International Journal of Environment and Climate Change

Volume 13, Issue 10, Page 4519-4525, 2023; Article no.IJECC.106997
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Effect of Vermicompost, Biofertilizers and in Organic Fertilizers on Nutrient Uptake and Physico-chemical Properties of Soil: A Case Study of Chickpea (*Cicer arietinum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2023/v13i103130

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/106997

Original Research Article

Received: 22/07/2023
Accepted: 26/09/2023
Published: 03/10/2023

ABSTRACT

A field trial was conducted during *Rabi* 2020-21 in randomized block design with three replications and seven treatments comprising individual and combined application of various organic and inorganic nutrient sources at Research Farm, MMU Sadopur (Ambala), Haryana. The experiment was intended to evaluate the effect of vermicompost, biofertilizers and inorganic fertilizers applied in chickpea on nutrient uptake and physico-chemical properties of soil pH (8.24). The highest organic

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carbon (0.58%), electrical conductivity (0.51 dS m^{-1}), particle density (2.50 g/cm^3) and porosity (48.47%) along with maximum available N (126.5 kg ha^{-1}), P (23.2 kg/ha) and K (98.33 kg/ha) were observed in the treatment of T_6 i.e., 3 t/ha Vermicompost + *Rhizobium* + PSB. Similarly, the nutrient content (N, P and K) was maximum in seed and stover of chickpea harvested from the plots receiving 3 t/ha Vermicompost + *Rhizobium* + PSB, which was statistically at par with T_7 i.e., 2.5 t/ha Vermicompost + *Rhizobium* + PSB. The highest net return was recorded in plots treated with 50% RDF (Recommended dose of fertilizer) + *Rhizobium* + PSB and 75% RDF + *Rhizobium* + PSB with a benefit cost ratio (B: C) of 3.2 and 3.1, respectively. However, the seed yield in integrated nutrient management was comparable to recommended dose of chemical fertilizers

Keywords: Chickpea; vermicompost; biofertilizer; inorganic fertilizers; rhizobium; phosphate solubilizing bacteria.

1. INTRODUCTION

Chickpea (*Cicer arietinum* L.), also known as Bengal gram, gram, *garbanzo* (Spanish), *Chana* (Hindi) and *Chanaka* (Sanskrit) is an important winter grain legume grown all over the world. It is an important source of protein for the vegetarians and is a good substitute of meat. Chickpea cultivation in India accounted for 85% of the world acreage and 69.75% of the chickpea production followed by Turkey (4.42%) and Russia (3.55%) [1]. Chickpea is cultivated on 9.85 mha of land with an annual production of 11.99 mt [1]. However, in Haryana, the crop is cultivated on a limited area of 44,000 ha with a production of 47,000 tonnes and productivity of 1068 kg/ha [2]. The crop requires annual rainfall of 600-1000 mm and average temperature of 20˚C. It contains 18-22% protein and 65-70% carbohydrate, 4-10% fat and sufficient quantity of other minerals like calcium, phosphorus, iron, and vitamins along with calorific value of 365 kcal/100 g. Besides, it is also used as livestock feed and cash crop and helps in improving the soil fertility by virtue of its capacity to fix atmospheric nitrogen [3].

Low productivity of chickpea in India is primarily due to its cultivation on marginal soil. Various factors such as phosphorus solubilizing bacteria, seed priming and *Rhizobium* inoculation are known to have significant effect on chickpea production and productivity. The higher chickpea productivity and grain yield can be achieved through proper crop management [4]. Although the use of inorganic fertilizers are necessary to fulfill the plant requirement for nitrogen, phosphorus, potassium and other micro-nutrients but their excessive use leads to reduction in soil fertility and quality of the produce. Therefore, it is necessary to balance this negative effect of inorganic fertilizers with the use of organic amendments and biofertilizers. Application of vermicompost has been considered as one of the best organic method to increase the soil fertility as it provides essential macro- and micro-nutrients beneficial for crop growth [5].

The application of vermicompost also exerts a positive effect on the physical and biological properties of the soil including increase in macropore space, soil pH, microbial population and soil enzyme activities. Biofertilizers are cost effective and eco-friendly source of plant nutrition. Biofertilizers such as *Rhizobium* culture and phosphorus solubilizing bacteria (PSB) help in enhancing the productivity and profitability of pulse crops by fixing atmospheric nitrogen and by solubilizing insoluble soil phosphates and discharging plant growth substances in the soil [6]. Therefore, present investigation was conducted to study the effect of vermicompost, biofertilizer and inorganic fertilizers on nutrient uptake, soil properties, seed and stover yield and economics of chickpea production.

2. MATERIALS AND METHODS

A field experiment was conducted during *Rabi* 2020-21 at the Research Field of Department of Agriculture, Maharishi Markandeshwar University, Sadopur, Ambala (Haryana) in triplicate sets of randomized block design (RBD) with seven treatments viz. T_1-Control, T_2-100% recommended dose of fertilizer (RDF), T_3- 75% RDF + *Rhizobium*+ phosphorus solubilizing bacteria (PSB), T_4-50% RDF + *Rhizobium* + PSB, T_5- 5 t/ha Vermicompost, T_6- 3 t/ha Vermicompost + *Rhizobium* + PSB and T_7- 2.5 t/ha Vermicompost + *Rhizobium* + PSB replicated thrice. Seeds of chickpea variety HC-5 were sown at 95 kg ha^{-1} with a row spacing of 30 cm in triplicated plots of 4×3m. The gross and net size of the plots was 4.0×3.0 m and 3.7×2.5 m respectively.

The experimental site is situated at 30˚42'39" N latitude and 76˚77'69" E longitude and at an altitude of 264 m above mean sea level. The climate of the experimental site is designated as sub-tropical and semi-arid with hot and dry summer (April-June), hot and humid monsoon period (July-September) and cold winter (December-February).

Seed and stover yield per plot were recorded and converted to kg/ha. Soil samples randomly collected from different sites of the field up to a depth of 0-15 cm were analyzed for the physico-chemical properties.

The data was subjected to analysis of variance and the treatments were compared at 5% level of significance (P= 0.05) following Statistical Software Package for Agricultural Research Workers (Sheoran *et al.,* 1998).

Economics (net and gross returns) of various treatments in chickpea cultivation was worked out on the basis of prevailing market price of various inputs and seed and stover yield of chickpea. The gross returns of the treatments were calculated based on sale price of chickpea in market during the period under study. The net return was worked out by subtracting the cost of cultivation from gross return and B: C was calculated by dividing net returns of the treatments by their cost of cultivation.

3. RESULTS AND DISCUSSION

3.1 Physico-Chemical Properties of Soil

The data presented in Table 1 revealed that the highest pH (8.24) and organic carbon (0.58%) of soil was observed with the treatment T_6: 3 t/ha vermicompost + *Rhizobium* + PSB and electrical conductivity (0.51dS m^{-1}) which were significantly better than 100% RDF and combinations of inorganic fertilizers with Rhizobium and PSB, followed by T_7: 2.5 t/ha Vermicompost + *Rhizobium* + PSB. In Ethopia, Chala and Obsa [7] found that the highest organic carbon contents 3.40% and 3.36% were found in plots treated with full doses of farm yard manure and compost, respectively. However, the lowest pH, electrical conductivity and organic carbon were recorded with untreated control plots. The maximum bulk density (1.37 g/cm^3) was recorded in the treatment T_1: Control while it was the lowest (1.26 g/cm^3) in treatment T_6: 3 t/ha Vermicompost + *Rhizobium* + PSB, T_7: 2.5 t/ha vermicompost + *Rhizobium* + PSB and T_5: 5 t/ha vermicompost, which were statistically on par with each other. On the other hand, maximum particle density (2.50 g/cm^3) and porosity (48.47%) were recorded with the treatment T_6: 3 t/ha Vermicompost + *Rhizobium* + PSB and the minimum particle density and porosity of 2.36 g/cm^3 and 45.08%, respectively were recorded in treatment T_1: Control (Table 2).

Yadav *et. al.* [8] indicated that available nitrogen, phosphorus, potassium were observed significantly maximum under the application of 2 t ha^{-1} vermicompost compared to other organic manure treatments while bulk density, particle density, pH, EC were non-significant due to organic manure treatment and liquid organic manure treatment.

Table 1. Effect of vermicompost, biofertilizers and inorganic fertilizers on physico-chemical properties of soil

Treatments	pH (1:2)	EC (dS m^{-1})	OC (%)	Bulk density (g/cm^3)	Particle density (g/cm^3)	Porosity (%)
T_1: Control	7.21	0.40	0.42	1.37	2.36	45.08
T_2: 100% RDF	7.30	0.42	0.46	1.34	2.41	45.17
T_3: 75% RDF + *Rhizobium*	7.45	0.45	0.54	1.31	2.43	45.22
T_4: 50% RDF + *Rhizobium* + PSB	7.63	0.43	0.51	1.30	2.39	46.12
T_5: 5 t/ha Vermicompost	7.92	0.46	0.49	1.29	2.44	44.32
T_6: 3 t/ha Vermicompost + *Rhizobium* + PSB	8.24	0.51	0.58	1.26	2.50	48.47
T_7: 2.5 t/ha Vermicompost + *Rhizobium* + PSB	8.11	0.48	0.55	1.27	2.47	47.60
S.E.m(±)	0.02	0.006	0.004	0.011	0.02	0.022
C.D. (P=0.05)	0.061	0.019	0.014	0.034	0.061	0.067
CV (%)	0.439	2.375	1.491	1.423	1.401	0.081

Table 2. Effect of vermicompost, biofertilizers and inorganic doses on soil available NPK content

Treatments	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
T1: Control	106.5	15.8	78.3
T2: 100% RDF	110.1	16.7	80.4
T3: 75% RDF + *Rhizobium*	114.7	18.4	85.2
T4: 50% RDF + *Rhizobium* + PSB	112.5	17.2	83.8
T5: 5 t/ha Vermicompost	120.1	19.4	88.3
T6: 3 t/ha Vermicompost + *Rhizobium* + PSB	126.5	23.2	98.3
T7: 2.5 t/ha Vermicompost + *Rhizobium* + PSB	123.2	21.6	94.3
S.E.m(±)	0.052	0.061	0.057
C.D. (P=0.05)	0.162	0.189	0.177
CV (%)	0.077	0.555	0.113

3.2 Available Nitrogen, Phosphorus and Potassium in Soil (kg ha^{-1})

The available N, P and K in the soil after harvest was significantly higher (126.5 kg/ha), (23.2 kg/ha) and (98.3 kg/ha) in treatment T_6: 3 t/ha Vermicompost + *Rhizobium* + PSB followed by T_7: 2.5 t/ha Vermicompost + *Rhizobium* + PSB while the control plots had significantly lower available N (106.5 kg/ha), P (15.8 kg/ha) and K (78.3 kg/ha). Among the various treatments, the treatments having biofertilizers resulted in higher nitrogen, phosphorus and potassium content after harvesting as the biofertilizers contain micro-organisms and are known to fix atmospheric nitrogen or solubilize insoluble phosphate or produce hormones, vitamins and other growth regulators required for plant growth. Balai *et al.* [9] found that increasing level of phosphorus application increased the available nitrogen, phosphorus and potassium content in soil after harvest of the crop. Likewise, the highest available phosphorus (23.2 kg/ha) and potassium (98.3 kg/ha) in the soil after harvest of chickpea crop was recorded in treatment T_6: 3 t/ha Vermicompost + *Rhizobium* + PSB which was statistically at par with treatment T_7: 2.5 t/ha Vermicompost + *Rhizobium* + PSB.

3.3 Nitrogen, Phosphorus and Potassium Content (%) in Stover and Seed

The data presented in Fig. 1, revealed that the maximum N, P and K content in stover (1.43, 0.37 and 1.53%) and seed (3.27, 0.88 and 0.91%) was found with the application of T_6: 3 t/ha Vermicompost + *Rhizobium* + PSB and T_7: 2.5 t/ha Vermicompost + *Rhizobium* + PSB while the N, P, K content in stover (1.27,0.17%, 1.37%) and seed (2.88,0.59%, 0.61%) was minimum in unfertilized plots. They also observed that N content and uptake in seed and straw increased significantly with increasing levels of phosphorus upto 60 kg ha^{-1} in straw increased significantly upto 40 kg P_2O_5 ha^{-1}. Balai *et al*. [9] reported that P content and uptake by grain and straw was significantly increased by applying increasing level of phosphorus upto 60 and 40 kg P_2O_5 ha^{-1}, respectively.

Kemal *et al.* [10] reported that in the first season, the maximum amount of nitrogen taken up by the grain (127.96 kg ha^{-1}) was recorded with application of 100% RDF (18 kg N ha^{-1} and 46 P_2O_5 kg ha^{-1}) followed by application of INM treatments, while the lowest value (50.22 kg ha^{-1}) was recorded from the unfertilized plot. The second season result indicated that application of chemical fertilizer and INM treatments were statistically at par and significantly improved grain N uptake compared to the unfertilized treatment. The two years mean result also indicated that application of chemical fertilizer and INM treatments significantly improved straw N uptake.

3.4 Seed and Stover Yield

The data presented in Table 3 revealed that the highest seed yield (18.89 q ha^{-1}), stover yield (23.47 q ha^{-1}) was recorded with application of T_6: 3 t/ha Vermicompost + *Rhizobium* + PSB which was statistically at par with T_4: 50% RDF + *Rhizobium* + PSB, T_5: 5 t/ha Vermicompost and T_7: 2.5 t/ha Vermicompost + *Rhizobium* + PSB (16.97 q ha^{-1}). The minimum seed and stover yield (12.37 and 17.89 q ha^{-1}) was observed in the control plots. Treatment T_6: 3 t/ha Vermicompost + *Rhizobium* + PSB gave the highest harvest index of 44.43% closely followed by T_7: 2.5 t/ha Vermicompost + *Rhizobium* + PSB and T_5: 5 t/ha Vermicompost. The highest biological yield was observed in T_6: 3 t/ha Vermicompost + *Rhizobium* + PSB (42.36 q ha^{-1}) which was statistically at par with T_7: 2.5 t/ha Vermicompost + *Rhizobium* + PSB (38.37 q ha^{-1}) and the lowest biological yield was observed in T_1: Control (30.26 q ha^{-1}) (Table 3).

3.5 Economics of Different Treatments

The data on economics of various treatments presented in Table 4 indicated that the cost of cultivation varied according to the application of different treatments. Among the various treatments, the cost of cultivation was the minimum 15657 ₹/ha in untreated control and maximum (35657 ₹/ha) in treatment T_5: 5 t/ha Vermicompost. Significantly higher gross returns were 98760 ₹/ha recorded with the application of T_6: 3 t/ha Vermicompost + *Rhizobium* + PSB and T_7: 2.5 t/ha Vermicompost + *Rhizobium* + PSB (91560 ₹/ha). Significantly higher net return of 68973 ₹/ha recorded with the application of T_6: 3 t/ha Vermicompost + *Rhizobium* + PSB followed

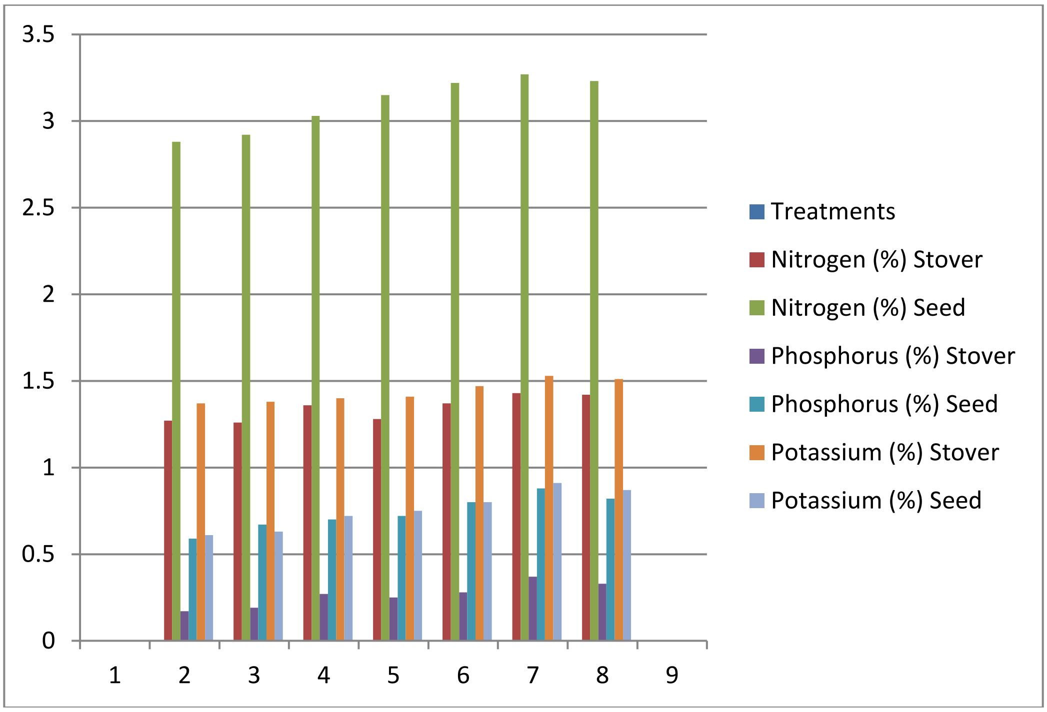

Fig. 1. Effects of vermicompost, biofertilizers and inorganic fertilizers on NPK content in stover and seed of chickpea

Table 3. Effect of vermicompost, biofertilizers and inorganic fertilizers on yield and harvest index of chickpea

Treatments	Seed yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)	Harvest index (%)
T_1: Control	12.37	17.89	30.26	40.87
T_2: 100% RDF	13.43	18.86	32.29	41.69
T_3: 75% RDF + *Rhizobium*	14.92	19.50	34.43	43.42
T_4: 50% RDF + *Rhizobium* + PSB	15.86	20.80	36.67	43.24
T_5: 5 t/ha Vermicompost	16.79	21.41	38.20	43.88
T_6: 3 t/ha Vermicompost + *Rhizobium* + PSB	18.89	23.47	42.36	44.43
T_7: 2.5 t/ha Vermicompost + *Rhizobium* + PSB	16.97	21.40	38.37	44.22
SEM(±)	1.19	1.20	1.96	1.97
C.D. (P=0.05)	3.71	3.76	6.12	3.48
CV (%)	13.24	10.20	9.44	7.92

Table 4. Effect of vermicompost, biofertilizers and inorganic fertilizers on economics of different treatments

Treatments	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C
T_1: Control	15657	56520	40863	2.6
T_2: 100% RDF	18468	74680	56212	3.0
T_3: 75% RDF + *Rhizobium* + PSB	19895	82520	62625	3.1
T_4: 50% RDF + *Rhizobium* + PSB	18349	78440	60091	3.2
T_5: 5 t/ha Vermicompost	35657	83600	47943	1.3
T_6: 3 t/ha Vermicompost + *Rhizobium* + PSB	29787	98760	68973	2.3
T_7: 2.5 t/ha Vermicompost + *Rhizobium* + PSB	27787	91560	63773	2.2

by T_7: 2.5 t/ha Vermicompost + *Rhizobium* + PSB (63773 ₹/ha). The minimum net return 40863 ₹/ha was recorded with the treatment T_1: Control. The highest B: C ratio of 3.2 and 3.1 was observed with the treatment T_4: 50% RDF + *Rhizobium* + PSB and T_3: 75% RDF + *Rhizobium*, respectively followed by 100% RDF (3.0). The treatments comprising of vermicompost + *Rhizobium* + PSB were found to be less economical as compared to T_3: 75% RDF + *Rhizobium* and T_4: 50% RDF + *Rhizobium* + PSB due to higher cost of vermicompost.

4. CONCLUSION

In present investigation, comparative analysis was intended to assess the efficacy of various components providing nutrients to chickpea crop. Seven treatments viz. T_1-Control, T_2-100% recommended dose of fertilizer (RDF), T_3- 75% RDF + *Rhizobium*+ phosphorus solubilizing bacteria (PSB), T_4-50% RDF + *Rhizobium* + PSB, T_5- 5 t/ha Vermicompost, T_6- 3 t/ha Vermicompost + *Rhizobium* + PSB and T_7- 2.5 t/ha Vermicompost + *Rhizobium* + PSB replicated thrice were compared for their effect on seed yield and its components, nutrient in grain and straw and soil properties.

Among seven nutrition treatments, combination of 3 t/ha Vermicompost + *Rhizobium* + PSB appeared best for better physico-chemical properties of soil, NPK content in stover and seed of chickpea, higher seed and stover yield and economics of chickpea.

Higher seed yield and nutrient uptake in seed and straw could be attributed to favorable effects of organic carbon provided though vermicompost, recommended dose of nitrogen supplemented by biological nitrogen fixation through rhizobium post-interaction and phosphorus solubilization and mobilization by phosphate solubilizing bacteria. Such synergetic effects among components of integrated nutrient management has been reported in some leguminous crops including chickpea [10,11].

The seed yield and nutrient contents in grain and straw were higher in T6 that indicated its worth for food for human beings and feed for livestock. Also, its economics was higher than the RDF, because of higher production and lower input cost. Also, the soil ecosystem is expected to be improved leading to better nutrient dynamics and higher nutrient use efficiency due to favourable impacts of organic adjuvants like vermicompost and PSP's, a view of above facts, it is concluded that integrated nutrient management including vermicompost, *rhizobium* should be followed for sustainable chickpea production and better soil environment [12,13,14,15,16,17].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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DOI: 10.1007/s42729-020-00313-y

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/106997