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The Collaborative Role of Non-Synthetic Fertilizers on Production of Faba Bean (*Vicia faba L.*) in Ethiopia's Central Highlands, Ejere District

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Abstract: This study sought to determine how non-synthetic fertilizers collaborated to produce faba bean in the 2019–20 and 2021–2022 cropping seasons in agricultural settings in the Ethiopian district of Ejere. The treatments were laid out in a randomized complete block design with three replications. The collected data were subjected to analysis of variance by SAS statistical platform version 9.3. Means were compared with the Least Significance Difference (LSD) at a 5% probability level. To compute the economic advantage of the intervention, farm get prices of inputs and outputs were considered and marginal rate of return (% MRR) was work out for each treatment, and values ≥100 was set as profitable in absolute terms. The mean outcome of the two years' worth of data analysis showed that there was substantial ($p \leq 0.05$) difference in all parameters among the treatments at Ejere. At Ejere, the treatments (FB-17 + 0.76 ton ha-1 VC), (FB-17+ 0.57 ton ha-1 VC), (0.76 ton ha-1 VC) and (FB-17+ 0.38 ton ha-1 VC) yielded the highest mean GYs (3582kg ha-1), (3535kg ha-1), (3430 kg ha-1) and (3234 kg ha-1), respectively. However, the results of the partial budget analysis showed that the treatments (FB-17) and (FB-17 + 0.57 ton ha-1 VC) had the greater marginal rates of return 7218% and 1148%, respectively. These treatments are thought to be very good candidates for more testing in farmers' fields across various aggro-ecologies in order to determine which ones are the best substitute non-synthetic fertilizers for faba bean production in Ethiopia's Nitisol zones.

Keywords: FB-17, N-Equivalence, Nitisol, Partial Budget Analysis, Vermicompost.

Research Paper

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INTRODUCTION

One of the most widely farmed highland pulse crops, faba beans (*Vicia faba L.*) are mostly grown in Ethiopia's colder highlands [7]. The main uses of faba beans are as food and feed for humans and animals, respectively, due to their high protein, mineral, vitamin, and fiber content [8].

Faba beans- rhizobia symbiotic association adds an enormous amount of reduced nitrogen to the soil ecosystem [20]. Ethiopia's national average grain yield (2.2 t/ha) is 51% less than the average grain yield (3.7 t/ha) of other major faba bean-producing nations [11]. This low productivity is caused by a variety of biotic and abiotic problems, including weeds, pathogens, and insufficient rhizobium in the soil, as well as soil acidity and low nutrient availability [16]. Faba beans growing highlands of Ethiopia are characterized by high rainfall, poor soil fertility, and acidified soil. In such poor ecosystems, the application of high levels of chemical fertilizers is becoming a customary practice to subsidize nitrogen and phosphorus insufficiency, which are inaccessible, unaffordable, have low use efficiency, and are environmentally unfriendly [5-15]. Thus, there has been growing attention to cost-effective, locally available, and eco-friendly sustainable agricultural practices such as biological and organic fertilizer technology alternatives that practically improve soil fertility, health, and crop productivity including faba bean [15, 16].

One of the alternative technologies that significantly contribute to reducing the need for chemical N fertilizers, cutting production costs, and removing the unfavorable environmental pollution caused by chemical fertilizers is biological fertilizer sources, primarily rhizobia inoculants.[2] It is predicted that nodulated legumes, such as pulses and oilseed legumes, fix nitrogen and add 21.45 Tg N to worldwide agricultural systems each year [2-9]. Other alternative fertilizer technologies that have gained attention in sustainable agricultural production include organic fertilizer sources like vermicompost; the casting of earthworms, which has low C: N ratio, high porosity, aeration, drainage, water holding capacity, microbial activity, and rich in major macronutrients (N 2-3%, K 1.85-2.25%, and P 1.55-2.25%), micronutrients, plant growth hormones, enzymes, and plant protection from pests and diseases.

The yield enhancement effect of rhizobial inoculants on faba beans is the focus of numerous practical works conducted in Ethiopia; however, little or no information regarding the collaborative role of non-synthetic fertilizers on faba beans yield enhancement impact is available. Thus, the purpose of this activity is to observe the collaborative role of none-synthetic fertilizers on the production of faba bean in Ethiopia's central highlands, namely in Ejere district.

MATERIALS AND METHODS

Field Experimental Sites

During the main cropping seasons of 2019/20 to 2021/22, the field experiment was carried out in the district of Ejre. For the previous five years, these experimental sites had no history of rhizobial inoculation. Ejere is situated at an altitude of 2400 meter above sea level, with an latitude ranges 8° 51' 16" N to 9°15’43” and a longitude ranges 38° 15' 2" E to 38° 28' 45" E 40 km west of Addis Ababa. The experimental sites were dominated by Nitisols, which are categorized under, moderately acidic to acidic characteristics (Table 1). The commonly grown crops in the experimental sites are wheat, barley, faba bean, field pea, and teff [10]. The average minimum and maximum temperatures and rainfall of the experimental sites recorded during the implementation of the trial are indicated in Fig. 1.

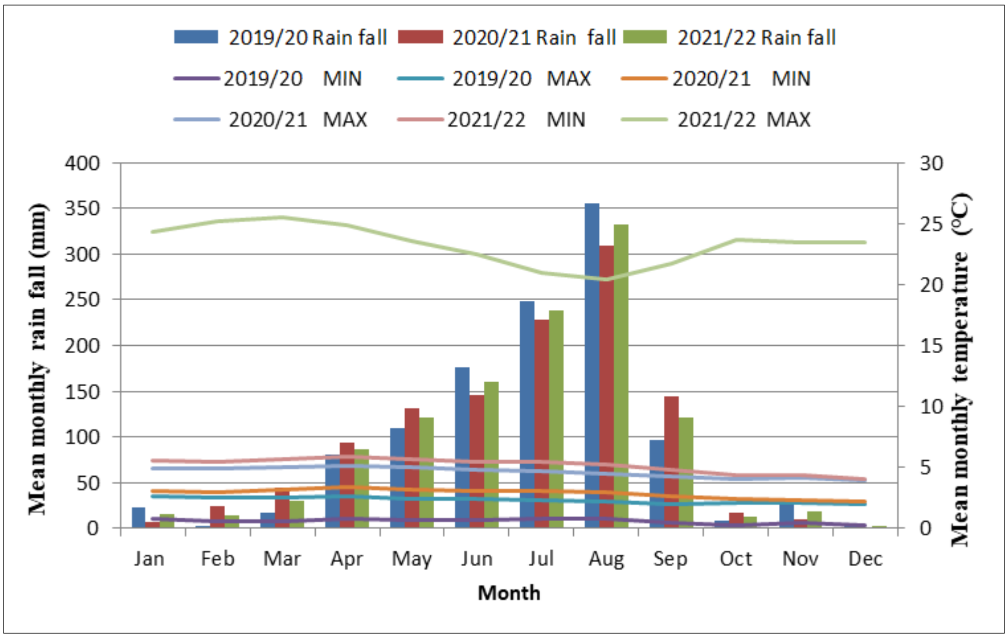

Figure 1: Mean monthly rainfall, and mean monthly maximum and minimum temperatures patterns of the experimental sites (Source: Holetta Agricultural Research Center weather station)

Elite Rhizobial Inoculant and Vermicompost Source

The Holeta Agricultural Research Center's Biological and Organic Soil Fertility Management Research Program provided an elite faba bean rhizobial inoculant (FB-1017) and vermicompost (which had a total nitrogen content of TN = 2.37% in wet weight basis). Holeta Agricultural Research Center is situated 29 kilometers from Ethiopia's capital city at 9.0581° N, 38.5049° E, at an elevation of 2400 meters above sea level.

Treatments and Experimental Design

Five treatments; (FB-17), (100% N from vermicompost; 0.76 ton ha-1), (FB-17+50% N from vermicompost; 0.38 ton ha-1), (FB-17+ 75% N from vermicompost; 0.57 ton ha-1), and (FB-17+ 100% N from vermicompost; 0.76 ton ha-1) were evaluated under Nitisol conditions of Ejere districts against 18 kg N ha-1(positive control or standard) and no FB-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. To reduce cross-contamination of treatments, the space between plots and blocks was enlarged to 0.5 and 1m, respectively, and un-inoculated treatments were planted before inoculated treatments. The space between plants and rows was 10 and 40 cm, respectively. All the experimental plots received a basal application of 20 kg P ha-1(TSP) at the time of planting. The positive control received 18 kg N ha-1 from urea at the time of planting. However, the negative control did not receive any form of external nitrogen source. The planting material was the Tumsa variety planted at 200 kg ha-1. The experimental fields and experimental units were managed as per the recommended agronomic practices for faba beans.

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 swing the inoculated seeds.

Seeds Dressing

Carrier-based rhizobial inoculants were applied at a rate of 1000 g ha-1. About 0.2 kg of faba bean seed was weighed, moistened with sticker solution; table sugar solution, and dressed carefully with the respective inoculant until all the seeds in plastic bags were uniformly coated.

The whole seed dressing procedure was carried out under the shade. The fully-dressed and air-dried seeds were planted and immediately covered with soil [15, 16].

Soil Sample Analysis

A combination of soil samples were composed from random spots of the trial plots at a depth of 0-30 cm just during trial field arrangement. The soil samples were air-dried and ground to pass through a 2 mm sieve. Soil pH was measured in 1:2.5 soils to water ratio. The wet digestion method was used to determine soil organic carbon [23]. Total nitrogen content of the soil was determined by the wet-digestion procedure [13]. And available phosphorus was determined by the Bray-II extraction method.

Data Collected and Yield Determination

Soil, agronomic and economic data were collected and analyzed to determine the top-performing treatments in the Ejere district of Ethiopia. The soil, agronomic and economic parameters were soil pH, available phosphorus, organic carbon, total nitrogen, above-ground biomass yield (AGBY), grain yield (GY), Haulm yield (HY), marginal net benefit (MNB), and marginal rate of return (MRR). The collected data were subjected to analysis of variance by SAS statistical platform version 9.3 [21]. Means were compared with the Least Significance Difference (LSD) at a 5% probability level. To compute the economic advantage of the intervention, farm get prices of inputs and outputs were considered and marginal rate of return (% MRR) was work out for each treatment, and values ≥100 was set as profitable in absolute terms [6].

RESULTS AND DISCUSSION

Soil Test Result

The soil's chemical properties were found similar among the experimental sites at Ejere (Table 1). The soil mean pH of the trial sites was 4.9. Therefore, trial sites were grouped in the ratings of acidic soil conditions [22]. The organic carbon and available phosphorus of the trial sites were 1.3 % and 10.0 ppm, respectively. The organic carbon and available phosphorus values in each site were found in low and moderate ratings, respectively [22]. Moreover, the mean total nitrogen contents of the study sites were found in moderate ranges [22].

Table 1: Major chemical properties of the experimental sites before planting

Parameter	Ejere(Mean)	Range	Test Method
pH	4.9	4.8-5.2	1:2.5 H_2O
Total N (%)	0.2	0.12-0.24	Modified Kjeldhal
Available P (ppm)	10.0	6.8-13	Bray II
OC (%)	1.3	1.24-1.5	Walkley and Black (1934)

Inoculation and Vermicompost Response to Faba Bean Yields at Ejere Hawase in 2019-2022

All metrics showed substantial ($p < 0.05$) variance among the treatments, according to the combined analysis of the two years' worth of data (Table 2). Years had a statistically significant impact on every indicator ($p<0.05$). There was no statistically significant variance among the treatments (FB-17+ 0.76 ton ha-1 VC), (FB-17+ 0.57 ton ha-1 VC), and (FB-17+ 0.38 ton ha-1 VC) that had the greatest mean AGBY (2661 kgha-1), (2504 kgha-1), and (2496 kgha-1). The above mentioned treatments showed (34% and 20%), (30.4% and 15.5%), and (30.2% and 15.2%) AGBY increment over the negative and positive controls, correspondingly.

The treatments with the highest mean GYs (3582 kg ha-1, 3535 kg ha-1, 3430 kg ha-1, and 3234 kg ha-1) exhibited no statistically significant variance in GYs. These treatments were (FB-17+ 0.76 ton ha-1 VC), (FB-17 + 0.57 ton ha-1 VC), (0.76 ton ha-1 VC), and (FB-17 + 0.38 ton ha-1 VC). The above declared treatments showed (36% and 32%), (35% and 31%), (33% and 29%), and (29% and 26%) grain yield increment over the negative and positive controls, respectively.

The treatments with the greatest mean HYs (4374 kg ha-1, 4259 kg ha-1, 94057 kg ha-1, and 4030 kg ha-1) were FB-17+ 0.76 ton ha-1 VC, FB-17 + 0.57 ton ha-1 VC, 0.76 ton ha-1 VC, and FB-17 + 0.38 ton ha-

1 VC. The statistical analysis revealed no significant variance in HYs among these treatments. These treatments mentioned above showed (37% and 27%), (35% and 25%), (32% and 21%), and (31% and 20%) HYs increment over the negative and positive controls, respectively. The three-year statistical analysis (Table 3) indicated that the treatments with the highest scores across all criteria were FB-17 + 0.76 ton ha-1 VC and FB-17 + 0.57 ton ha-1 VC. In terms of the previously specified factors, these treatments are the best options for Ethiopia's Nitisol faba bean growing locations.

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

Treatment	AGBY (kg/ha)	GY (kg/ha)	HY at harvest (kg/ha)
No inoculation	1743c	2283c	2759c
Recommended N+	2116b	2426c	3205c
FB-17	1924bc	2834b	3823b
0.76 ton ha-1 VC	2020bc	3430a	4057ab
FB-17+ 0.38 ton ha-1 VC	2496a	3234a	4030ab
FB-17+ 0.57 ton ha-1 VC	2504a	3535a	4259ab
FB-17+ 0.76 ton ha-1 VC	2661a	3582a	4374a
LSD (P<0.05)	308	385	487
Year			
Welmera (2019/20)	527c	3332a	1703b
Welmera (2020/21)	2086b	2797b	4958a
Welmera (2021/22)	4014a	3010b	4699a
LSD (P<0.05)	202	253	319
CV (%)	15	13	13
Mean	2209	3046	3729

AGBY= above ground biomass yield at maximum maturity, GY= grain yield, HY= Haulms yield, VC= vermicompost.

The current study's results indicated a significant increase in faba bean AGBY, GY, and HY as vermicompost application increased; the maximum values were observed at 0.75 tons per hectare (Table 3). This result is in line with studies by [3-7], which discovered that faba bean growth and grain output were greatly enhanced by the addition of vermicompost and rhizobial inoculant.

The study's results (Tables 3) also revealed that, in contrast to the un-inoculated control, all inoculant-vermicompost combined treatments demonstrated notably higher faba bean yield values. These findings corroborate those of [12-18], who observed that the addition of biofertilizer and vermicompost to bell pepper, french bean, and garden pea, and faba beans increased their fruit yield (t ha–1) statistically when compared to the unaltered control. 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 [1-19]. Furthermore, the first years mean GY (3332 kg ha-1) in Welmera was statistically larger than the second and third (Table 3). The fact that the first year's rainfall distribution was superior to the second and third years' during the faba bean pod-setting stage may help to explain this disparity.

The results of [3, 4], which discovered that variations in yearly rainfall lead to variations in mean total biomass and grain output between seasons in faba beans, are in line with this conclusion.

Partial Budget Analysis

The partial budget analysis results (Tables 4) showed that treatment (FB-17 + 0.76 ton ha-1 VC) produced the maximum net benefits (ETB 145075 ha-1) at Ejere district. The total variable cost (TVC) is the total of all the expenses that a farmer may incur, such as labor, vermicompost, rhizobial inoculant FB-17, field pricing of seed, etc. A sachet of rhizobial inoculant FB-17 (125g) cost 40 ETB in the field. Eight sachets (1000 g ha-1) of inoculant are the recommended national rate for faba bean seed dressing. In the Ejere district, the average field price for a kilogram of vermicompost was 9 ETB. The dominance study revealed that all treatments were none dominated, with the exception of treatments 0.76 ton ha-1 VC and Recommended N+. Thus, those non-dominated treatments 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 faba bean to the mutual beneficial effects of a Rhizobium FB-17 inoculant and vermicompost at Ejere district in 2019-2022

Treatment	AGY (kg ha-1)	Adj GY (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 (%)
Negative control	2283	1941	97027	0	97027				
FB-17	2834	2409	120445	320	120125	ND	320	23097	7218
Recommended N+	2426	2062	103105	1674	101431	D			
FB-17 + 0.38 ton ha-1 VC	3234	2749	137445	3740	133705	ND	3420	13580	397
FB-17 + 0.57 ton ha-1 VC	3535	3005	150237	5450	144787	ND	3776	43356	1148
0.76 ton ha-1 of VC	3430	2915	145775	6840	138935	D			
FB-17 + 0.76 ton ha-1 VC	3582	3045	152235	7160	145075	ND	1710	287	17

AGY= average grain yield, AdjGY= adjusted grain 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 4) above the highest marginal rate of returns 7218% and 1148% were obtained from faba bean production in Ejere only with treatments FB-17 and FB-17 + 0.57 ton ha-1 of VC and This means, the producer can receive an additional return of ETB 72 and 12, for every ETB 1.00 invested in faba bean production using treatments mentioned above on Ejere district.

The experiment's minimum acceptable rate of return was 100%, therefore the treatments listed above were profitable choices in Ejere district. Therefore, in terms of economic yield at above mentioned district treatments FB-17 and FB-17 + 0.57 ton ha-1 of VC emerged as the most promising treatments.

CONCLUSION AND RECOMMENDATIONS

During the three consecutive main cropping seasons, field trials were conducted at Ejere district to examine how a rhizobium inoculant FB-17 and vermicompost work together to augment faba bean outputs in Nitisol condition. The results showed that the treatments (FB-17+ 0.76 ton ha-1 VC), (FB-17 + 0.57 ton ha-1 VC) and (0.76 ton ha-1 VC) ranked first to third in terms of mean GY. Nevertheless, in terms of economic yield, (FB-17) and (FB-17+ 0.57 ton ha-1 VC) emerged as the most promising treatments. Therefore, these treatments described above are considered as highly promising candidates for further validation in farmers' fields at different agro-ecologies to identify them as best alternative non-synthetic fertilizers for faba bean production on Nitisol 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 faba beans. This indicates that the production of faba beans 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.

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