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Original Research Article

Impact of Natural Fertilizers on Chickpea (*Cicer arietinum L.*) Productivity: A Field Study in Dendi District, Central highlands of Ethiopia

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Abstract
This research aimed to evaluate the impact of natural fertilizers on chickpea productivity within agricultural systems in the Dendi district of Ethiopia, spanning the 2019–2020 and 2021–2022 growing seasons. Three replications and a randomized complete block design were used to arrange the treatments. 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 get prices of inputs and products were taken into account in order to calculate the economic advantage of the intervention. The marginal rate of return (% MRR) was calculated for each treatment, with values ≥100 being considered lucrative in absolute terms. The average result of the data analysis throughout the three years indicated that all parameters in the Dendi district varied significantly ($p \leq 0.05$) amongst the treatments. In the Dendi district, CP-17 + 0.76 ton ha^{-1} VC, CP-17 + 0.57 ton ha^{-1} VC, and CP-17 + 0.38 ton ha^{-1} VC were the treatments that yielded the highest average GYs (3366 kg ha^{-1}), (3209 kg ha^{-1}) and (3106 kg ha^{-1}),respectively. The economical analysis's findings, however, indicated that the treatment at Dendi district (CP-17), (CP-17 + 0.38 ton ha^{-1} of VC), (CP-17 + 0.76 ton ha^{-1} of VC), and (CP-17 + 0.57 ton ha^{-1} VC) had higher marginal rates of returns (12554%), (12554%), (452%), (368%), and (207%), respectively. To find the finest natural fertilizer substitutes for chickpea production in Ethiopia's Vertisol zones, these treatments are considered to be excellent candidates for additional testing in farmers' fields across different agro-ecologies.

Keywords: *CP-17, Dendi district, Economic yield, Grain yield, Vermicompost.*

Introduction
The chickpea (*Cicer arietinum*) is one of the oldest pulse crops cultivated in many countries in the world, including Ethiopia. Chickpeas have multiple uses, such as being rich in nutritional value, bringing money, and having atmospheric nitrogen-fixing potential (Corp et al., 2004). As a legume crop, chickpeas contain nodules that convert N2 into NH3, which is nitrogen required for the crop's productive and healthy growth. Rhizobia and the host legume generate the plants' root nodules through a symbiotic relationship (Abere and Getahun, 2003; Corp et al., 2004).

According to recent research, depending on the cultivar, bacterial strain, and environmental conditions, the symbiotic interaction between Rhizobium leguminosarum bv. ciceri and chickpeas can take 140–176 kg N/ha from the air. In comparison to other known legumes, this is a significant amount of nitrogen. This increases the soil's fertility for upcoming crops in addition to providing chickpeas with the majority of the nitrogen they need for optimum growth (Abere and Getahun, 2003; Beyene, 2015; Eshete and Fikre, 2014). Apart from fixing nitrogen, the plant residue of chickpea contributes a momentous amount of humus to the soil, which can maintain and recover soil fertility. These drastically cut the cost of fertilizers, which are now unavailable and environment unfriendly (Eshete and Fikre, 2014; Mulugeta and Abere, 2022).

Many known and unknown biophysical factors are responsible for Ethiopia's low potential chickpea output. The absence or scarcity of sufficient and efficient native rhizobia in the rhizosphere is a biotic problem that should be brought to light (Gopinath, 2011; Jones, 2003). Therefore, meanness that can replenish native rhizobia or adequately inoculate the soil with the appropriate rhizobia should be present if native rhizobia are missing. Another effective way to boost chickpea yield while preserving the soil's fertility and health is to add organic amendments like vermicompost, which is rich in important macro and micro-nutrients, plant growth boosters, and plant protection from pests and diseases. The aforementioned bio-organic fertilizers are well-known for providing the crop with what it needs for productivity while also drastically lowering the requirement for synthetic nitrogen fertilizers by lowering manufacture expenses and eliminating the harmful environmental contamination that synthetic fertilizers create (Abere, 2003; Adhikary, 2012).

The combination of several natural fertilizers that boosts chickpea yield is not well understood, despite the fact that many researchers in Ethiopia has carried out a number of practical studies on the subject. Therefore, the aim of this study is to investigate the effects of various natural fertilizers on chickpea productivity in the Dendi district.

Materials and Methods

Field experimental sites

Field trials took place in Ethiopia's Dendi area throughout the core farming time of year of 2019 and 2022. For the preceding four years, neither vermicompost nor any other inoculant was applied to these trial locations. The testing locations were situated at an altitude of 2200 meters above the head of the water level in the 6Z UTM Zone, between 611213.30 Easting and 100200744.30 Northing. Vertisol, which has the ability to swell and contract based on moisture content, predominates at the experimental site. At the experiment site, barley, wheat, and teff are the usual crops grown. The trial sites' characteristic lowest and highest temperatures as well as their precipitation levels are displayed in Fig. 1.

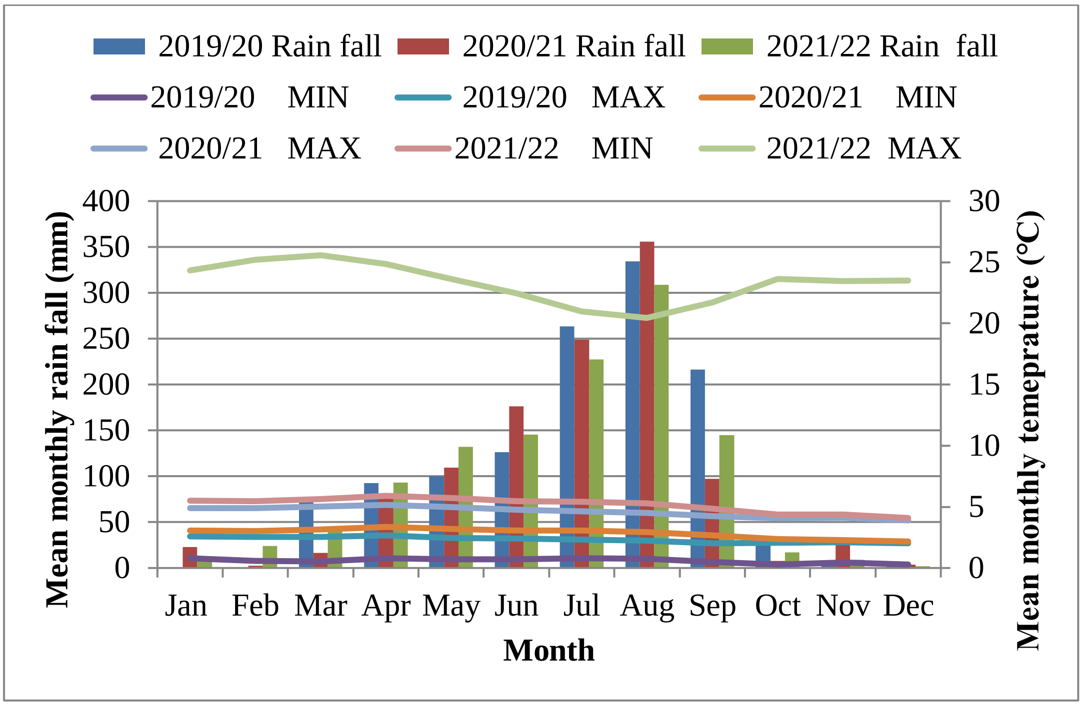

Figure 1: Mean monthly rainfall, and mean monthly maximum and minimum temperatures patterns of the experimental sites (Source: Holetta Agricultural Research Center weather station).

Elite rhizobial inoculant and vermicompost source

The Holeta Agricultural Research Center supplied vermicompost with a total nitrogen content of 2.37% in wet weight basis as well as an elite faba bean rhizobial inoculant (CP-17). The Holeta Agricultural Research Center is located 2400 meters above sea level, 29 kilometers from Ethiopia's capital, and at 9.0581° N, 38.5049° E.

Treatments and Experimental Design

Under the Vertisols of Dendi district, five treatments were assessed against 18 kg N ha^{-1} (positive control or standard), no CP-17 and no vermicompost (untreated or negative control), and 100% N from vermicompost (CP-17), 0.76 ton ha-1, 0.38 ton ha^{-1}, CP-17+50% N from vermicompost, and 0.57 ton ha^{-1} without CP-17. The trials were set up on a 4 m × 3 m plot with three replications using a randomized complete block design (RCBD).

The distance between blocks and plots was increased to 0.5 and 1 meters, respectively, to lessen treatment cross-contamination. Additionally, un-coated treatments were planted before CP-17 coated treatments. Rows and plants were spaced 10 and 30 centimeters apart, respectively. At planting, 20 kg P ha^{-1} (Triple Super Phosphate) was applied as a base treatment to each experimental plot. At planting, urea provided 18 kg N ha^{-1} to the positive control. On the other hand, the negative control did not get any outside nitrogen. 140 kg ha^{-1} was the planting density for the Arerti cultivar. The units and experimental fields were run in accordance with the suggested agronomic methods for chickpeas.

Application of vermicompost to the soil

Weighing well-prepared vermicompost in N equivalent base (0.76 ton ha^{-1}), (0.57 ton ha^{-1}), and (0.38 ton ha^{-1}) revealed that the vermicompost's N content was 100%, 75%, and 50%, respectively. A permanent marker was used to write a realistic proportion on each weighted container of vermicompost that was placed within a polyethylene plastic bag. Before the inoculated seeds were sown, integrated parts of the vermicompost from each treatment were evenly placed to each plot row.

Seeds dressing

The application rate of carrier-based rhizobial inoculants was 500 g ha^{-1}. After weighing and moistening the seeds with sticker solution such as 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. The seeds were immediately planted and covered with soil after being fully dressed and allowed to air dry.

Soil sample analysis

A composite of soil samples were collected at random points inside the trial plots at a depth of 0 to 30 cm shortly after the trial field was set up. The soil samples were allowed to air dry before being crushed to fit through a 2 mm screen. A 1:2.5 soil to water ratio was used to calculate the pH of the soil. The wet digestion method was used to measure the amount of organic carbon in the soil (Walkley and Black, 1934). The total nitrogen content of the soil was determined using the wet-digestion method (Kjeldahl, 1883). The amount of available phosphorus was measured using the Olsen extraction method (Olsen, 1954).

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 Dendi district. Soil pH, accessible phosphorus, organic carbon, total nitrogen, 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 (SAS Institute, 2002). Least Significance Difference (LSD) was used to compare means at a 5% probability level. Prices for farm inputs and production were included for determining the intervention's economic benefit. Each treatment's marginal rate of return (% MRR) was determined; in absolute terms, numbers ≥100 were regarded as profitable (CIMMYT 1988).

Results and discussion

Soil Analysis

The overall nitrogen content of the soil at the experimental sites is low, as shown in Table 1. The test locations' average soil pH was 6.8, which indicates that the soil is ideal for growing a variety of field crops because it is somewhat acidic (Tekalign et al., 1991). The average amount of accessible phosphorus (P) was likewise higher than the essential values (15.3 ppm), according to the results of the soil test.

For chickpea cultivation, which requires 14 kg ha-1 P_2O_5 in 1.5 tons of grain production, the phosphorus rating will be in the medium ranges, which is less than ideal (Tekalign et al., 1991; Jones, J.B. 2003). The soil samples utilized for testing had an average organic carbon content of 1.13%, which is regarded as low and gives the soil an average level of stability and structural condition. This is probably caused by a lack of organic matter input, erosion, heavy land usage, and quick decomposition in the local environment.

Table 1: Major soil physicochemical properties of Vertisols of Dendi district

Parameter	Mean	Range	Test Methods
pH	6.8	6.5-7.11	1:2.5 H2O
Total N (%)	0.8	0.07-0.1	Modified Kjeldhal
Available P (ppm)	15.3	8.8-20.1	Olsen
OC (%)	1.13	0.78-1.9	Walkley and Black

Inoculation and vermicompost response to chickpea yields at Dendi district in 2019-2022

Based on the combined analysis of the two years of data and years effect, Table 2 demonstrates that there was a significant ($p < 0.05$) difference between the treatments on all parameters. Although there was no statistically significant differences in AGBY among treatments (CP-17+ 0.76 ton ha^{-1} VC) and (0.76 ton ha^{-1} VC), the treatment with the greatest mean AGBY (2512 kg ha^{-1}) was CP-17+ 0.76 ton ha^{-1} VC. In comparison to the negative and positive controls, the aforementioned therapies showed an AGBY augmentation of 27% and 11%, respectively.

Even though no statistical differences were observed among treatments (CP-17+ 0.76 ton ha^{-1} VC), (CP-17+ 0.57 ton ha^{-1} VC) and (CP-17+ 0.38 ton ha^{-1} VC) in mean GYs (3366 kg ha^{-1}), (3209 kg ha^{-1}) and (3106 kg ha^{-1}), respectively they scored the highest GY that ranked one up to three. The above mentioned treatments showed 30% and 29%, 27% and 25%, and 25% and 23% mean GY increment over the negative and positive controls, respectively. The negative control was used to score the list SDBY (4030 kg ha^{-1}). The lack of biological nitrogen fixation is probably the cause of this, which lowers the amount of nitrogen available for plant growth. In comparison to treated varieties, the crop might have had poorer root formation, less nutrient uptake, and less than ideal biomass buildup in the absence of rhizobial inoculation.

The mean SDBY did not differ statistically significantly across the other treatments. Conversely, CP-17, 0.76 ton ha^{-1} VC, and (CP-17+ 0.57 ton ha^{-1} VC) were the treatments with the highest mean SDBYs (4748 kg ha^{-1}, 4718 kg ha^{-1}, and 4589 kg ha^{-1}). The best options for chickpea-growing Vertisols areas of Ethiopia in terms of grain output are those treatments that rated first to second in GYs, according to the three-year statistical analysis. Chickpea AGBY, GY, and SDBY increased significantly as vermicompost treatment increased, according to the current study's results; the maximum values were recorded at 0.75 tons per hectare (Table 2).

Table 2: Yield responses of chickpea in 2019-2022 growing seasons

Treatment	AGBY (kg ha^{-1})	GY (kg ha^{-1})	SDBY (kg ha^{-1})
No inoculation	1840d	2339c	4030b
Recommended N	2224bc	2404cd	4235ab
CP-17	2201bc	2736bcd	4589a
0.76 ton ha-1 VC	2358ab	2764bc	4748a
CP-17+ 0.38 ton ha-1 VC	2243bc	3106ab	4385ab
CP-17+ 0.57 ton ha-1 VC	2099c	3209a	4718a
CP-17 + 0.76 ton ha-1 VC	2512a	3366a	4363ab
LSD (P<0.05)	226	404	519
Year			
2019/20	1101c	1754c	5217b
2020/21	1756b	4262a	2184c
2021/22	3777a	2523b	5914a
LSD (P<0.05)	148	278	340
CV (%)	11	16	12
Mean	2211	2846	4438

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

This outcome is consistent with research by Mulugeta and Abere (2025), Mulugeta and Abere (2024), Özge Uçar (2021) and Anteneh and Abere (2017), 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 Mulugeta and Abere (2025), Mulugeta and Abere (2024), Gopinath et al. (2011), Pashaki et al. (2016), and Özge Uçar (2021) who found that in comparison to the untreated control, faba ban, Bell pepper, French bean and garden pea all produced more fruit when biofertilizer and vermicompost were added (t ha^{-1}). This is accomplished by increased concentrations of readily absorbed macro and micronutrients, soil microbiota (including nitrogen-fixing and phosphorus-fixing organisms), and vermicompost derivatives (Adhikary, 2012; Lim et al., 2015; Rehman et al., 2023). At Dendi, the second year's mean GY (4004 kg ha^{-1}) was also statistically higher than the first and third years' (Table 2). This disparity could be explained by the fact that during the chickpea pod-setting stage, the rainfall distribution in the second year was superior to that in the first and third years.

This conclusion is in line with research by Mulugeta and Abere (2025), Mulugeta and Abere (2024), Anteneh and Abere (2017) and Asrat (2023), who discovered that variations in yearly rainfall lead to variations in the mean total biomass and grain output of faba beans across seasons.

Cost-benefit analysis

According to the results of the partial budget analysis (Table 3), the Dendi district's treatment (CP-17 + 0.76 ton ha^{-1} VC) generated the highest net benefits (ETB 164666 ha^{-1}). The sum of all potential costs for a farmer, including labor, vermicompost, CP-17 (a rhizobial inoculant), seed prices in the field, etc., is known as the total variable cost (TVC). In the field, a 125g sachet of the rhizobial inoculant CP-17 cost 40 ETB. The recommended national rate for chickpea seed dressing is four sachets (500 g ha^{-1}). The average field price for one kilogram of vermicompost in the Dendi district was 9 ETB. Except for treatments 0.76 ton ha^{-1} VC and Recommended N, the dominance research showed that none of the treatments were dominated. Therefore, from an economic perspective, those non-dominated treatments are feasible. Since no beneficiary will select an option with lower net benefits over one with higher net benefits and lower total variable costs, the dominant treatments were not included in additional economic analysis.

Table 3. Partial budget analysis response of chickpea at Dendi district in 2019-2022.

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	2339	1988	119289	0	119289				
CP-17	2736	2326	139536	160	139376	ND	160	20087	12554
Recommended N	2404	2043	122604	1674	120930	D			
CP-17+ 0.38 ton ha-1 VC	3106	2640	158406	3580	154826	ND	3420	15450	452
CP-17+ 0.57 ton ha-1 VC	3209	2728	163659	5290	158369	ND	1710	3543	207
0.76 ton ha-1 VC	2764	2349	140964	6840	134124	D			
CP-17 + 0.76 ton ha-1 VC	3366	2861	171666	7000	164666	ND	1710	6297	368

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.

The chickpea production in Dendi district solely with treatment (CP-17), (CP-17 + 0.38 ton ha^{-1} of VC), (CP-17 + 0.76 ton ha^{-1} of VC), and (CP-17 + 0.57 ton ha^{-1} VC) yielded the best marginal rate of returns (12554%), (452%), (368%), and (207%), respectively, as shown in Table 3 above. This implies that for every ETB 1.00 invested in chickpea production in the Dendi district utilizing the aforementioned treatments, the producer can obtain an additional return of ETB (126), (4.52), (3.68), and (2.07), respectively. The aforementioned treatments were profitable options in Dendi district because the experiment's minimum allowable rate of return was 100%.

Conclusion and Recommendations

To find out how the combination of natural fertilizers might enhance chickpea yields in Vertisol conditions, field studies were carried out at Dendi district over the course of three consecutive main cropping seasons. In terms of mean GY, the treatments CP-17+ 0.76 ton ha^{-1} VC, CP-17 + 0.57 ton ha^{-1} VC, and CP-17+ 0.38 ton ha^{-1} VC were rated first, second, and third, respectively, according to the data. However, (CP-17), (CP-17 + 0.38 ton ha^{-1} of VC), (CP-17 + 0.76 ton ha^{-1} of VC) and (CP-17 + 0.57 ton ha^{-1} VC) were the most promising treatments in terms of economic yield.

Due to their notable advantages in both mean grain yield and economic returns, the aforementioned treatments are considered highly promising for further validation in farmers' fields across diverse agro-ecological zones. This additional testing aims to identify them as the most viable natural fertilizer alternatives for chickpea cultivation in the Vertisols regions of Ethiopia. The soil's analytical data were deemed suboptimal for chickpea production, with the exception of phosphate. This suggests that adopting the previously described treatments in combination with 46 kg P_2O_5 to produce chickpeas on such soil conditions is fairly promising in terms of grain and financial yields. Therefore, it is advised that these treatments be confirmed across a larger range of Ethiopia's previously specified soil and meteorological parameters under duplicated settings.

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