OPEN ACCESS
Global Journal of Research in Agriculture & Life Sciences
ISSN: 2583-4576 (Online)
Volume 05 | Issue 03 | May-June | 2025
Journal homepage: https://gjrpublication.com/gjrals/
Original Research Article

Enhancing Chickpea (*Cicer arietinum L.*) Productivity in Kersa Malima district of Ethiopia: The Role of Combined Bio-Organic Fertilization

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DOI: 10.5281/zenodo.15343648 **Submission Date: 25 March 2025 | Published Date: 05 May 2025**

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Abstract
In the 2019–20 and 2020–21 cropping seasons, this study sought to investigate the productivity responses of chickpea to the synergistic effects of an elite rhizobium inoculant (CP–17) and N-equivalency-based rates of vermicompost (0.38, 0.57, and 0.76 ton ha^{-1}) (TN = 2.37%, in wet weight bas). The farm settings were located in the Ethiopian districts of Kersa Malima district. Three replications of each treatment were included in the randomized complete block design. The SAS statistical platform version 9.3 was used to do an analysis of variance on the gathered data. At a 5% probability level, means were compared using the Least Significance Difference (LSD). Farm input and output prices were taken into account for calculating the economic benefit of the intervention. The marginal rate of return (% MRR) for each treatment was calculated, with values ≥100 being considered lucrative in absolute terms. The average result of the two years of data analysis indicated that all parameters among the treatments in Kersa Malima district differed significantly ($p < 0.05$). In the Kersa Malima district, the treatments that yielded the highest average GYs (3523 kg ha^{-1}) and (3283 kg ha^{-1}) were (CP-17 + 0.76 ton ha^{-1} VC) and (0.76 ton ha^{-1} VC). However, the treatment in Kersa Malima area (CP-17) and (CP-17 + 0.76 ton ha^{-1} VC) had higher marginal rates of return (13797 %) and (9958%), according to the conclusions of the partial budget study. To find the best alternative bio-organic fertilizers for chickpea production in Ethiopia's pelic Vertisol zones, these treatments are believed to be excellent candidates for additional testing in farmers' fields across different agro-ecologies.

Keywords: *Economic Yield, Grain Yield, CP-17, Organic Input, Vermicompost.*

INTRODUCTION
Ethiopia produces more than 400 thousand metric tons of chickpeas annually, making it the sixth-largest producer in the world [1]. However, the amount produced falls well short of the country's proven capacity [2]. Ethiopia's poor potential output of chickpeas can be attributed to numerous known and unknown biophysical factors [3]. A possible explanation for Ethiopia's low chickpea output is the presence or absence of sufficient native rhizobia in the rhizosphere that are productive. [4,5]. Soil fertility deterioration is a physical phenomenon that is the other reason for Ethiopia's low chickpea output [6].

Organic farming, a sustainable agricultural method that reduces the use of potentially dangerous agro-chemicals, can mitigate the major difficulties impacting chickpea productivity described above [5, 7].

One type of sustainable agriculture technique suitable for organic farming is the use of organic inputs. One type of organic input that has practically raised the productivity of field crops like chickpeas while improving the fertility, resilience, and health of the soil is compost, such as vermicompost. Vermicompost is a peat-like organic fertilizer made by bacteria and earthworms that has high nutritional values, aeration, porosity, and water-holding capacity. Vermicompost is known to be a successful plant growth stimulator in addition to managing organic waste [8]. Microbial activity in vermicompost increases the availability of micronutrients such as nitrogen (N), phosphorus (P), potassium (K), and others [9].

According to Rehman *et al.* [10], a chemical examination of vermicompost shows that its levels of N, K, and Ca are higher (5 times, 7 times, and 1.5 times) than those of topsoil at a depth of 15 cm, where plants are found. Another form of organic input that practically increased pulse crops like chickpea is Biofertilizer, Biofertilizer is selective live micro-organism like bacteria, fungi and algae.

They offer an affordable, sustainable, and renewable supply of nutrients. Bio-fertilizers increase the crops' availability of nutrients through biological processes. According to Mulugeta and Abere [5], Anteneh and Abere [11], they are essential for enhancing soil fertility and ensuring long-term sustainability. There is a dearth of knowledge regarding the combined effects of two or more organic inputs that boosted the yield of pulses like chickpea in Ethiopia, despite the fact that several studies have been conducted on the individual productivity enhancement benefits of various organic inputs.

This study aims to determine how the combined impacts of bio-organic inputs improved chickpea's productivity in the Kersa Malima area in central Ethiopia's highlands.

MATERIALS AND METHODS

Field experimental sites

During the main cropping seasons of 2019/20 to 2020/21, the field experiment was carried out in the district of Kersa Malima. For the previous five years, these experimental sites had no history of rhizobial inoculation. Kersa Malima is situated between 1500 and 2900 meters above sea level, with latitude of 8° 29' 59.99" N and a longitude of 38° 34' 59.99" E. According to KMWBoA [12], Kersa Malima is characterized by an average temperature between 10 and 19 °C and an average rainfall between 974 and 1319 mm. At the experiment site wheat, faba bean and teff are the usual crops grown.

Elite rhizobial inoculant and vermicompost source

Vermicompost with a total nitrogen concentration of TN = 2.37% in wet weight basis and an elite chickpea rhizobial inoculant (CP-17) were provided by the Holeta Agricultural Research Center's Biological and Organic Soil Fertility Management Research Program. The Holeta Agricultural Research Center is located at 9.0581° N, 38.5049° E, 29 kilometers from the capital city of Ethiopia, and 2400 meters above sea level.

Treatments and Experimental Design

Five treatments; (CP-17), (100% N from vermicompost; 0.76 ton ha^{-1}), (CP -17+50% N from vermicompost; 0.38 ton ha^{-1}), (CP -17+ 75% N from vermicompost; 0.57 ton ha^{-1}), and (CP-17+ 100% N from vermicompost; 0.76 ton ha^{-1}) were evaluated under pelic vertisols of Kersa Malima district against 18 kg N ha^{-1} (positive control or standard) and no CP-17 and no vermicompost (untreated or negative control). The experiments were laid out in a randomized complete block design (RCBD) with three replications on a plot size of 4 m x 3 m.

The distance between blocks and plots was increased to 1 and 0.5 meters, respectively, to lessen treatment cross-contamination. Additionally, un-inoculated treatments were planted before infected treatments. Plants and rows were separated by 10 and 30 centimeters, respectively. Each experimental plot received a basal treatment of 20 kg P ha^{-1} (TSP) at the time of planting.

The positive control received 18 kg N ha^{-1} from urea at planting. Conversely, the negative control received no external nitrogen supply. Planting density for the Arerti cultivar was 140 kg/ha. The experimental fields and units were managed according to the recommended agronomic practices for chickpea.

Application of vermicompost to the soil

Well-prepared vermicompost was weighed in N equivalent base (0.76 ton ha^{-1}), (0.57 ton ha^{-1}), and (0.38 ton ha^{-1}) to represent (100%), (75%), and (50%) N contain of the vermicompost, in that order.

Each weighed containing the vermicompost was stuck down in a polyethylene plastic bag and a representative percentage was written on it with a permanent marker. Integrated portions of the vermicompost in each treatment were added uniformly on each row of the plots prior sowing the inoculated seeds.

Seeds dressing

The application rate of carrier-based rhizobial inoculants was 500 g ha^{-1}. After weighing and moistening the seeds with sticker solution (table sugar solution), about 0.17 kg of chickpea seed was meticulously dressed with the appropriate inoculant until every seed in the plastic bags had an even coating. Under the shade, the entire process of applying seed dressing was completed. Following their full dressing and air drying, the seeds were planted and covered with soil right away [13, 14].

Soil sample analysis

Just after the trial field setup, a composite of soil samples were taken at random locations inside the trial plots at a depth of 0 to 30 cm. The soil samples were crushed to fit through a 2 mm filter after being air-dried. The soil pH was determined using a ratio of 1:2.5 soils to water. Soil organic carbon was measured using the wet digestion method [15]. The wet-digestion method was used to ascertain the soil's total nitrogen concentration [16]. The Olsen extraction procedure was used to determine the amount of accessible phosphorus.

Data collected and yield determination

Data on soil, agronomy, and economy were gathered and examined in order to identify the best treatments in Ethiopia's Kersa Malima district. Soil pH, accessible phosphorus, organic carbon, total nitrogen, above ground biomass yield (AGBY), grain yield (GY), shoot dry biomass yield (SDBY), marginal net benefit (MNB), and marginal rate of return (MRR) were the soil, agronomic, and economic factors. Version 9.3 of the SAS statistical platform was used to perform an analysis of variance on the gathered data [17]. At a 5% probability level, means were compared using the Least Significance Difference (LSD). Farm input and output prices were taken into account for calculating the economic benefit of the intervention. The marginal rate of return (% MRR) for each treatment was calculated, with values ≥100 being considered lucrative in absolute terms [18].

RESULTS AND DISCUSSION

Soil Analysis

The soil's chemical properties were found similar among the experimental sites at Kersa Malima district (Table 1). The soil mean pH of the trial locations was 7.9. Therefore, trial sites were grouped in the ratings of moderately alkaline condition [19]. The mean of organic carbon and available phosphorus of the trial sites were 1.14 % and 9.6 ppm, respectively. The mean organic carbon and available phosphorus values of the trial locations were found in low ratings [19]. Moreover, the mean total nitrogen contents of the study sites were 0.07% which found in low ratings [19].

Table 1. Major soil physicochemical properties of pelic Vertisols of Kersa Malima district

Parameter	Mean	Range	Test Methods
pH	7.9	6.5-7.11	1:2.5 H_2O
Total N (%)	0.07	0.07-0.1	Modified Kjeldhal
Available P (ppm)	9.6	8.8-12.1	Olsen
OC (%)	1.14	0.78-1.9	Walkley and Black

The 2019–2021 Kersa Malima district chickpea yields' reaction to inoculation and vermicompost

Table 2 shows that there was substantial ($p < 0.05$) difference among the treatments on all parameters based on the combined analysis of the two years of data and years effect. Though, treatments (CP-17 + 0.76 ton ha^{-1} VC), (CP-17 + 0.57ton ha^{-1} VC), (0.76 ton ha^{-1} VC) and (CP-17) had not shown significant statistical differences in mean AGBY, treatment (CP-17+ 0.76 ton ha^{-1} VC) bared numerically the highest mean AGBY (4280kg ha^{-1}). The aforementioned treatments demonstrated mean AGBY augmentation of 37% and 15% over the negative and positive controls, respectively.

However, there were no statistically significant differences between the mean GYs of treatments CP-17+ 0.76 ton ha^{-1} VC and 0.76 ton ha^{-1} VC; these two treatments had the highest mean GYs (3523 kg ha^{-1}) and (3283 kg ha^{-1}), respectively, compared to the other treatments that displayed the list mean GYs. The GYs increased by 43% and 38%, and 38% and 34%, respectively, over the negative and positive treatments, when treated with CP-17+ 0.76 ton ha^{-1} VC and 0.76 ton ha^{-1} VC.

In GYs, the treatments (CP-17 + 0.57 ton ha^{-1} VC) and (CP-17+ 0.38 ton ha^{-1} VC) came in third and fourth place, respectively. Other than treatments (CP-17+ 0.38 ton ha^{-1} VC), negative, and positive controls, the remaining treatments with the greatest mean SDBYs showed no statistically significant differences among themselves. The treatments with the greatest mean SDBYs were CP-17 + 0.76 ton ha^{-1} VC, CP-17, (0.76 ton ha^{-1} VC), and CP-17 + 0.57 ton ha^{-1} VC, with respective mean values of 3605 kg ha^{-1}, 3394 kg ha^{-1}, 3191 kg ha^{-1}, and 3180 kg ha^{-1}.

The best options for chickpea-growing on pelic Vertisols areas of Ethiopia in terms of grain output are those treatments that rated first and second in mean GYs, according to the two-year statistical analysis. The current study's results demonstrated that chickpea yields increased significantly with an increase in vermicompost treatment across all metrics, with 0.76 tons per hectare being the highest figure recorded (Table 2).

Table 2. Yield responses of chickpea in 2019-2021 growing seasons

Treatment	AGBY (kg/ha^{-1})	GY (kg/ha^{-1})	SDBM (kg/ha^{-1})
No inoculation	2694c	2021e	2054d
Recommended N	3624b	2169de	2666c
CP-17	3975ab	2458de	3191ab
0.76 ton ha-1 VC	4069ab	3283ab	3394ab
CP-17+ 0.38 ton ha-1 VC	3636b	2798cd	3018bcb
CP-17+ 0.57 ton ha-1 VC	3893ab	2960bc	3180ab
CP-17 + 0.76 ton ha-1 VC	4280a	3523a	3605a
LSD (P<0.05)	613	510	434
Year			
Kersa Malima (2019/20)	2913b	1665b	3509a
Kersa Malima (2020/21)	4564a	3781a	2522b
LSD (P<0.05)	328	273	232
CV (%)	14	16	12
Mean	3739	2723	3016

AGBY=Aboveground biomass yield, GY=Grain Yield, SDBY= Shoot dry biomass yield after harvest

This outcome is consistent with research by Anteneh and Abere [11], Özge [20], which found that adding vermicompost and rhizobial inoculant significantly increased faba bean growth and grain output. The study's findings (Tables 2) also showed that all inoculant-vermicompost combined treatments showed noticeably greater chickpea yield values than the uninoculated control.

These results support those of Özge [20], Gopinath *et al.* [21] and Pashaki *et al.* [22], who found that in comparison to the untreated control, the addition of biofertilizer and vermicompost to bell pepper, french bean, garden pea, and faba beans increased their fruit yield (t ha^{-1}).

Increased concentrations of easily absorbed macro and micronutrients and soil microbiota (which includes organisms that fix nitrogen and phosphorus), as well as derivatives of vermicompost, are used to achieve this Rehman *et al.* [10], Adhikary [23] and Lim *et al.* [24]. Additionally, at Kersa Malima, the mean AGBY (4564kg ha^{-1}) and GY (3781 kg ha^{-1}) were statistically higher in the second year than in the first year (Table 3). This discrepancy might be explained by the fact that the second year's rainfall distribution was better than the first year's during the chickpea pod-setting stage. This conclusion is consistent with the findings of Asrat *et al.* [6], Anteneh and Abere [11] who found that differences in annual rainfall cause differences in mean total biomass and grain production between seasons in faba beans.

Cost-benefit analysis

The partial budget analysis results (Tables 3) showed that treatment (0.76 ton ha^{-1} VC) produced the maximum net benefits (ETB 160593 ha^{-1}) at Kersa Malima district. The total variable cost (TVC) is the total of all the expenses that a farmer may incur, such as labor, vermicompost, rhizobial inoculant CP-17, field pricing of seed, etc. A sachet of rhizobial inoculant CP-17 (125g) cost 40 ETB in the field.

Four sachets (500 g ha^{-1}) of inoculant are the recommended national rate for chickpea seed dressing. In the Kersa Malima district, the average field price for a kilogram of vermicompost was 9 ETB. The dominance study revealed that all treatments were dominated, with the exception of treatments (CP-17) and (CP-17 + 0.76 ton ha-1 VC). Thus, those non-dominated treatments mentioned above are viable from an economic standpoint. The dominated treatments were excluded from further economic analysis because no beneficiary will choose an option that provides lower net benefits over one with higher net benefits and lower total variable costs.

Table 3. Partial budget analysis response of chickpea at Kersa Malima district in 2019-2021.

Treatment	AGY (kg ha^{-1})	AdjY (kg ha^{-1})	Gross benefit (Birr ha^{-1})	TVC (Birr ha^{-1})	Net benefit (Birr ha^{-1})	DO (Birr ha^{-1})	MC (Birr ha^{-1})	MNB (Birr ha^{-1})	MRR (%)
No inoculation	2022	1719	103122	0	103122				
CP-17	2458	2089	125358	160	125198	ND	160	22076	13797
CP-17 + 0.76 ton ha-1 VC	3523	2994	179673	700	178973	ND	540	53775	9958
Recommended N	2169	1844	110619	1674	108945	do			
CP-17+ 0.38 ton ha-1 VC	2798	2378	142698	3580	139118	do			
CP-17+ 0.57 ton ha-1 VC	2960	2516	150960	5290	145670	do			
0.76 ton ha-1 VC	3283	2790	167433	6840	160593	do			

AGY= average grain yield, AdjY= adjusted yield by 15%, TVC= total variable cost, MC= marginal cost, MNB = marginal net benefit, MRR= marginal rate of return, DO = Dominance ND = none dominated = dominated VC= vermicompost.

According to (Table 3) above the highest marginal rate of returns (13797%) and (9958%) were obtained from chickpea production in Kersa Malima district only with treatment (CP-17) and (CP + 0.76 ton ha^{-1} of VC). This means, the producer can receive an additional return of ETB (13797), and (9958), for every ETB 1.00 invested in chickpea production using treatments mentioned above in Kersa Malima district. The experiment's minimum acceptable rate of return was 100%, therefore the treatments listed above were profitable choices in Kersa Malima district. Therefore, in terms of economic yield at above mentioned district treatments (CP-17) and (CP + 0.76 ton ha^{-1} of VC) emerged as the most promising treatments.

CONCLUSION AND RECOMMENDATIONS

During the two consecutive main cropping seasons, field trials were conducted at Kersa Malima district to examine how a rhizobium inoculant CP-17 and vermicompost work together to augment chickpea outputs in pelicVertisols condition. The result showed that the treatments (CP-17 + 0.67 ton ha^{-1} VC) and (0.76 ton ha^{-1} VC) ranked first and second in terms of mean GY. Nevertheless, in terms of economic yield, (CP-17) and (CP-17 + 0.67 ton ha^{-1} VC) emerged as the most promising treatments.

Therefore, these treatments described above are considered highly promising candidates for further validation in farmers' fields at different agro-ecologies to identify them as the best alternative bio-organic fertilizers for chickpea production in pelic Vertisols areas of Ethiopia, owing to their reasonable superiority in mean grain and economic yields. With the exception of phosphorus, the analytical results of the soil were found to be sub-optimal for the production of chickpea. This indicates that the production of chickpea on such soil condition using the aforementioned treatments in conjunction with 46 kg P_2O_5 is reasonably promising in terms of grain and economic yields. Consequently, it is recommended that these treatments be verified under replicated conditions in a wider range of the aforementioned soil and weather conditions of Ethiopia.

ACKNOWLEDGMENTS

Sincere gratitude is extended by the authors to the Ethiopian Institute of Agricultural Research (EIAR) for providing financing for this project. The authors would also like to express their gratitude to all of the field and technical assistants of the Holeta Agricultural Research Center's Biological and Organic soil fertility management program for their outstanding assistance in overseeing the experimental fields, collecting data, and managing the microbiological laboratory tasks.

Funding

The author(s) did not get any funding for the publishing of this research, despite the Ethiopian Institute of Agricultural Research supporting this activity.

Conflict of Interest

The writers have no conflicts of interest.

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CITATION

Mulugeta M., & Gezahign T. (2025). Enhancing Chickpea (Cicer arietinum L.) Productivity in Kersa Malima district of Ethiopia: The Role of Combined Bio-Organic Fertilization. In Global Journal of Research in Agriculture & Life Sciences (Vol. 5, Number 3, pp. 8–13). https://doi.org/10.5281/zenodo.15343648