10)	16.00	33.10	51.60	1.02	2.71	2.11	0.69	8.31	12.01
T_5 - SA of $ZnSO_4$ @ 25 kg ha^{-1} incubated with 125 kg Vermicompost (1:5)	20.51	41.56	64.00	1.10	3.15	3.11	0.84	9.04	16.33
T_6 - SA of $ZnSO_4$ @ 25 kg ha^{-1} incubated with 125 kg Biochar (1:5)	19.07	39.32	59.02	1.07	3.06	2.80	0.81	8.88	15.18
T_7 - SA of $ZnSO_4$ @ 25 kg ha^{-1} incubated with 250 kg Poultry manure (1:10)	17.34	36.41	54.27	1.04	2.90	2.40	0.72	8.57	13.13
T_8 - TNAU Micronutrient Mixture @ 5 kg ha^{-1} incubated with 50 kg FYM (1:10).	18.41	38.95	58.78	1.07	3.00	2.72	0.80	8.77	14.28
SEd	0.37	0.80	1.16	0.006	0.03	0.11	0.01	0.15	0.51
CD (p=0.05)	0.81	1.72	2.50	0.013	0.07	0.25	0.02	0.30	1.11

Table 4. Effect of Organically fortified Zinc on 100 seed weight, pods plants^{-1}, grains pod^{-1}, grain yield and haulm yield of green gram (*Vigna radiata* (L). Wilczek) in *Typic chromustert.*

Treatments	Test weight (g)	Pods plant^{-1}	Grains pod^{-1}	Grain yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
T_1 - Absolute control	3.20	14.34	6.75	710	1210
T_2 - RDF (25:50:25 kg ha^{-1} N: P_2O_5: K_2O)	3.28	16.54	7.84	735	1262
T_3 - SA of $ZnSO_4$ @ 25 kg ha^{-1}	3.31	18.75	8.92	756	1308
T_4 - SA of $ZnSO_4$ @ 25 kg ha^{-1} incubated with 250 kg FYM (1:10)	3.34	20.95	10.04	797	1351
T_5 - SA of $ZnSO_4$ @ 25 kg ha^{-1} incubated with 125 kg Vermicompost (1:5)	3.48	28.46	13.5	950	1520
T_6 - SA of $ZnSO_4$ @ 25 kg ha^{-1} incubated with 125 kg Biochar (1:5)	3.42	26.24	12.4	908	1470
T_7 - SA of $ZnSO_4$ @ 25 kg ha^{-1} incubated with 250 kg Poultry manure (1:10)	3.38	23.36	11.09	838	1400
T_8 - TNAU Micronutrient Mixture @ 5 kg ha^{-1} incubated with 50 kg FYM (1:10).	3.41	25.62	12.2	880	1455
SEd	0.08	0.97	0.46	18.68	19.22
CD(p=0.05)	0.01	2.09	0.99	40.07	41.23

gram under loamy sand soil in semi-arid regions of Rajasthan (Todawat *et al*., 2017). Masu *et al*. (2019) revealed that applying 75 % RDF along with 5 t ha^{-1} of vermicompost enhanced blackgram haulm yield on silty clay loam in Madhya Pradesh. Incorporation of 4 t ha^{-1} vermicompost and 5 kg ha^{-1} zinc increased seed yield of mustard by 48 percent over control (Meena *et al*., 2018) on *Typic Haplustepts*. Application of 25% N through vermicompost and 75 % RDF enhanced photosynthates translocation from source to sink and resulted maximum straw yield by 34% in rice on sandy loam above, alluvial plain, Varanasi (Gour *et al*., 2015). The findings of a similar trend (Puli *et al*., 2017) have been observed in rice at Bapatla, Andhra Pradesh.

Conclusion

Application of Zn in conjoint with organic sources significantly increased growth and yield parameters in green gram (*Vigna radiata*). The results concluded that soil application of $ZnSO_4$ @ 25 kg ha^{-1} fortified with 125 kg vermicompost (1:5) with recommended nitrogen, phosphorous and potassium fertilizer significantly (p=0.05) increased the growth and yield of green gram. The application of 20:50:25 kg ha^{-1} NPK and vermicompost fortified zinc is recommended for better crop growth and yield of green gram.

Conflict of interest

The authors declare that they have no conflict of interest.

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