Ethiop. J. Agric. Sci. 27(2) 17-29 (2017)

Vermicompost Application as Affected by *Rhizobium* Inoculation on Nodulation and Yield of Faba Bean (*Vicia Faba* L.)

Anteneh Argaw[1] and Abere Mnalku[2]

[1]*School of Natural Resources Management and Environmental Sciences, College of Agriculture and Environmental Sciences, Haramaya University, Dire Dawa, Ethiopia*

[2]*Holleta Agricultural Research Center, Ethiopia Institute of Agricultural Research, Holleta, Ethiopia, E-mail: antenehargaw@gmail.com; anteneh.argaw@haramaya.edu.et*

አህፅሮት

የቨርሚኮምፖስትና የራይዞቢየም ህያው ማዳበሪያ በቅንጅት በባቄላ ሰብል ላይ መጨመር ከኖዱዩል፣ ከምርታማነት እና ከምርታማነት ጋር ተያያዥ የሆኑ ባህርያት ላይ ያላቸውን ተፅዕኖ ለማወቅ የሚያስችል የምርምር ስራ በምስራቅ ኢትዮጵያ፣ ሃረማያ ወረዳ ላይ ተሰርቷል፡፡ በጥናቱም በመጀመሪያ ከአምስት (5) የቨርሚኮምፖስት መጠኖች ማለትም 0፣2፣4፣6 እና 8 ቶን በሄክታር እና ከሁለት (2) የራይዞቢየም ደረጃዎች ማለትም 125 ግራም የባቄላ ራይዞቢየም ህያው ማዳበሪያ በሄክታር እና ባዶ ግራም ራይዞቢየም ህያው ማዳበሪያ በሄክታር በብዜታዊ መንገድ አስር (10) የተለያዩ እከማዎች ተዘጋጁ፡፡ አነዚህ እከማዎች መሬት ላይ በሶስት ተመሳሳይ ኩታ- ገጠም ረድፎች የተቀመጡ ሲሆን በያንዳንዱ ረድፍ ሁሉም የእከማ ዘዴዎች በፍጹም ዘፈቀዳዊ አኳኋን እንዲቀመጡ ተደርጓል፡፡ የመለዋወጥ ትንተናው እንደሚያመለክተውም የራይዞቢየም ህያው ማዳበሪያን መጨመር፣ የቨርሚኮምፖስት መጨመር፣ የሰብል ዘመን፣ እና የእርስ በርስ ተፅዕኖ መደራረግ በአመርቂ ሁኔታ (ኢጋጣሚነቱ ከ5 በመቶ በታች የሆነ) ሁሉንም የተለዩ የባቄላ ባህርያት ላይ ተፅዕኖ ማሳደር ችለዋል፡፡ በእነዚህ ዓመታት ውስጥም ከፍተኛ የሆነ የነፍስ-ወከፍ የኖድዩል ቁጥር (298) እና የኖድዩል ክብደት (0.7598) በግራም ከ4 ቶን የቨርሚኮምፖስት መጠን ላይ ተመዝግቧል፡፡ በሌላ በኩል 125 ግራም በሄክታር ራይዞቢየም ህያው ማዳበሪያ መጨመር ካልተጨመረበት ጋር ሲነፃፀር የአንድን እግር ባቄላ የኖድዩል ቁጥር እና የኖድዩል ክበደት በግራም በቅደም ተከተል በስድስት (6) እና አስራ አንድ (11) በመቶ ማሳደጉ ታይቷል፡፡ የቨርሚኮምፖስት እና የራይዞቢየም ህያው ማዳበሪያ መጠን በመጨመረ ቁጥር በቀሪዎቹ የተለዩ የባቄላ ባህርያትም የሚያስደንቅ ጭማሪ ታይቶባቸዋል፡፡ ራይዞቢየም ህያው ማዳበሪያ ሳይጨመርም ቢሆን፣ የዓመታት አማካይ የእህል ምርት ከቨርሚኮምፖስት መጠን ጭማሪ ጋራ ዕድገት ማሳየቱ ተመዝግቧል፡፡ ከዚህ አንፃር ከፍተኛው የእህል ምርት (4822.1 ኪ.ግ. በሄክ.) በ 8 ቶን የቨርሚኮምፖስት መጠን ላይ መመዝገብ ችሏል፡፡ ጥቅል የፎስፈረስ ክምችት በሚታይበት ጊዜ የቨርሚኮምፖስት መጠን ከባዶ ወደ 8 ቶን በሄክ. ሲጨምር ፎስፈረስም በተመሰሳይ ከ0.12894 ወደ 0.1711 በመቶ ዕድገት አሳይቷል፡፡ ይሁን እንጅ የራይዞቢየም ህያው ማዳበሪያ እና ቨርሚኮምፖስት በጥምረት መጨመር አማካይ ጥቅል የዕፅዋት የናይትሮጅን ይዘትን አመርቂ በሆነ ደረጃ ተፅዕኖ መፍጠር አልቻለም፡፡ በመሆኑም ራይዞቢየም ህያው ማዳበሪያ እና ስምንት (8) ቶን በሄክ. ቨርሚኮምፖስትን አጣምሮ መጠቀም በሃረማያ አካባቢ የባቄላ ምርታማነትን እንደሚጨምር ተረጋግጧል፡፡

Abstract

The effect of vermicompost on the effectiveness of Rhizobium inoculation on nodulation, yield and yield traits of fava bean at Haramaya, eastern Ethiopia, was investigated. Ten treatments were made by afactorial combination of five levels of vermicompost (0, 2, 4, 6 and 8 ton ha^{-1}) and two levels of Rhizobium inoculation (inoculated anduninoculated. The treatments were laid out in arandomized complete block design with three replications. Analysis of variance revealed that Rhizobium inoculation, vermicompost application, cropping season and their interactions significantly (P <0.05) affected all investigated traits of faba bean. Over years, the highest mean nodule number (NN) (298.00) and nodule dry weight (NDW) (0.7598 g) were recorded at 4 ton ha^{-1}. Rhizobiuminoculation increased the mean NN and NDW by 6 and 11%over uninoculated, respectively. The remaining investigated traits remarkably increased with increasing levels of vermicompost application and Rhizobium inoculation. Regardless of inoculation, the mean grain yield over years was increased with increasing vermicompost application rates. The highestmean grain yield (4822.1 kg ha^{-1}) was found at 8 ton ha^{-1} vermicompost application. Total mean P accumulation increased from 0.12894 to 0.17110% when the vermicompost rates were increased from unfertilized at 8 ton ha^{-1}. However, inoculation and vermicompost application did not affect significantly (P >0.5) mean total plant N concentration. Hence, integrated application of Rhizobiumand8 ton ha^{-1}vermicompost is needed to boost the productivity of faba bean in the study site.

Introduction

Vermicomposts are the product of the aerobicbio degradation of organic materials byintegrated actions of various microorganisms and earthworms. Vermicompostis amajorsourceof plant nutrients to reduce chemical fertilizer input thereby minimize thecost of crop production (Adhikary, 2012; Lazcano *et al*., 2013).The effect of vermicompost in improving plant growth can be broadly classified into four categories. Vermicompost contain large amounts of an inorganic and organic form of nitrogen (N)which is immediately available for plant uptake (Lazcano *et al*., 2013). Plant available N in vermicompostis found in the forms of nitrate (NO_3^-) and ammonium (NH_4^+).

Low soil fertility is the major constraints for crop production in sub-Saharan Africa in general and Ethiopia in particular (Smaling *et al*., 1993). To improve the crop productivity in this region, adequate and balanced nutrients application is required especially in soils with poor nutrient content. Caliskan *et al*. (2008) also suggested that maintaining soil fertility and use of plant nutrient in sufficient and balanced amounts is one of the key factors in increasing crop yield in sub-Saharan countries. Recently, reports indicated that micronutrient deficiency which limits cell division, chloroplast development, enzyme activity, and reduced drymatter yields is becoming the major yield limiting for crop production beside N and phosphorus (P) in Ethiopia (Tulema *et al*., 2007).

Inoculation of seeds with *Rhizobium* is known to increase nodulation, N uptake, growth, and yield parameters of legume crops (Sogut, 2006).However, the effectiveness of inoculation on nodulation and N derived from the atmosphere by biological N fixation are reduced when *Rhizobium* inoculation integrated with high N-containing fertilizer(Ogutcu *et al*., 2008). For instance, Clayton *et al.* (2004) examined there sponse of field pea to N fertilization and reported that application rates greater than 40 kg N ha^{-1} had reduced nodulation and N fixation.

On the other hands, organic input amendment enhanced the nodulation and yield of peanut (Agegnehu *et al*., 2015). The presence of high P attenuated the negative effect of available inorganic Non nodulation and N_2 fixation (Hellsten and Huss-Danell, 2000). However, the information on the effect of vermicompost reached in inorganic N and other essential nutrients in combination with *Rhizobium* inoculation on nodulation and growth of high N_2 fixer faba bean is poorly studied. The hypothesis of this work has been formulated that use of vermicompost with high plant nutrients including N improve the plant production without affecting nodulation. Therefore, this study was conducted to determine the effect of vermicompost application and elite *Rhizobium* inoculation on nodulation, yield and yield traits of faba bean at the Haramaya experimental site.

Materials and Methods

Description of experimental site

A field experiment was established in 2012 and 2013 cropping seasons on a Sandy clay loam soil under a rainfed condition at the research station of Haramaya University. The experimental site is situated at 09°24.954′N and 042°02.037′E at an altitude of 2020 m above sea level. Climatically, the area placed in the semi-humid. The rainfall distribution during the experiments is indicated in figure 1.

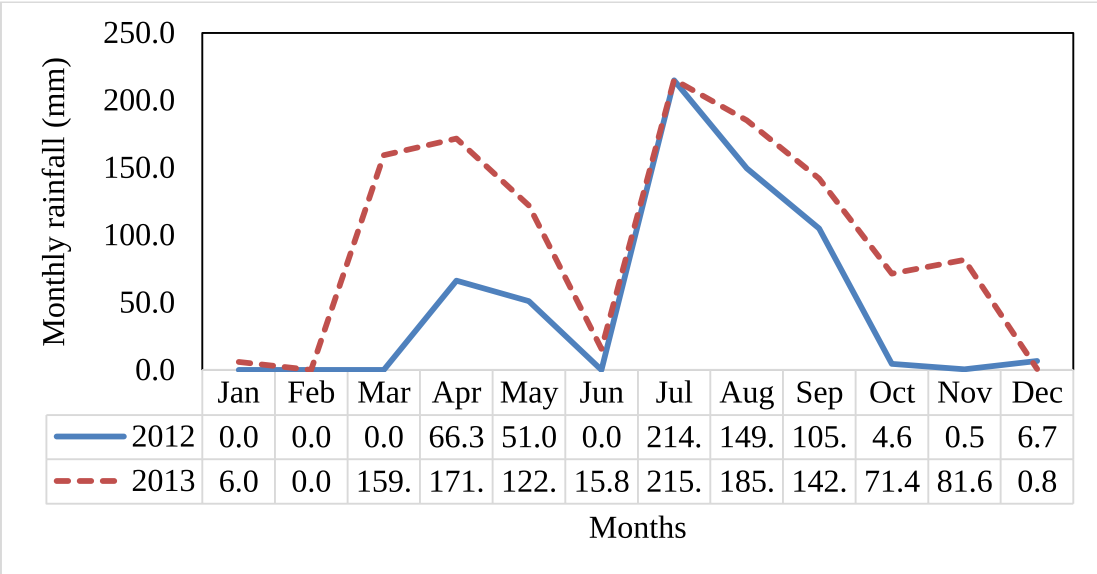


Figure 1. The monthly rainfall distribution during the experiments

Soil sampling and analysis

Soil samples were taken from the surface20 cm before treatment applications. The soil had sandy clay loam with 33, 18 and 49% of clay, silt and sand content, respectively. The organic carbon (C) content of the soil was 1.96% determined as per Walkley and Black (1934), Kjeldahl nitrogen (N) of 0.12% and Olsen phosphorus (P) of 2.13 mg kg^{-1} soil. The 1 N ammonium acetate extractable Potassium (K^{+1}), Calcium (Ca^{+2}), Sodium (Na^{+1}) and Magnesium (Mg^{+2}) were0.14, 31, 0.33 and 8.7 cmol(+) kg^{-1}, respectively. The pH (1:2.5 soil/water suspensions) of the soil was7.84. The cation exchange capacity and EC of the experimental soil were 25.98 cmol (+) kg^{-1} and 0.14 mS cm^{-1}, respectively.

Vermicompost preparation

Vermicompost was produced at the Research Farm of Haramaya University, Ethiopia. *Parthenium* weeds and partially decomposed cattle dung were used in 2:1 ratio (w/w) for vermicomposting. Matured vermicompost samples werecollected for analysis of major chemical properties. The result of the analysis was presented in Table 1.Vermicompost was applied by hand 2 weeks before sowing and was immediately incorporated after application with a spade.

Table 1. The chemical composition of vermicompost prepared from *Parthenium* weed and cow dung

No.	Parameters	value
1.	$pH_{H2O(1:2.5)}$	7.86
2	EC(mS/cm)	9.35
3	Total N (%)	1.31
4	Organic Carbon (%)	35.22
5	NH_4^+N (mg/kg)	37.60
6	NO_3^-N (mg/kg)	8839.05
7	Available K (cmol(+)/kg soil)	27.34
8	Available P (mg/kg)	930.13
9	Zn (mg/kg)	39.57
10.	B (mg/kg)	7.75

Sources of seeds and Rhizobium inocula

Improved cultivar "Gachena" of Faba bean, with favorable agronomic characteristics and high yielder in Hararghe highland, was obtained from Haramaya University, highland pulses research project, Ethiopia.

The *Rhizobium* strain (HUFBR-15) which has been isolated from root nodules of faba bean collected from eastern Ethiopia soil (Mnalku *et al*.,2009) was used as inoculant preparation. The inoculum was produced by mixing culture liquid medium containing 10^8viable rhizobia $ml^{-1}$with well-decomposed filter mud. This production was undertaken at the Biofertilizer Research and Production Laboratory of Haramaya University, Ethiopia.

Treatments and experimental design

The experimental design was randomized complete block design where10treatments were randomized within a block and there were three blocks (10treatments × 3 replications = 30plots). Ten treatments consisted of selected combinations of different rates of vermicompost (0, 2, 4, 6 and 8 ton ha^{-1}) and two levels of *Rhizobium* inoculations (inoculated and uninoculated). Vermicompost applications were rated on a dry-weight basis. Each plot consisted of five rows, 3m long and 40cm apart. The area was moldboardplowed and disked before planting. Seeds for inoculation treatments were inoculated with *Rhizobium* just before planting.

At late flowering and early pod setting stage, five plants from three central rows were excavated to determine nodulation (nodule number and nodule dry weight) and shoot dry weight. The dried shoots were later ground to pass a 0.5 cm sieve. Total N determinations were done by the Kjeldahl method of Bremner (1965). The total P concentration in aboveground biomass which has been sampled at the late flowering stage was analyzed. The plants were harvested at physiological maturity in the second week of November and yield components such as plant height, the number of pods per plant, the number of seeds per pod, and 100 seeds weight were recorded on 5 randomly selected plants from the central three rows. Grain and total biomass yields were determined by harvesting the middle three rows of each plot.

Statistical analysis

Analysis of variance (ANOVA) was done using the SAS computer software package. Differences between mean values were evaluated by a two-way analysis of variance (ANOVA) using least square difference (LSD) at the 0.05 probability level.

Result and Discussion

Due to soil nutrient depletion and other soil degradation, the soil of sub-Saharan Africa including Ethiopia contains a deficient amount of essential plant nutrients. As a result, the crop productions in this region by subsistent farmers are very low. The cost-effective and environmentally friendly ways of improving the crop production are essential. Accordingly, the experiment was conducted at Haramaya experimental site to evaluate the effect of vermicompost on the effectiveness of *Rhizobium* inoculation of nodulation and yield of faba bean. Analysis of variances revealed that the main effect of vermicompost application rate, *Rhizobium* inoculation and cropping season and their interaction significantly affected most of the investigated traits measured at late flowering and at harvest (Table 2).

Results of this study revealed a significant increase in nodule number and dry weight up to 4 and 6 ton ha^{-1} vermicompost application in 2012 and 2013, respectively (Table 3). This enhancement of nodulation could be due to the fact that vermicompost contains different essential nutrients including macronutrients and micronutrients necessitate for nodule initiation and development (Al-Chammaa *et al*., 2014).The present study found the significant reduction of nodule number and dry weightwith8 ton ha^{-1} vermicompost application (Figure 2a and b). This could be because of the fact that vermicompost contains relatively large amounts of N immediately available for plant uptake (Datta*et al*., 2011)which may reduce the nodule initiation and development (Clayton *et al*., 2004). Though the soil had high indigenous rhizobia population nodulating faba bean, a slight increase in nodule number and dry weight due to *Rhizobium* inoculation was also noted. Similarly, Mrabet*et al*. (2005) found a significant increase in nodulation of common bean by using locally isolated *Rhizobium* inoculation though the soil had high rhizobial population.

The result of the current study revealed a remarkable increase in shoot dry weight, shoot length, then umber of tillers per plant, the number of pods per plant and number of seeds per pod of faba bean with increasing vermicompost application with the highest values recorded at 8 ton ha^{-1} (Table 3, 4 and 5).The results obtained here are in agreement with those of Gopinath *et al*. (2011) who revealed a significant increase in growth and yield by the organic input. This is through delivering greater amounts of available C, Mg, Ca, P, and Kfor the plant (Lim *et al*., 2015). In addition to mineral nutrition content of vermicompost, further stimulate plant growth through enhancing beneficial microorganisms and the microbially mediated release of phytohormones (Frankenberger and Arshad, 1995).

Inoculating *Rhizobium* in the year 2013hadsignificantly increased all investigated traits of faba bean when compared to the uninoculated treatment but this effect was non-significant in2011 (Table 3, 4, 5 and 6). This difference could be related to the high competitiveness of the native rhizobia population in soil in which the experiment was conducted in the year2012 against the inoculated *Rhizobium* (Charman and Ballard, 2004). The results in the year 2013 agree with those of Ankomah *et al*. (1996), who reported that N derived from atmosphere correlated well with grain yield and drymatter production.

Table 2. Summary of ANOVA results for all investigated parameters affected by vermicompost application rate, *Rhizobium* inoculation and year of planting, in Haramaya, 2012-2013

Sources of variation	df	F value											
		NN	NDW	SDW	SL	NT	NPP	NSP	100 wt	TBY	GY	Tot P	Tot N
Vermicompost (V)	4	12.09***	54.22***	4.14**	10.83***	2.88*	16.07***	3.96**	4.26**	6.15***	24.12***	77.20***	25.74***
Inoculation (I)	1	9.17**	65.94***	0.64ns	5.01*	22.68***	31.94***	0.01ns	0.69ns	0.64ns	9.28**	48.76***	2.64ns
Year (Y)	1	0.13ns	432.51***	472.14***	124.57***	180.10***	304.25***	24.04***	64.06***	523.44***	61.57***	192.48***	1271.25***
V× I	4	11.79***	21.45***	8.52***	5.22**	0.45ns	5.19**	1.60ns	2.78*	0.73ns	2.47ns	22.94***	9.36***
Y × I	4	8.29***	47.14***	12.14***	7.34***	3.83**	7.62***	2.69*	3.60*	0.37ns	2.07ns	13.68***	4.42**
Y ×V	1	15.67***	49.19***	43.94***	6.73*	3.89ns	31.92***	3.94ns	0.89ns	17.21***	24.05***	0.72ns	0.04ns
Y ×V× I	4	17.29***	29.99***	3.97**	4.62**	9.15***	0.97ns	1.42ns	0.56ns	6.07***	5.32**	3.98**	8.71***

*NS- non-significant; * significant at 0.05; **significant at 0.01; ***significant at 0.001; NN- Nodule number; NDW- Nodule dry weight; SDW-Shoot dry weight; SL- Shoot length; NT- Number of tiller per plant; NPP- Number of pods per plant; NSP- Number of seeds per pod; GY- Grain yield; TBY- Total biomass yield; Tot N- total nitrogen; Tot P- Total phosphorus*

Table 3. Nodule number, nodule dry weight and shoot dry weight of common bean as affected by vermicompost application rate and *Rhizobium* inoculation, Haramaya, 2012-2013cropping seasons

Treatments (ton ha^{-1})	Nodule number			Nodule dry weight (g plant^{-1})			Shoot dry weight (g plant^{-1})		
	2012	2013	Average	2012	2013	Average	2012	2013	Average
0	239.83ab	220.00cd	229.92ab	0.5562b	0.1656c	0.3609b	121.07b	69.47ab	95.27a
2	245.33ab	173.33d	209.33b	1.0882a	0.1915c	0.6398ab	149.72a	52.05b	100.88a
4	294.33a	301.67b	298.00a	1.0122a	0.5073a	0.7598a	130.82b	85.15a	107.98a
6	235.83b	333.33a	284.58ab	0.6735b	0.4227ab	0.5481ab	133.25ab	86.40a	109.83a
8	173.33c	248.33bc	210.83b	0.6862b	0.3399b	0.5130ab	138.83ab	79.25a	109.04a
LSD	57.29	70.48	77.95	0.2167	0.1404	0.3709	18.54	18.59	43.72
Inoculated	219.13a	288.67a	253.90a	0.8468a	0.3447a	0.5957a	126.65b	84.77a	105.71a
Uninoculated	256.33a	222.00b	239.17a	0.7598b	0.3061a	0.5329a	142.82a	64.16b	103.49a
LSD	25.29	31.07	34.99	0.0955	0.0619	0.1665	8.17	8.19	19.63
CV (%)	13.97	15.98	27.37	15.61	24.97	56.89	7.96	14.45	36.18
Mean	237.73	255.33	246.53	0.8033	0.3254	0.5643	134.74	74.46	104.60

Notes. Means in the same column followed by the same letter are not significantly different at the 5% probability level by Tukey's test

Table 4. Shoot length, number of tiller per plant and number of pods per plant of common bean as affected vermicompost application rate and *Rhizobium* inoculation, Haramaya, 2012-2013 cropping seasons

Treatments (ton ha^{-1})	Shoot length (cm)			Number of tiller per plant			Number of pods per plant		
	2012	2013	Average	2012	2013	Average	2012	2013	Average
0	116.67c	151.67ab	134.17b	2.28b	3.29bc	2.78a	19.17b	26.55b	22.86a
2	140.83ab	155.00ab	147.92ab	2.62a	3.17c	2.89a	22.61a	26.77b	24.69a
4	127.50bc	158.33ab	142.92ab	2.28b	3.61abc	2.94a	21.56ab	33.89a	27.72a
6	140.50ab	149.17b	144.83ab	2.48ab	3.82ab	3.15a	21.83ab	31.44a	26.64a
8	144.83a	160.83a	152.83a	2.55ab	4.05a	3.30a	23.28a	33.16a	28.22a
LSD	14.34	10.46	17.57	0.31	0.66	0.90	3.28	3.38	6.38
Inoculated	138.60a	154.67a	146.63a	2.61a	3.82a	3.21a	21.69a	33.17a	27.43a
Uninoculated	129.53b	155.33a	142.43a	2.27b	3.35b	2.81b	21.69a	27.55b	27.62a
LSD	6.32	4.61	7.89	0.14	0.29	0.40	1.44	1.49	2.86
CV (%)	6.19	13.90	10.52	7.30	10.61	25.71	8.74	6.44	21.21
Mean	134.07	155.00	144.53	2.44	3.59	3.01	21.69	30.36	26.03

Notes. Means in the same column followed by the same letter are not significantly different at the 5% probability level by Tukey's test

Table 5. Number of seeds per pod, 100 seeds weight and total biomass yield of common bean as affected by vermicompost application rate and *Rhizobium* inoculation, Haramaya, 2012-2013 cropping seasons

Treatments (ton ha^{-1})	Number of seeds per pod			100 seeds weight (g)			Total biomass yield (kg ha^{-1})		
	2012	2013	Average	2012	2013	Average	2012	2013	Average
0	3.13c	3.50a	3.32b	57.17b	54.87b	56.02a	6208.3b	11564.8b	8887a
2	3.27bc	4.05a	3.66ab	58.82ab	55.25ab	57.03a	7477.8ab	12226.9ab	9852a
4	3.27bc	3.89a	3.58ab	61.77a	54.77b	58.27a	7555.6ab	12768.5a	10162a
6	3.53ab	3.55a	3.54ab	59.67a	55.73ab	57.70a	7169.4ab	12355.6ab	9763a
8	3.70a	3.94a	3.82a	59.78ab	57.80a	58.79a	8183.3a	12870.4a	10527a
LSD	0.36	0.70	0.48	3.34	2.93	3.27	1816.6	1021.0	3431.5
Inoculated	3.29b	3.86a	3.58a	59.41a	56.10a	57.76a	6950.0a	12901.9a	9925.9a
Uninoculated	3.47a	3.71a	3.58a	59.47a	55.27a	57.37a	7687.8a	11812.6b	9750.2a
LSD	0.18	0.31	0.22	1.47	1.29	1.47	800.9	450.14	1540.5
CV (%)	6.11	10.66	11.62	3.25	3.04	4.92	14.37	4.78	30.19
Mean	3.38	3.79	3.58	59.44	55.68	57.56	7318.89	12357.22	9838.06

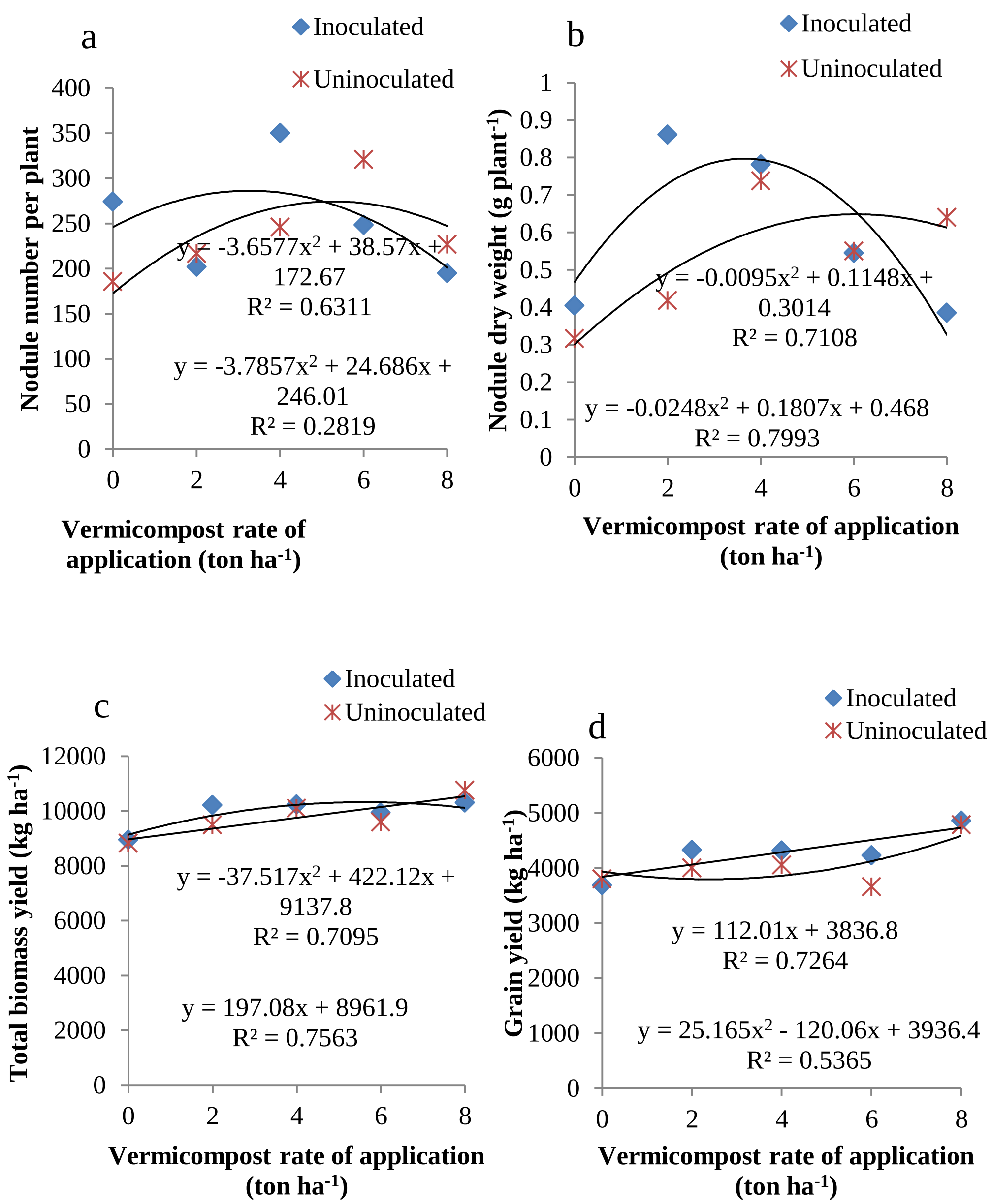
Notes. Means in the same column followed by the same letter are not significantly different at the 5% probability level by Tukey's test

Table 6. Grain yield, total P accumulation and total N accumulation of common bean as affected by vermicompost application rate and *Rhizobium* inoculation, Haramaya, 2012-2013 cropping seasons

Treatments (ton ha^{-1})	Grain yield (kg ha^{-1})			Total P accumulation			Total N accumulation		
	2012	2013	Average	2012	2013	Average	2012	2013	Average
0	3418.7c	4072.1c	3745.4b	0.1082c	0.1497b	0.1289c	2.9706bc	4.2280ab	3.5993a
2	3692.1bc	4639.2ab	4165.6b	0.1292b	0.1637b	0.1464bc	3.2922a	4.3305a	3.8114a
4	4014.9b	4353.7bc	4184.3b	0.1606a	0.1638b	0.1622ab	3.1089ab	4.3660a	3.7374a
6	3679.7bc	4210.0bc	3944.9b	0.1626a	0.1801a	0.1713a	3.2000ab	4.1180bc	3.6590a
8	4609.7a	5034.6a	4822.1a	0.1552a	0.1870a	0.1711a	2.7476c	3.9863c	3.3669a
LSD	517.5	468.6	581.49	0.00969	0.01461	0.02043	0.2337	0.1795	0.7487
Inoculated	3814.5a	4755.22a	4284.9a	0.1504a	0.1745a	0.1625a	3.0927a	4.2182a	3.6554a
Uninoculated	3951.5a	4168.63b	4060.1a	0.1359b	0.1632b	0.1495b	3.0350a	4.1933a	3.6142a
LSD	228.16	206.6	261.04	0.00427	0.00644	0.00917	0.1030	0.0791	0.3361
CV (%)	7.71	6.08	12.06	3.92	5.01	11.34	4.41	2.47	17.83
Mean	3883.02	4461.93	4172.47	0.1432	0.1689	0.1560	3.0638	4.2058	3.6318

Notes. Means in the same column followed by the same letter are not significantly different at the 5% probability level by Tukey's test

In the present study, the total biomass and grain yield of faba bean increased significantly (P <0.05)with increasing vermicompost application in both cropping seasons (Table 5 and 6).These results suggest that Haramaya soil could not have delivered sufficient amount of essential for faba bean production. This result indicates the need forhigh-quality organic fertilizer for low fertile soil (Mete *et al*., 2015). Inoculating *Rhizobium* also increased the mean value of grain and total biomass yields along increasing rates of vermicompost application (Figure 2c and d), indicating the importance of *Rhizobium* inoculation beside vermicompost application.



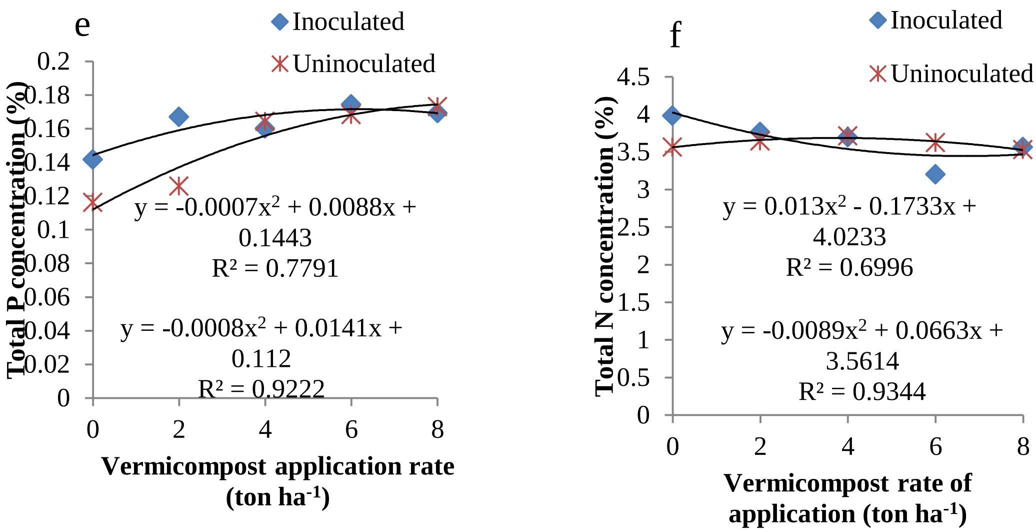


Figure 2. The regression analysis between rates of compost application with (a) Nodule number, (b) Nodule dry weight, (c) Total biomass yield, (d) Grain yield, (e) Total Pconcentration, (f) Total N accumulation

The current work revealed that the higher mean total biomass and grain yield were recorded in the year 2013 than 2012 (Table 5 and 6). This difference could be related tosignificant effect of inoculation in 2013but not in2012 in most of the investigated traits of faba bean. Inoculation could have increased chlorophyll content (Elkoca*et al*., 2010) thereby improves the photosynthetic product and productivity of the host plant. Beside this, rainfall distribution in 2011 was not as good as 2012 season during the pod setting stage of faba bean (Figure 1).

We found a significant increase in total plant P uptake and total plant N accumulation by increasing vermicompost application (Table 6).Figure 2e and f showed the significant increase in P uptake and plant N accumulation by *Rhizobium* inoculation with vermicompost application <4 ton ha^{-1}. This finding is in concur with Parry *et al*. (2008) and Al-Chammaa *et al*. (2014)who found that applying manure had significantly increase P concentrations in cowpea and total N accumulation in soybean. It has been known that the application of organic matter to soil may increase P solubility and the absorption by the plant (Herencia *et al*., 2007).Their beneficial effects were mainly attributed to the enhancement of N_2 fixation through root growth and enhance P and other nutrients that are essential for theN_2-fixation process (Divitoa and Sadras, 2014).As we have found in yield traits, the higher mean total plant P uptake and total plant N accumulation were recorded in 2013 than 2012 season.

Conclusion

In conclusion, the result shows a remarkable improvement of faba bean production in the study site by vermicompost application. Though the high rates of vermicompost application reduced the nodule formation, the result revealed a moderate increase in productivity of faba bean. The effectiveness of *Rhizobium* inoculation is determined by the rainfall distribution at pod filling stage. In general, the integrated application of high-quality organic fertilizer (vermicompost) and *Rhizobium* inoculation is needed to boost the faba bean producing in low fertile soils.

Acknowledgment

This research was funded by the Ethiopia Institute of agricultural Research, under Biofertilizer and organic fertilizer research project. The authors would like to express their sincere thanks to the field and technical assistant for their field experiment management and data collection.

References

Adhikary S. 2012. "Vermicompost, the story of organic gold: A review."*Agr. Sci.* 3(7):905-17.

Agegnehu G, AM Bass,PN Nelson,B Muirhead,GWright, and MIBird.2015. Biochar and biochar-compost as soil amendments: Effects on peanut yield, soil properties and greenhouse gas emissions in tropical North Queensland, Australia. *Agr. Ecosyst. Environ.* 213:72-85.

Al-Chammaa M, F Al-Ain,and KKhalifa. 2014. Growth and Nitrogen Fixation in Soybean as Affected by Phosphorus Fertilizer and Sheep Manure using N Isotopic Dilution. *Commun. Soil Sci. Plan.* 45(4):487-497.

Ankomah AB, F Zapata, G Hardarson, and SKA Danso.1996. Yield, nodulation, and N fixation by cowpea cultivars at different phosphorus levels. *Biol. Fert. Soils* 22:10–15.

Bremner JM. 1965. Inorganic forms of nitrogen. In *Methods of soil analysis*. Edited by Black CA. et al. Part 2, 2^{nd} ed., agron. Monogr. 9. ASA and SSSA, Madison, WI.

Caliskan, S, I Ozkaya,ME Caliskan,and M Arslan. 2008. The effect of nitrogen and iron fertilization on growth, yield, and fertilizer use efficiency of soybean in Mediterranean type soil. *Field Crop Res.* 108:126-132.

Charman N, and RABallard. 2004. Burr medic (*Medicagopolymorpha* L.) selections for improved N_2 fixation with naturalised soil rhizobia. *Soil Biol. Biochem.*36:1331-1337.

Clayton GW, WA Rice,NZ Lupwayi,AM Johnston,GP Lafond,CA Grant,and FWalley.2004. Inoculant formulation and fertilizer nitrogen effects on field pea: Nodulation, N fixation, and nitrogen partitioning. *Can. J. Plant Sci.* 84:79-88.

Datta A, BM Sindel,P Kristiansen,C Birchall,RS Jessop,and WLFelton.2011. Influence of nitrogen fertilization and isoxaflutole on the nodulation of chickpea (*Cicerarietinum*). *Weed Biol.Manage.*11:91-99.

Divito GA, and VOSadras. 2014.How do phosphorus, potassium and sulphur affect plant growth and biological nitrogen fixation in crop and pasture legumes? A meta-analysis. *Field Crops Res.*156:161-171.

Elkoca E, M Turan,and MFDonmez.2010. Effects of single, dual and triple inoculations with *Bacillus subtilis*, *Bacillus megaterium* and *Rhizobium leguminosarum*bv. phaseoli on nodulation, nutrient uptake, yield and yield parameters of common bean (*Phaseolusvulgaris* l. cv. 'elkoca-05'). *J. Plant Nutr.* 33:14.

Frankenberger WTJr, and MArshad. 1995. Phytohormones in soils: Microbial production and function. New York: Marcel Dekker Inc.

Gopinath KA, S Saha, and BLMina. 2011. Effects of Organic Amendments on Productivity and Profitability of Bell Pepper–French Bean–Garden Pea System and on Soil Properties during Transition to Organic Production. *Commun. Soil Sci. Plan.* 42:2572-2585.

Hellsten A, and KHuss-Danell. 2000. Interaction Effects of Nitrogen and Phosphorus on Nodulation in Red Clover (*Trifoliumpratense* L.). *Acta Agr. Scand. B-S P.*50:135-142.

Herencia JF, JC Ruiz-Porras,S Melero,PA Garcia-Galavis,E Morillo,and CMaqueda.2007. Effect of organic versus mineral fertilization in soil fertility, macronutrients content in crops, and yield. *Agron. J.*99:973-983.

Lazcano C, M Gómez-Brandón,P Revilla,and JDomínguez.2013. Short-term effects of organic and inorganic fertilizers on soil microbial community structure and function:A field study with sweet corn. *Field Crops Res.* 49:723-733.

Lim, SL, TY Wu,PN Lim,and KPY Shak.2015. The use of vermicompost in organic farming: overview, effects on soil and economics. *J. Sci. Food Agr.*95:1143-1156.

Mete FZ, S Mia,FA Dijkstra,MdAbuyusuf,and ASMIHossain.2015. Synergistic effects of biochar and NPK fertilizer on soybean yield in an alkaline soil. *Pedosphere* 25(5):713-719.

MnalkuA, H GebreKidan,and FAssefa.2009.Symbiotic effectiveness and characterization of *Rhizobium* strains of faba bean (*Viciaefaba* L.) collected from Eastern Western Hararghe highland of Ethiopia. *Ethiopia J. Nat. Resour.* 11(2):223-244.

Mrabet M, R Mhamdi,F Tajini,R Tiwari,M Trabelsi,and MEAouani.2005. Competitiveness and symbiotic effectiveness of *Rhizobiumgallicum* strain isolated from root nodule of *Phaseolus vulgaris*. *Eur. J. Agron.*22:209-216.

Ogutcu H, OF Algur, E Elkoca, and F Kantar. 2008. The determination of symbiotic effectiveness of *Rhizobium* strains isolated from wild chickpea collected from high altitudes in Erzurum. *Turk. J. Agric. Forestry* 32:241-248.

Parry MM, MDSA Kato, and JCDe Carvalho. 2008. Macronutrients in cowpea cultivated under two doses of phosphorus and different planting times. *Rev. Bras. Eng. Agríc. Ambient.* 12(3):236-242.

Smaling EMA, S Nandwa,and BHJanssen. 1997. Soil fertility in Africa is at stake!. In *Recapitalization of Soil Nutrient Capital in sub-Saharan Africa*. Buresh RJ, PA Sanchez, F Calhoun. ASSA/CSSA/SSSA, Madison, Wisconsin. pp. 47-61.

Sogut T. 2006. *Rhizobium* inoculation improves yield and nitrogen accumulation in soybean (*Glycinemax*) cultivars better than fertilizer. *New Zeal. J. Crop Hort.* 34:115-120.

Tomati U, A Grappeili,and EGaili. 1988. The hormone-like effect of earthworm casts on plant growth.*Biol. Fert. Soils* 5:288-94.

Tulema B, JB Aune,and TA Breland. 2007. Availability of organic nutrient sources and their effects on yield and nutrient recovery of tef [*Eragrostistef* (Zucc.) Trotter] and on soil properties.*J. Plant Nutr. Soil Sc.* 170:543-550.