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Yield of faba bean (*Vicia faba* L.) as affected by lime, mineral P, farmyard manure, compost and rhizobium in acid soil of Lay Gayint District, northwestern highlands of Ethiopia

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Abstract

Background: Soil acidity with associated low nutrient availability is one of the major constraints to faba bean (*Vicia faba* L.) production on Ethiopian highlands. Integrated use of organic and inorganic amendments is believed to reduce soil acidity and improve crop production. Therefore, this field experiment was conducted with the objective of evaluating the effects of lime, mineral P, farmyard manure (FYM), compost and rhizobium in acid soil of Lay Gayint District, northwestern highlands of Ethiopia, in 2016–2017 main cropping season. The experiment comprised twenty sole and combined treatments arranged in a completely randomized block design with three replications.

Results: Combined application of 8 t FYM ha^{-1} + 30 kg P ha^{-1} + 3.6 t lime ha^{-1} significantly ($P < 0.05$) increased plant height, number of leaves and branches per plant, pod length, biological and straw yields. Grain per pod, grain yield and thousand grain weight were significantly ($P < 0.05$) increased with the application of 4 t FYM ha^{-1} + 15 kg P ha^{-1} + 7.2 t lime ha^{-1}. This treatment resulted in 102% grain yield advantage over the control. The next higher grain yield advantage of 89% was achieved with 4 t FYM ha^{-1} + 15 kg P ha^{-1} + 3.6 t lime ha^{-1}. Nodule number and nodule dry weight per plant were also improved due to 4 t FYM ha^{-1} + 15 kg P ha^{-1} + 7.2 t lime ha^{-1} application. Among sole treatments applied separately, 8 t FYM ha^{-1} was observed to be superior in all parameters considered followed by 7.2 t lime ha^{-1}.

Conclusion: Combined application of 4 t FYM ha^{-1} + 15 kg P ha^{-1} + 3.2 t lime ha^{-1} could be suggested as effective amendment to improve the yield of faba bean and therefore contribute the effort to insure food security in strongly acid soils of the study area.

Keywords: Grain yield, Organic amendment, Biofertilizer, Inoculation, Nodulation

Background

Faba bean (*Vicia faba* L.) is an important highland pulse crop of Ethiopia, which covered 520,519 ha of the cultivated land with annual production of 6,88,667 tons and a productivity of 1323 kg ha^{-1} [1]. The crop takes the largest share of the area under pulses production. It is a crop of manifold merits in the economy of the farming communities in the highlands of Ethiopia and serves as a source of food and feed [2]. It is one of the legumes being integrated into the smallholder farming systems to improve soil fertility through atmospheric dinitrogen (N_2) fixation and serve as cheap source of protein. However, the yield in the country in general and in the study area in particular is still low, which is below the world average where faba bean yield is 1700 kg ha^{-1} [3]. Several

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factors account for the low productivity of faba bean, of which soil acidity and fertility decline, frequent disease occurrence, parasitic weeds and lack of high yielding varieties could be mentioned [4].

Soil acidity and associated low nutrient availability is one of the major constraints to faba bean (*Vicia faba* L.) production on Ethiopian highlands. Under such acid soils, severe chemical imbalance caused by toxic levels of exchangeable aluminum (Al), manganese (Mn) and hydrogen (H) ions coupled with a parallel critical deficiency in available nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn) and molybdenum (Mo) limits the growth and production of legumes [5].

Low diversity of *Rhizobium leguminosarum* has been reported in acid soils compared to limed soils [6]. Thus, limited persistence of rhizobium in the soil can depress nodulation and growth of faba bean in acid soils. Similarly, Kellman [7] reported abundance of rhizobium in soil and on plant roots is reduced due to soil acidity which directly inhibited colonization and nodulation. High concentration of Al^{3+} inhibits root infection with rhizobium and nodule initiation even in the presence of sufficient number of rhizobium [8].

Soil acidity, either natural or developed by human activity, has serious negative effects on the sustainability of annual crop production in various parts of the world. Soil acidity management and crop productivity improvement are therefore important for enhancing food provision globally and regionally.

The adoption of management practices involving integrated application of lime and OM of animal and plant origin increases the quality of soils, by reducing acidity and improving soil chemical and physical properties, serves as a source of nutrients, maintains soil moisture and neutralizes toxic Al [9]. Research has shown that application of FYM or compost has significant impact on the chemical, physical and biological properties of the soil. Most of these effects are due to an increase in soil OM [10]. Manure is an excellent source of major plant nutrients such as N, P and K, and also provides many of the secondary nutrients that plants require. Manure also has a liming effect, which neutralizes the acid characteristic of most smallholder soils [11]. This could in turn provide favorable conditions for rhizobium survival. Changes observed in soil physical properties include increased infiltration, water-holding capacity and reduced compaction and erosion [12].

The use of composts has been recognized generally as an effective means for improving soil aggregation, structure and fertility, increasing microbial diversity and populations, improving the moisture-holding capacity of soils, increasing the soil cation exchange capacity (CEC) and increasing crop yields [13]. The improvement in the nodulation, growth and yield characters of faba bean and other legumes from organic amendments has been reported by different researchers [14–16].

Moreover, application of lime tends to raise the soil pH by displacement of H^{+}, Fe^{2+}, Al^{3+} and Mn^{4+} ions from soil adsorption site, and subsequent neutralization of H^{+} and precipitation of Fe, Al, Mn as hydroxides [17]. More than increasing soil pH, it also supplies significant amounts of Ca and Mg, depending on the type of liming materials. Indirect effects of lime include increased availability of P, Mo and B, and more favorable conditions for microbially mediated reactions such as N_2 fixation and nitrification, and in some cases improved soil structure [18].

Phosphorus nutrition plays important role in legumes and symbiotic N_2 fixation. The formation of seeds and fruits is especially depressed in plants suffering from P deficiency. Thus, not only yields but also poor quality seeds and fruits are obtained from P-deficient soils [19]. It has been reported that faba bean requires high P for energy expenditure in nodule formation [20].

Several researchers [21–23] have conducted studies on soil fertility management of faba bean in different areas of Ethiopia. Most of the reports revealed significant improvements on the yield of faba bean due to chemical fertilizers and manure applications. However, the integrated effects of lime, organic, inorganic and biofertilizers on the growth and yield of faba bean remain less investigated.

Farmers in Lay Gayint District have access to FYM and compost, though there is strong competition of these organic amendments for fuel. On the other hand, the cost of mineral fertilizers and lime is getting high, beyond their purchasing capacity. Therefore, the contributions of these locally available amendments integrated with inorganic and biofertilizers on faba bean yield need investigation. Consequently, this study aimed at evaluating the effects of lime, mineral P, FYM, compost and *Rhizobium leguminosarum* and their combination on faba bean yields in acid soil of Lay Gayint District, northwestern highlands of Ethiopia.

Methods

Description of the study area

The study was conducted at Lay Gayint District of South Gondar Zone of the Amhara National Regional State (ANRS), Ethiopia. It is located at about 175 km northeast of Bahir Dar, along the Woreta–Woldia highway. The district lies within the geographical grid coordinates of 11°32′–12°16′ N and 38°12′–38°19′ E, and covers an estimated area of 1548 km^2. It is one of the districts of the

ANRS where food insecurity is a chronic problem for the majority of the rural population.

Altitude of Lay Gayint District varies between 1500 and 4231 meters above sea level (masl). The area is characterized by plain (10%), undulating (70%), mountainous (15%) and gorges and valleys (5%) topographic features. The major land use patterns of the study area comprise cultivated land (45%), grazing land (14%), forest/bush land (5%), water body (2%) infrastructure and settlement (6%) and unproductive land (28%). Agro-ecologically, the district is divided into four elevation and temperature zones, namely: lowland (*kolla*) (13%), midland (*woina-dega*) (39%), highland (*dega*) (45%) and *wurch* (very cold or alpine) (3%) [24].

Based on a 20-year climate data (1997–2016) obtained from Ethiopian National Meteorological Service Agency [25], Lay Gayint District receives a mean annual rainfall of 1020 mm. The main rainy season occurs between June and September which represents the long rainy season (*meher*), and the small rainy season (*belg*) occurs between March and May. The mean minimum and maximum air temperature of the district is 6.9 and 21.9 °C, respectively.

Geologically, the study area is covered with loosely compacted tuff, boulders tuffs and normal light, fine-grained tuff and basalts of varying texture which changes laterally to pyroclasts erupted during Cenozoic Tertiary and mid to late Tertiary period in the Pliocene [26]. The majority of the soils in Lay Gayint District include Cambisols, Luvisols, Leptosols and Regosols [27].

Most of the people in the district are engaged in mixed agriculture (crop cultivation and livestock rearing). Crop production is entirely rain-fed, except in very specific and small areas where vegetables are cultivated using traditional and small-scale irrigation. The most commonly produced crops in the study area are annual crops such as *Triticum aestivum* L., *Eragrostis tef* (Zuccagni), *Zea mays* L., *Sorghum bicolor* L., *Hordeum vulgare* L., *Cicer arietinum* L., *Vicia faba* L., *Phaseolus vulgaris* L. and *Solanum tuberosum* L.

The agricultural activity in the area is not productive enough because of the recurrent natural calamities. Natural resources are deteriorating, and soil erosion is marked by the presence of expanding gullies. Rapid population growth has resulted in shrinking the farmland sizes and grazing lands. Land degradation, moisture shortage, ground and surface water depletion, increasing infertility of soil and natural hazards like drought, landslide, incidence of crop pests and weed and livestock diseases, coupled with cultural and attitudinal factors, are among the major problems in the study area. All these, in turn, have made the district one of the food- and nutrition-insecure areas of the ANRS.

Soil sampling and samples preparation

Surface soil samples of the experimental field at Lay Gayint District, with pH less than 5.5 measured at field condition using portable pH meter, were collected using auger at 0–20 cm soil depth. The collected soil samples were bulked to make a composite sample. The soil samples were air-dried, crushed and made to pass through a 2 mm sieve size for the analysis of soil pH, texture, available P, exchangeable bases, exchangeable acidity and CEC, whereas, for analysis of OC and total N, samples were made to pass through 0.5 mm sieve size.

Determination of soil physical and chemical properties

Soil texture was determined using Bouyoucos hydrometer method [28]. Bulk density (BD) was determined on the undisturbed soil sample using the core method, in which the samples were dried in an oven set at 105 °C to constant weight [29]. The oven-dried weight was divided by the volume of the soil core to get the bulk density value. The pH of the soil was measured potentiometrically in the supernatant suspension of a 1:2.5 soil-to-water ratio using a pH meter as described by [30]. Organic carbon was determined using the wet oxidation method [31] where the carbon was oxidized under standard conditions with potassium dichromate ($K_2Cr_2O_7$) in sulfuric acid (H_2SO_4) solution. Total N was determined by the Kjeldahl method [32], while available P was extracted using the sodium bicarbonate solution following the procedure described by Olsen et al. [33]. The exchangeable cations (Ca, Mg, K and Na) were extracted with 1 M ammonium acetate (NH_4OAc) solution at pH 7.0 [43]. Exchangeable Ca and Mg in the leachate were determined by atomic absorption spectrophotometer (AAS), while exchangeable K and Na were determined by flame photometry [34]. The potential cation exchange capacity (CEC) of the soil was determined from the NH_4^+ saturated samples that were subsequently replaced by K^+ using KCl solution. The excess salt was removed by washing with ethanol and the NH_4^+ that was displaced by K^+ was measured using the micro-Kjeldahl procedure [35] and reported as CEC. Total exchangeable acidity was determined by saturating the soil samples with 1 M KCl solution and was titrated with 0.02 M NaOH as described by Rowell [34]. From the same extract, exchangeable Al in the soil samples was determined by application of 1 M NaF which formed a complex with Al and released NaOH and then NaOH was back-titrated with a standard solution of 0.02 M HCl [36].

Manure, compost and liming material analysis, and lime requirement determination

Manure and compost pH was measured in water (soil-to-solution ratio of 1:5) using a pH meter with a glass and reference calomel electrode after the suspensions were shaken for 30 min and allowed to stand for 1 h. Total N content was determined by Kjeldahl method as described by Jackson [32]. The organic carbon was determined by wet oxidation method through chromic acid digestion [31]. Total P, K, Ca and Mg were determined following wet digestion with H_2O_2/H_2SO_4 [37]. Total Ca, Mg, K and Na were determined by AAS and P measured as described by [38]. The calcium carbonate equivalent (CCE) of the Dejen lime was determined by dissolving a graduated amount of lime with excess of standard 0.5 M HCl followed by boiling for 5 min. The excess acid was back-titrated with standard 0.1 M NaOH solution using phenolphthalein as an indicator after filtration. From the amount of NaOH used to neutralize the excess acid of the blank and the filtrate, the CCE of the lime was calculated by Issam and Antoine [39] as:

$$[(\text{ml HCl} \times 1\ \text{M}) - (\text{ml NaOH} \times 0.5\ \text{M})] \times \frac{\text{Volume of HCl (100 ml)}}{\text{Volume of infiltrate aliquate (10 ml)}} \times \frac{100}{1000 \times 2} \times \frac{100\ \text{g}}{\text{Weight of soil g}}$$

Lime requirement (LR) of the soil was determined by Shoemaker, McLean and Pratt (SMP) single-buffer procedure [40], where triplicate dry soil samples each weighing one kg were thoroughly mixed with 0, 800, 1600, 2400, 3200, 4000 and 4800 mg of $CaCO_3$. Each soil sample weighing 1 kg was filled in polyethylene bags and mixed with the rate of lime to be tested. Then, the soil was mixed thoroughly and incubated under room temperature for a period of 30 days. The soil and the $CaCO_3$ were wetted with distilled water to maintain field capacity. Finally, soil samples were collected, dried and ground to pass through a 2 mm sieve and then the pH was measured. From the relationships between the amounts of $CaCO_3$ applied and the corresponding pH values, the level of $CaCO_3$ sufficient to raise the pH of the soils to 5.5 was selected as the lime requirement of the soils.

Experimental design treatments and procedures

The experiment comprised of 20 treatments with various combinations of lime, mineral P, FYM, compost, and rhizobium (Table 1). These treatments were assigned to each plot of 2.4 m × 4 m in RCBD with three replications. Gross plot size consisted of 12 rows of faba bean spaced at 40 cm of 4 m length. The net plot size was 1.6 m × 3.2 m leaving one outer most row on both sides of each plot and 0.4 m row length at both ends of rows as borders. The land was plowed two times before planting by using oxen drawn implements. Lime ($CaCO_3$), FYM, and compost were applied thoroughly and evenly distributed to the plots and worked into the soil 40 days before sowing the seed of faba bean where as P was applied at planting.

Table 1 List of treatments for field experiment

Treatments	Descriptions
Control	No lime, FYM, P, compost and rhizobium
Compost only	8 t compost ha^{-1}
FYM only	8 t FYM ha^{-1}
P only	30 kg P ha^{-1}
Lime only	7.2 t ha^{-1} lime
P + lime R	30 kg P ha^{-1} + 7.2 t lime ha^{-1}
Compost + ½ lime	8 t compost ha^{-1} + 3.6 t lime ha^{-1}
FYM + ½ lime	8 t FYM ha^{-1} + 3.6 t lime ha^{-1}
P + ½ lime	30 kg P ha^{-1} + 3.6 t lime ha^{-1}
Compost + P + ½ lime	8 t compost ha^{-1} + 30 kg P ha^{-1} + 3.6 t lime ha^{-1}
FYM + P + ½ lime	8 t FYM ha^{-1} + 30 kg P ha^{-1} + 3.6 t lime ha^{-1}
½ Compost + ½ P + lime R	4 t compost ha^{-1} + 15 kg P ha^{-1} + 7.2 t lime ha^{-1}
½ FYM + ½ P + lime R	4 t FYM ha^{-1} + 15 kg P ha^{-1} + 7.2 t lime ha^{-1}
½ Compost + ½ P + ½ lime	4 t ha^{-1} compost + 15 kg P t P ha^{-1} + 3.6 t lime ha^{-1}
½ FYM + ½ P + ½ lime	4 t ha^{-1} compost + 15 kg P t P ha^{-1} + 3.6 t lime ha^{-1}
P + lime + rhizobium	30 kg P ha^{-1} + 7.2 t lime ha^{-1} + rhizobium
Compost + P + ½ lime + rhizobium	8 t ha^{-1} compost + 30 kg P ha^{-1} + 3.6 t lime ha^{-1} + rhizobium
FYM + P + ½ lime + rhizobium	8 t FYM ha^{-1} + 30 kg P ha^{-1} + 3.6 t lime ha^{-1} + rhizobium
½ P + ½ FYM + ½ lime + rhizobium	15 kg P ha^{-1} + 4 t FYM ha^{-1} + 3.6 t lime ha^{-1} + rhizobium
Rhizobium only	

Faba bean (*Vicia faba* L.) variety Kasech which was used as a test crop was collected from the Adet Agricultural Research Center (AARC). *Rhizobium leguminosarum* biovar. viciae strain EAL-110, was used as inoculant. It was obtained from the Menagesha Biotech Industry (MBI), Addis Ababa, Ethiopia. Faba bean seeds were inoculated at the time of sowing with a powder containing an equivalent of 10^8 viable bacteria cells g $powder^{-1}$. Faba bean seeds were sown at a rate of 200 kg ha^{-1} during the mid of June 2016. The necessary field management practices were carried out as per the practices followed by the farming community around the area.

Data collected

At harvest, ten plants were taken at random from the center to estimate: plant height (cm), number of branches and leaves per plant, pod length (cm), number of pods per plant, grain per pod (g), thousand seeds weight (g). Total aboveground biomass yield was determined by weighing after complete sun-drying at harvest from the net plot of 5.12 m^2 and converted into kilogram per hectare. Grain yield was measured by threshing the dried plants from the net plot area and adjusted to 12.5% seed moisture content and straw yield was determined as the difference between the total aboveground biomass (straw plus grain) and the grain yield of the respective treatments.

Nodule number and dry weight per plant were assessed from each treatment. The root of faba bean plant was uprooted using a hand fork and washed by tap water. Nodules remaining in the soil were picked by hand. Nodules attached to each plant root were also removed and separately spread on a sieve for some minutes until the water drained from the surface of the nodule. Finally, the average number of nodules $plant^{-1}$ was recorded for each treatment. After the nodules were oven-dried to 65 °C for 48 h, the average nodule weight per plant was measured for each treatment.

Statistical analysis

The data obtained were subjected to analysis of variance (ANOVA) that is appropriate to experimental design as described by Gomez and Gomez [41] by using the generalized linear model (GLM) procedure of statistical analysis system (SAS) software package version 9.1 [42]. Duncan's multiple range test (DMRT) was employed to test the significant difference between treatment means.

Results and discussion

Soil fertility status prior to experiment and quality of organic amendments

Following the USDA [43] soil textural class triangle, the soil is clay in texture and the clay separate is the dominant one (Table 2). The soil bulk density value was below the critical value of 1.4 cm^{-3} for a clay texture to restrict root growth [44]. The soil was strongly acid in reaction [56]. The exchangeable soil acidity and exchangeable Al^{3+} were 3.84 and 1.52 $cmol_c$ kg^{-1} soil, respectively. Under such soil acidity environment, crop growth is adversely affected due to the toxicity of Al on plant roots, reduced availability P and microbial activity such as atmospheric N_2 fixation, and OM decomposition [45]. The available P falls within the low range (6–10 mg kg^{-1}) for clay soils [46] and therefore indicates the need for applying supplemental P in these soils. Exchangeable Ca^{2+} and K^+ were in the range of medium, while exchangeable Mg^{2+} and Na^+ were in the range of high and low, respectively, in the soil [47].

The moderate range of exchangeable K^+ indicates that supplemental K fertilization is required based on the types and varieties of crops grown in the area. The soils at the experimental site had low organic C (0.5–1.5%) and medium total N (0.05–0.12%) [48].

The result of LR determination indicates that the amount of lime required to raise the pH of the soils to the target pH value, which was 5.5, was 7.2 t $CaCO_3$ ha^{-1}. Since the soil has high clay content and CEC and thus high buffering capacity, high amount of lime was required to alleviate acidity and increase the productivity of acid sensitive crops. The analysis of manure and compost is given in Table 3.

Table 2 Selected physical and chemical properties of the experimental soil

Parameter	Value
Sand (%)	22
Silt (%)	31
Clay (%)	47
Textural class	Clay
Bulk density (g cm^{-3})	1.25
pH (H_2O)	5.1
Exchangeable Ca^{2+} ($cmol_c$ kg^{-1})	8.18
Exchangeable Mg^{2+} ($cmol_c$ kg^{-1})	3.40
Exchangeable K^+ ($cmol_c$ kg^{-1})	0.41
Exchangeable Na^+ ($cmol_c$ kg^{-1})	0.18
Cation exchange capacity ($cmol_c$ kg^{-1})	35.2
Exchangeable acidity ($cmol_c$ kg^{-1})	3.84
Exchangeable Al^{3+} ($cmol_c$ kg^{-1})	1.52
Organic C (%)	1.41
Total N (%)	0.11
Olsen P (mg kg^{-1})	6.24

Effects of amendments on growth characteristics of faba bean

Application of organic and inorganic amendments significantly ($P < 0.05$) increased plant height, number of branches and leaves per plant and pod length over the control and the magnitude varied with treatments (Table 4). Application of 8 t FYM ha^{-1} + 30 kg P ha^{-1} + 3.2 t lime ha^{-1} showed maximum number of branches and leaves per plant and pod length of faba bean (Table 4). Among the sole treatments, addition of 8 t FYM ha^{-1} was superior in bringing about improved growth parameters of faba bean in acid soil. On the other hand, these growth attributes were found to be the lowest with sole P application at 30 kg P ha^{-1}.

The observed increased growth characteristics of faba bean could be due to the incorporation of FYM, which supply favorable chemical, physical and biological soil environment in the growth medium. The release of N through decomposition of FYM augmented with biological N_2 fixation by the host crop itself favored the growth in height, leaves and pod length of faba bean. Integration of lime further played significant role in reducing

Table 3 Some chemical characteristics of FYM and compost

Amendment	pH–H_2O (1:5)	N (%)	C (%)	P (%)	Ca (%)	Mg (%)	K (%)	Na (%)
Farmyard manure	7.5	0.98	10.62	0.36	1.47	0.62	1.77	0.11
Compost	7.4	0.81	16.40	0.32	1.39	0.56	1.70	0.13

Table 4 Effects of rhizobium, organic and inorganic amendments on growth parameters

Treatments	Plant height (cm)	Number of branches $plant^{-1}$	Number of leaves $plant^{-1}$	Pod length (cm)
Control	44.2ij	8.1f	24.8f	3.1 m
8 t compost ha^{-1}	44.2ij	10.6ef	51.0e	4.2j
8 t FYM ha^{-1}	75.7cdef	13.5cde	62.5bcde	4.2j
30 kg P ha^{-1}	33.7j	7.3f	18.5f	3.5 l
7.2 t lime ha^{-1}	41.6fgh	12.7de	59.5de	3.8 k
30 kg P ha^{-1} + 7.2 t lime ha^{-1}	59.9fgh	15.2bcd	66.4abcde	5.5 g
8 t compost ha^{-1} + 3.6 t lime ha^{-1}	74.3cdef	15.5abcd	69.1abcd	5.0i
8 t FYM ha^{-1} + 3.6 t lime ha^{-1}	80.8 cd	16.8abc	78.5abc	6.4c
30 kg P ha^{-1} + 3.6 t lime ha^{-1}	64.5defgh	15.8abcd	71.5abcd	5.6f
8 t compost ha^{-1} + 30 kg P ha^{-1} + 3.6 t lime ha^{-1}	77.4cde	17.6abc	77.0abcd	5.6f
8 t FYM ha^{-1} + 30 kg P ha^{-1} + 3.6 t lime ha^{-1}	99.8a	19.5a	84.6a	7.0a
4 t compost ha^{-1} + 15 kg P ha^{-1} + 7.2 t lime ha^{-1}	72.8cdefg	15.2bcd	70.5abcd	5.6f
4 t FYM ha^{-1} + 15 kg P ha^{-1} + 7.2 t lime ha^{-1}	70.5cdefg	17.9ab	73.2abcd	6.0e
4 t FYM ha^{-1} + 15 kg P ha^{-1} + 3.6 t lime ha	74.8cdef	16.3abcd	75.0abcd	6.2d
4 t compost ha^{-1} +15 kg P ha^{-1} + 3.6 t lime ha^{-1}	84.0bc	17.1abc	78.7abc	6.6b
30 kg P ha^{-1} + 7.2 t ha^{-1} lime + rhizobium	79.0cde	17.0abc	75.9abcd	6.0e
8 t ha^{-1} compost + 30 kg ha^{-1} P + 3.6 t ha^{-1} lime + rhizobium	75.1cdef	17.9ab	80.4ab	5.4 h
8 t ha^{-1} FYM + 30 kg P ha^{-1} + 3.6 t ha^{-1} lime + rhizobium	96.0ab	17.4abc	79.7abc	6.6b
15 kg ha^{-1} P + 4 t FYM ha^{-1} + 3.6 t lime ha^{-1} + rhizobium	57.5 ghi	16.0abcd	70.5abcd	5.4 h
Rhizobium only	54.1hi	14.6bcd	61.8cde	3.1 m
CV (%)	12.7	13.5	13.8	0.9

Means within a column followed by the same letter are not significantly different at $P \geq 0.05$

CV Coefficient of variation

soil acidity and Al toxicity, and therefore increasing the availability of the applied P. The availability of P in turn might hasten root growth to explore wider volume of soil and absorb water and nutrients that increased the aboveground biomass of faba bean. The lowest growth indicated with sole P application could be due to P fixation in acid soil. Additional studies reported increase in plant height of faba bean due to FYM and P application [23], number of branches and leaves of faba bean due to combination of FYM and rhizobium [49]. Consistent with this finding, Chinthapalli et al. [50] indicated that application of cow dung at 15 t ha^{-1} showed significant growth over the inorganic fertilizer urea and potassium chloride in terms of germination percentage, fresh weight and dry weight, plant height, shoot length, root length as well as number of leaves in faba Bean and pea plants at Arbaminch.

Effects of amendments on yield characteristics of faba bean

The yield parameters such as grain per pod, grain yield, straw yield, biological yield and thousand grain weight were found to be significantly (P < 0.05) influenced with the application of sole and combined organic and inorganic treatments. Application of 8 t FYM ha^{-1} + 30 kg P ha^{-1} + 3.6 t lime ha^{-1} increased number of pod per plant from 3.4 to 9.2, straw yield from 1037 to 2904 kg ha^{-1} and biological yield from 1910 to 4431 kg ha^{-1} (Table 5). The other treatment having 4 t FYM ha^{-1} + 15 kg P ha^{-1} + 7.2 t lime ha^{-1} increased grain per pod from 2.0 to 3.6, grain yield from 873 to 1769 kg ha^{-1} and thousand grain weight from 357 to 650 g. This combination marked 102% grain yield advantage over the control. The result implied that reducing the rate of FYM and P by half and increasing the rate of lime from half to full in the treatment combinations caused

Table 5 Effects of rhizobium, organic and inorganic amendments on yield parameters

Treatments	Pod per plant	Grain per pod	TBY (kg ha^{-1})	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	TSW (g)
Control	3.4gh	2.0c	1910f	873i	1037de	357 h
8 t compost ha^{-1}	4.2efgh	2.0c	2653ef	985gh	1668cd	437fgh
8 t FYM ha^{-1}	4.6efgh	2.3bc	3072de	1223fgh	1849bcd	515cdef
30 kg P ha^{-1}	2.6h	1.0d	1770f	843i	927e	402gh
7.2 t lime ha^{-1}	4.1fgh	2.3bc	2930de	1153efg	1777cd	465efg
30 kg P ha^{-1} + 7.2 t lime ha^{-1}	7.2abcd	3.3ab	3492abcd	1457bcde	2035bc	562abcd
8 t compost ha^{-1} + 3.6 t lime ha^{-1}	5.7defg	3.0abc	3170cde	1447bcde	1723bcd	502def
8 t FYM ha^{-1} + 3.6 t lime ha^{-1}	8.4abc	3.0abc	3651abcd	1384cde	2267abc	543bcde
30 kg P ha^{-1} + 3.6 t lime ha^{-1}	4.4efgh	3.3ab	3290bcde	1283def	2007bc	507def
8 t compost ha^{-1} + 30 kg P ha^{-1} + 3.6 t lime ha^{-1}	7.7abcd	3.0abc	3597abcd	1402cde	2195abc	562abcd
8 t FYM ha^{-1} + 30 kg P ha^{-1} + 3.6 t lime ha^{-1}	9.2a	3.0abc	4431a	1625abc	2904a	631ab
4 t compost ha^{-1} + 15 kg P ha^{-1} + 7.2 t lime ha^{-1}	8.6abc	3.0abc	3439bcde	1404cde	2035bc	563abcd
4 t FYM ha^{-1} + 15 kg P ha^{-1} + 7.2 t lime ha^{-1}	8.1abcd	3.6a	4088abc	1769a	2319abc	650a
4 t FYM ha^{-1} +15 kg P ha^{-1} + 3.6 t lime ha^{-1}	8.9ab	3.6a	3860abcd	1648ab	2212abc	642a
4 t compost ha^{-1} +15 kg P ha^{-1} + 3.6 t lime ha^{-1}	8.9ab	3.0abc	3162cde	1421bcde	1741bcd	561abcd
30 kg P ha^{-1} + 7.2 t ha^{-1} lime + rhizobium	6.6bcde	3.3ab	3375bcde	1418bcde	1957bc	584abcd
8 t ha^{-1} compost + 30 kg ha^{-1} P + 3.6 t ha^{-1} lime + rhizobium	7.3abcd	3.3ab	3404bcde	1386cde	2018bc	603abc
8 t ha^{-1} FYM + 30 kg P ha^{-1} + 3.6 t ha^{-1} lime + rhizobium	8.7ab	3.3ab	4165ab	1526bcd	2540ab	619ab
4 t FYM ha^{-1} +15 kg ha^{-1} P + 3.6 t lime ha^{-1} + rhizobium	4.3efgh	3.3ab	3375bcde	1421bcde	1954cd	590abcd
Rhizobium only	3.6gh	2.3bc	2641ef	1044ghi	1597cde	431fgh
CV (%)	20.6	19.4	15.5	9.4	21.1	8.6

Means within a column followed by the same letter are not significantly different at $P \geq 0.05$

CV Coefficient of variation, *TSW* thousand seed weight the highest grain yield increase over the control. The next higher grain yield advantage of 89% was achieved with 4 t FYM ha^{-1} + 15 kg P ha^{-1} + 3.6 t lime ha^{-1}. With regard to sole treatment applications, 8 t FYM ha^{-1} applied to the soil improved the yield traits, while lower yields were obtained from sole P. The effect of 8 t FYM ha^{-1} + 30 kg P ha^{-1} + 3.6 t lime ha^{-1} to show increased growth in height, branches and leaves was not reflected in the grain yield of the crop. Although more number of pods per plant were observed, the seeds filled in the pod were less in number and weight indicating that application of 4 t FYM ha^{-1} combined with 15 kg P ha^{-1} was sufficient to give better grain yield provided that the soil is limed with 3.6 t lime ha^{-1}.

The importance of P nutrition in increasing dry matter production was noticed in soils treated with lime and FYM. For instance, application of 8 t FYM ha^{-1} + 30 kg P ha^{-1} + 3.6 t lime ha^{-1} added the yield by 17% as compared with the same combination but without P integration (8 t FYM ha^{-1} + 3.6 t lime ha^{-1}). Getachew and Chilot [51] revealed that FYM and P fertilizer had a highly significant effect on plant height, number of pods per plant, total biomass and seed yield of faba bean in acid soil. Likewise, pods and seed yields per plant were increased significantly with applying chemical + biofertilizer + organic as one treatment which produced the highest pods and seed yields per plant of faba bean [52].

Manisha et al. [53] revealed that the integrated application of organic wastes and chemical fertilizer in conjunction with lime significantly improved the yield and quality of peanut. Application of FYM was superior to NPK application, while further liming showed the maximum increase in plant height, pod length and pod number per plant of pea in acid soil over the control [54].

The decomposition of FYM and the resultant nutrient release, the increase in soil pH due to lime together with P nutrition contributed for the increase in grain, straw and biological yields of faba bean. Hellal et al. [55] explained that these increases in yield and its components as a result of application of the FYM may be attributed to the release of micro- and macronutrients, which might enhance the activity of photosynthesis and protein synthesis in the leaves that in turn reflected positively on faba bean yield attributes.

The significant effect of P with FYM may be due to the fact that organic anions and hydroxy acids liberated during organic matter decay have immobilized Fe and Al through complexation or chelation and therefore prevented phosphate ions from reacting with Fe and Al [56]. The growth and yield responses to adding lime in the combination might be attributed to the decrease in exchangeable Al^{3+} content and to an increase exchangeable Ca^{2+}, and stimulated P nutrition and increased the P content in the tissue of faba bean. In the same way, Ayodele and Shittu [57] suggested that manure enhanced maize response to lime and fertilizer application through the improvement in soil pH, available P and exchangeable Ca and Mg, and reduction in Al, Fe and Mn. The presence of P in the combination could contribute for the growth and yield increase. This increase in yield may be due to the physiological role of P on the meristematic activity of plant tissues and consequently increasing plant growth. Phosphorus also functions as a part of enzyme system, having a vital role the synthesis of other foods from carbohydrate [58]. The lack of significant yield response due to inoculation is attributed mainly to the presence of native effective strains of rhizobium in the soil, which could be activated when pH is improved [59]. Furthermore, the rhizobial strain might not be effective to the soil conditions of the study area. The lower yield obtained due to only P may be attributed to the acidity of the soil that renders P unavailable through P fixation.

Effects of amendments on nodule characteristics of faba bean

Nodule number and nodule dry weight were significantly ($P < 0.05$) affected with the application of organic and inorganic treatments over the control. The highest nodule number and dry weight per plant were obtained from the application of 4 t FYM ha^{-1} + 15 kg P ha^{-1} + 7.2 t lime ha^{-1} (Table 6). Considering sole treatment application, maximum number of nodules and nodule dry weight per plant were recorded due to the application of 8 t FYM ha^{-1}, followed by 7.2 t lime ha^{-1}, while the lowest was from sole P.

In consent to the present finding, nodule number and weight of various legumes were increased due to P and FYM applications [60]. The plants which were not inoculated with rhizobium, but treated with FYM, lime and P formed nodules with a higher number as compared with plants inoculated and received the same treatment. This could also be verified by comparing the results from sole rhizobium inoculation and sole lime application. The result showed that the soil contained indigenous rhizobium that could be activated and effective in nodule formation and when the soil pH is corrected, sufficient carbon is supplied and P is supplemented.

Liming reduces Al^{3+} and H^{+} ions as it reacts with water leading to the production of OH^{-} ions, which react with Al^{3+} and H^{+} in the acid soil to form Al $(OH)_3$ and H_2O. The precipitation of Al^{3+} and H^{+} by lime causes the pH to increase, enhances microbial activity and nutrient availability [61]. Mineral P which is readily available is involved in the high rates of energy transfer that must take place in nodule formation. Besides, P promotes the development of extensive root systems and nodule

Table 6 Effects of rhizobium, organic and inorganic amendments on nodule characteristics of faba bean

Treatments	Nodule dry weight (mg plant^{-1})	Nodule number plant^{-1}
Control	21h	34g
8 t compost ha^{-1}	34gh	44f
8 t FYM ha^{-1}	45fg	58e
30 kg P ha^{-1}	20i	31g
7.2 t lime ha^{-1}	44fg	58e
30 kg P ha^{-1} + 7.2 t lime ha^{-1}	63c	81bc
8 t compost ha^{-1} + 3.6 t lime ha^{-1}	47ef	64de
8 t FYM ha^{-1} + 3.6 t lime ha^{-1}	58cde	73cd
30 kg P ha^{-1} + 3.6 t lime ha^{-1}	49def	64de
8 t compost ha^{-1} + 30 kg P ha^{-1} + 3.6 t lime ha^{-1}	69abc	82bc
8 t FYM ha^{-1} + 30 kg P ha^{-1} + 3.6 t lime ha^{-1}	67bc	84bc
4 t compost ha^{-1} + 15 kg P ha^{-1} + 7.2 t lime ha^{-1}	64c	77bc
4 t FYM ha^{-1} + 15 kg P ha^{-1} + 7.2 t lime ha^{-1}	80a	95a
15 kg P ha^{-1} + 4 t FYM ha^{-1} + 3.6 t lime ha^{-1}	78ab	88ab
15 kg P ha^{-1} + 4 t compost ha^{-1} + 3.6 t lime ha^{-1}	60bcd	75c
30 kg P ha^{-1} + 7.2 t ha^{-1} lime +rhizobium	64c	78bc
8 t ha^{-1} compost + 30 kg ha^{-1} P + 3.6 t ha^{-1} lime + rhizobium	65c	78bc
8 t ha^{-1} FYM + 30 kg P ha^{-1} + 3.6 t ha^{-1} lime + rhizobium	71abc	87ab
15 kg ha^{-1} P + 4 t FYM ha^{-1} + 3.6 t lime ha^{-1} + rhizobium	61c	82bc
Rhizobium only	29hi	40fg
CV (%)	12.5	8.6

Means within a column followed by the same letter are not significantly different at $P \geq 0.05$

CV Coefficient of variation

development. The addition of FYM supplies of microorganism's food enhancing their population and therefore mineralization. Zengeni et al. [62] also indicated that indigenous rhizobium numbers is increased with manure application, which serve as a source of C and provide a favorable environment for bacterial multiplication.

Conclusion

The production and productivity of faba bean are constrained due to soil fertility decline and soil acidity, among other factors. In order to investigate the growth and yield of the crop, field experiment was conducted with separate and combined application of lime, mineral P, FYM, compost and rhizobium on acid soil of Lay Gayint District. The growth and yield parameters were significantly increased due to the treatments applied except sole mineral P.

The contribution of lime in reducing soil acidity, food and energy derived from FYM and the role of P in nodule formation and overall growth of faba bean were the important effects observed from the combination of treatments. Generally, 4 t FYM ha^{-1} + 15 kg P ha^{-1} + 3.6 t lime ha^{-1} could be recommended provisionally to reduce soil acidity and improve the productivity of faba bean in the study area. However, the experiment should be repeated over years including various strains of rhizobia isolated for acid soils.

Abbreviations

ANRS: Amhara National Regional State; ANOVA: analysis of variance; AAS: atomic absorption spectrophotometer; BD: bulk density; CCE: calcium carbonate equivalent; CEC: cation exchange capacity; CSA: central statistical agency; CV: coefficient of variation; FYM: farmyard manure; DMRT: Duncan's multiple range test; ENMSA: Ethiopian National Meteorological Service Agency; FAO: Food and Agricultural Organization; GLM: generalized linear model; LR: lime requirement; MBI: Menagesha Biotech Industry; Masl: meters above sea level; OC: organic carbon; RCBD: randomized complete block design; SMP: Shoemaker, McLean and Pratt; SAS: statistical analysis software; USDA: United States Department of Agriculture.

Authors' contributions

This work was carried out in collaboration with all authors. Author EF designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KK and AM managed the analyses and interpretations of the study. Author BB managed the literature searches and edited the manuscript. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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References

1. Central Statistical Agency (CSA). Agricultural sample survey. Report on area and production for major crops (private peasant holdings, meher season). Addis Ababa: Statistical Bulletin; 2008.
2. Tekle E, Raghavaiah CV, Ibrahim H. Production potential of faba bean (*Vicia faba* L.) genotypes in relation to plant densities and phosphorus nutrition on vertisols of central highlands of West Showa Zone, Ethiopia, East Africa. Adv Crop Sci Technol. 2016;4:1–9.
3. Akibode S, Maredia M. Global and regional trends in production, trade and consumption of food legume crops. In: Report submitted to SPIA. Department of Agriculture, Food and Resource Economics, Michigan State University; 2011.
4. Getachew A, Rezene F. Response of faba bean to phosphate fertilizer and weed control on Nitisols of Ethiopian highlands. Int J Agron. 2006;2:281–90.
5. Fageria NK. Nutrient management for sustainable dry bean production in the tropics. Commun Soil Sci Plant Anal. 2002;33:1537–75.
6. Andrade DS, Murphy PJ, Giller KE. The diversity of Phaseolus-nodulating rhizobiuml populations is altered by liming of acid soils planted with *Phaseolus vulgaris* L. in Brazil. Appl Environ Microbiol. 2002;68:4025–34.
7. Kellman AW. Rhizobium inoculation, cultivar and management effects on the growth, development and yield of common bean (*Phaseolus vulgaris* L.). Ph.D. Thesis. Lincoln University Canterbury; 2008.
8. Bationo A, Waswa BS. New challenges and opportunities for integrated soil fertility management in Africa. In: Bationo AW, editor. Innovation as key to the green revolution in Africa. Exploring the scientific facts, vol. 1. Berlin: Springer; 2011. p. 3–18.
9. Fageria NK, Baligar VC. Ameliorating soil acidity of tropical Oxisols by liming for sustainable crop production. Adv Agron. 2008;99:345–99.
10. Souza RF, Faquin V, Sobrinho RRL, Oliveira EAB. Influence of cattle manure and limestone on residual effects of phosphorus fertilizer in *Brachiaria brizantha* grown after common bean. Rev Bras Ciênc Solo. 2010;34:143–50.
11. Nzuma JK, Mpepereki S, Murwira HK. Cattle manure management option for reducing nutrient losses: farmer perceptions and solutions in Mangwende, Zimbabwe. In: Waddington S, Murwira HK, Kumwenda J, Hikwa D, Tagwira F, editors. Soil fertility research for maize-based farming systems in Malawi. Harare: CIMMYT; 1998. p. 183–90.
12. Risse LM, Cabrera ML, Franzluebbers AJ, Gaskin JW, Gilley JE, Killorn R, Radcliffe DE, Tollner, WE, Zhang H. Land application of manure for beneficial reuse. In: Paper 65. Biological Systems Engineering: Papers and Publications; 2006.
13. Zink TA, Allen MF. The effects of organic amendments on the restoration of a disturbed coastal sage scrub habitat. Restor Ecol. 1998;6:52–8.
14. Singh MS. Effects of rhizobium, FYM and chemical fertilizers on legume crops and nutrient status of soil: a review. Agric Rev. 2005;26:309–12.
15. Chinthapalli B, Dagne T, Chitra DSV, Melaku B. A comparative study on the effect of organic and inorganic fertilizers on agronomic performance of faba bean (*Vicia faba* L.) and pea (*Pisum sativum* L.). Agric For Fish. 2015;4:263–8.
16. Tadele B, Zemach S, Alemu L. Response of faba bean (*Vicia faba* L.) to phosphorus fertilizer and farm yard manure on acid soils in Boloso sore woreda, Wolaita zone, southern Ethiopia. Food Sci Qual Manag. 2016;53:15–21.
17. Onwonga RN, Lelei JJ, Mochoge BB. Mineral nitrogen and microbial biomass dynamics under different acid soil management practices for maize production. J Agric Sci. 2010;2:16–30.
18. Crawford TW Jr., Singh U, Breman H. Solving problems related to soil acidity in Central Africa's Geat Lakes Region. In: International Center for Soil Fertility and Agricultural Development (IFDC)-USA; 2008.
19. Fageria NK. The Use of Nutrients in Crop Plants. Taylor and Francis Group, Boka Raton, London: CRC Press; 2009.
20. Kopke U, Nemecek T. Ecological services of faba bean. Field Crops Res. 2010;115:217–33.
21. Ghizaw A, Mamo T, Yilma Z, Molla A, Ashagre Y. Nitrogen and phosphorus effects on faba bean yield and some yield components. J Agron Crop Sci. 1999;182:167–74.
22. Asgelil D. Effect of fertilizer on the yield and nodulation pattern of faba bean on a Nitisols of Adet, Northwestern Ethiopia. Ethiop J Nat Resour. 2000;2:237–44.
23. Getachew A, Taye B, Agajie T. Phosphorus fertilizer and farmyard manure effects on the growth and yield of faba bean and some soil chemical properties in acid Nitisols of the central highlands of Ethiopia. Ethiop J Nat Resour. 2005;7:23–39.
24. Addisu B, Menberu T. Crop sensitivity to inter-annual climate variability in Lay Gayint woreda, Northwest Ethiopia. Ethiop Renaiss J Soc Sci Humanit. 2015;2:27–42.
25. ENMSA (Ethiopian National Meteorological Service Agency). Lay Gayint weather station rain fall and temperature data. Bahir Dar; 2017.
26. Adise M. Geology and geochemistry of guna volcanic massif northwestern Ethiopian plateau. M.Sc. Thesis. Addis Ababa, Addis Ababa University; 2006.
27. FAO (Food and Agriculture Organization). Soils map of the world 1:5,000,000. FAO/UNESCO, Rome; 1981.
28. Day PR. Hydrometer method of particle size analysis. In: Black CA, editor. Methods of soil analysis. Agronomy Part I, No. 9. Madison: American Society of Agronomy; 1965.
29. Baruah TC, Barthakur HP. A textbook of soil analyses. New Delhi: Vikas Publishing House Pvt. Ltd.; 1997.
30. Chopra SH, Kanwar JS. Analytical agricultural chemistry. New Delhi: Kalyani Publisher Ludhiana; 1976.
31. Walkley A, Black CA. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 1934;37:29–38.
32. Jackson ML. Soil chemical analysis. New Delhi: Prentice Hall Pvt. Ltd.; 1967.
33. Olsen SR, Watenabe VC, Dean LA. Estimate of available phosphorous in soil by extraction with sodium bicarbonate. In: USDA, Circular. No. 939; 1954.
34. Rowell DL. Soil science: method and applications. England: Addison Wesley Longman Limited; 1994.
35. Chapman HD. Cation exchange capacity by ammonium saturation. In: Black CA, editor. Methods of soil analysis. Agronomy Part II, No. 9. Madison: American Society of Agronomy; 1965.
36. Sahlemedhin S, Taye B. Procedures for soil and plant analysis. Addis Ababa: National Soil Research Center; 2000.
37. Okalebo JR, Gathua KW, Woomer PL. Laboratory methods of soil and plant analysis. 2nd ed. Nairobi: A working Manual; 2002.
38. Murphy J, Riley JP. A modified single solution method for the determination of phosphate in natural waters. Anal Chem Acta. 1962;27:31–6.
39. Issam IB, Antoine HS. Methods of analysis for soils of arid and semi-arid regions. Rome: Food and Agriculture Organization of the United Nations; 2007.
40. Shoemaker HE, McLean EO, Pratt PF. Buffer methods of determining lime requirements of soils with appreciable amounts of extractable aluminum. Soil Sci Soc Am J. 1961;25:274–7.
41. Gomez KA, Gomez AA. Statistical procedures for agricultural research. 2nd ed. New York: John Wiley and Sons; 1984.
42. SAS (Statistical Analysis System). Institute. SAS/STAT user's guide. In: Proprietary software version 9.1. SAS Institute Inc., Cary; 2004.
43. USDA (United States Department of Agriculture). Textural soil classification. In: Study guide, soil mechanics level I, Module 3; 1987.
44. Hazelton P, Murphy B. Interpreting soil test results: What do all the numbers mean? 2nd ed. Australia: Csiro Publishing; 2007.
45. Kisinyo PO, Opala PA, Gudu SO, Othieno CO, Okalebo JR, Palapala V, Otinga AN. Recent advances towards understanding Kenyan acid soils for improved crop production. Afr J Agric Res. 2014;9:2397–408.
46. Jones JB. Agronomic handbook: management of crops, soils, and their fertility. Boca Raton: CRC Press LLC; 2003.
47. FAO (Food and Agriculture Organization of the United Nations). Plant nutrition for food security: A guide for integrated nutrient management. In: FAO, Fertilizer and Plant Nutrition Bulletin 16. Rome; 2006.
48. Tekalign T. Soil, plant, water, fertilizer, animal manure and compost analysis. In: Working document no. 13. International Livestock Research Center for Africa, Addis Ababa; 1991.

49. Mohamed HA, Gomaa AM. Faba bean growth and green yield and its quality as influenced by the application of bio-organic farming system. J Appl Sci Res. 2005;1:380–5.
50. Chinthapalli B, Dagne T, Chitra DSV, Melaku B. A comparative study on the effect of organic and inorganic fertilizers on agronomic performance of faba bean (*Vicia faba* L.) and pea (*Pisum sativum* L.). Agric Forest Fish. 2015;4:263–8.
51. Getachew A, Chilot Y. Integrated nutrient management in faba bean and wheat on Nitisols. In: EIAR, research report no. 78. Addis Ababa; 2009.
52. Mekki BE. Effect of bio-organic, chemical fertilizers and their combination on growth, yield and some macro and micronutrients contents of faba bean (*Vicia faba* L.). Biosci Res. 2016;13:08–14.
53. Manisha B, Singh PBB, Mahapatra SC. Comparative effectiveness of different organic and industrial wastes on peanut: plant growth, yield, oil content, protein content, mineral composition and hydration coefficient of kernels. Arch Agron Soil Sci. 2007;53:645–58.
54. Negi S, Singh RV, Dwivedi GK. Effect of biofertilizers, FYM, NPK and lime on pea in acid soils of Uttaranchal Hills. Short Commun Veg Sci. 2004;31:193–5.
55. Hellal FA, Zewainy RM, Khalil AA, Ragab AAM. Effect of organic and biofertilizer management practices on nutrient availability and uptake by faba bean-maize sequence. Am Eurasian J Sustain Agric. 2014;8:35–42.
56. Venkatesh MS, Majumdar B, Kumar K. Effect of P, FYM and lime on yield, P uptake by Maize and forms of soil acidity in Typic Hapludalf of Meghalaya. J Indian Soc Soil Sci. 2002;50:254–8.
57. Ayodele OJ, Shittu OS. Fertilizer, lime and manure amendments for Ultisols formed on coastal plain sands of southern Nigeria. Agric Forest Fish. 2014;3:481–8.
58. Ahmed MA, El-Abagy HMH. Effects of bio- and mineral phosphorus fertilizer on the growth, productivity and nutritional value of some faba bean (*Vicia faba* L.) cultivars in newly cultivated land. J Appl Sci Res. 2007;3:408–20.
59. Damascene NJ. Effectiveness of native rhizobium isolates on productivity of climbing beans on limed acid soil of Rwanda. M.Sc. Thesis. Makerere University, Rwanda; 2014.
60. Ganeshamurthy AN, Reddy KS. Effect of integrated use of farmyard manure and sulphur in a soybean and wheat cropping system on nodulation, dry matter production and chlorophyll content of soybean on swell-shrink soils in Central India. J Agron Crop Sci. 2000;185:91–7.
61. Onwonga RN, Lelei JJ, Freyer B, Friedel JK, Mwonga SM, Wandhawa P. Low cost technologies for enhance N and P availability and maize (*Zea mays* L.) performance on acid soils. World J Agric Sci. 2008;4:862–73.
62. Zengeni R, Mpepereki S, Giller KE. Manure and soil properties affect survival and persistence of soyabean nodulating rhizobium in smallholder soils of Zimbabwe. Appl Soil Ecol. 2006;32:232–42.