Turkish Journal of Agriculture - Food Science and Technology, 7(2): 320-324, 2019
DOI: https://doi.org/10.24925/turjaf.v7i2.320-324.2296

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology

Enhancing Agronomic Efficiency of P Fertilizer through Integration with Agricultural Lime Coffee Husk Ash and Charcoal on Faba Bean (*Vicia faba* L.) Grown in Acidic Soil of Masha District Ethiopia

Teshale Tadesse Kebede[1*], Mitiku Weldesenbet

[1*]*Department of Plant Science, Mizan Tepi University, P.O.Box 260, Etiyopya*
Corresponding author, E-mail: tshltdsskbd@gmail.com, ORCID: http://orcid.org/0000-0003-1495-7607
[2]*Department of Plant Science, Mizan Tepi University, P.O.Box 260, Etiyopya, E-mail: wesenbet@gmail.com*

A R T I C L E I N F O

Research Article

Received : 19/10/2018
Accepted : 11/01/2019

Keywords:
Faba bean
Soil
Acidity
Yield
Agronomic efficiency

A B S T R A C T

Poor soil fertility is important constraints that limited crop production in Ethiopia. The Masha district was highly prone to phosphorus fixation with ions like Aluminum ion since soil of the area is prone to acidity. This experiment was therefore conducted to investigate the effect of of phosphorus fertilizer with agricultural lime, coffee husk ash and coffee husk charcoal on yield of faba bean and agronomic efficiency of the fertilizer on acidic soils of Masha district. Field experiment involving two rates of phosphorus (23 and 46 kg P_2O_5/ha) and the three soil amendments was in randomized complete block design with three replication. The result indicated that significantly high grain yield was obtained from integrated application of 46 kg P_2O_5/ha with the agricultural lime, coffee husk ash and coffee husk charcoal with the observed values of 2265, 1953 and 1943 kg/ha, respectively. Agronomic efficiency significantly great values were obtained from treated with the agricultural lime+23 kg P_2O_5/ha, agricultural lime+46 kg P_2O_5/ha, coffee husk ash+23 kg P_2O_5/ha and coffee husk charcoal+23 kg P_2O_5/ha with the observed values of 14.86, 14.60 and 10.07, respectively. It can be concluded that 46 kg P_2O_5 with 2.5 ton agricultural lime, 7.5 ton coffee husk ash or 7.5 ton coffee husk charcoal per hectare on acid soils for high yield and yield components on faba bean at Masha district. When 23 kg P_2O_5/ha was integrated with the soil amendments, relatively high agronomic efficiency was observed.

Introduction

Faba bean (*Vicia faba* L.) is an important high land crop of Ethiopia, covering 520,519 ha of the cultivated land with annual production of 688667 tons and a productivity of 1323kha^{-1} (CSA. 2017). Despite the importance of the crop in the traditional farming systems, the yield is generally low. Inadequate plant nutrition, poor seedbed preparation, untimely sowing, sub-optimal weed control, and poor varieties are the major factors for the low yield (Asnakech et al., 2010) According to the same researchers weed competition and poor soil fertility were the major constraints of faba bean production in Ethiopian highlands.

In most highland of Ethiopia in general and in in particular, soil acidity is a noticeable constraint to crop production. It is estimated that about 40% of the total arable land of Ethiopia is affected by soil acidity (Abdenna et al., 2007). Crop productivity is affected because of toxic levels of aluminium and manganese and characterized by deficiency of essential plant nutrients such as P, Ca, K, Mg, and Mo in acid soil (Wang et al., 2006). According to the same authors, more than 80% of applied phosphate converted into unavailable forms in acid soils within very short period of time. This means that even if P fertilizer is applied at levels normally sufficient for maximum crop yield, there is a strong possibility that it will become a restraining factor due to poor availability.

Acid soils are predominant in those areas receiving up to 2000 mm annual rainfall and small seasonal variation in temperature (Mesfin, 2007). The same is true in a case of Masha district thus the agro ecology is highly prone to soil acidity due to leaching of basic cations by heavy frequently received rainfall. Despite application of fertilizers to crops like faba bean, farmers in the area complain about none responsiveness of the added P fertilizers and the decline in crop yield from year to year which has even gone to the extent of total crop failure. This revealed commonness of poor P use efficiency in the area and need for management options that can tackle the problem.

There are considerable literatures suggesting that integrated application of P with lime and/or locally available organic materials can effectively increase P availability in acid soils (Wassie et al., 2010; Jafer and Gebresilassie, 2017; Abay, 2018; Abay and Tesfaye, 2011). The study area is known by high biomass production the fact there is sustainable release of by products from dry and wet coffee processing industries. However, these materials are not technically tested and demonstrated as either source of plant nutrient and/or liming material, rather even considered as waste material and dumped in to landfills or water bodies so that polluting the environment. Therefore; this study was carried out to investigate the effect of integrated use of P fertilizer with coffee husk ash, charcoal and agricultural lime on agronomic efficiency of the fertilizer on faba bean grown in acidic soil of Masha district, south west Ethiopia.

Materials and Methods

Description of the Study Area

The study was conducted at Masha district (south west Ethiopia) during 2017 cropping season. The altitudinal range between 1800-2300 meter, but the agro ecology is cool humid highland. Annual rainfall average is 1800 to 2300 mm and almost lasting during year also, very higher intensity in July and August than January, February and March (according to the information obtained from agriculture and rural development bureau of the District). Minimum and maximum temperatures are 15 and 25°C, respectively.

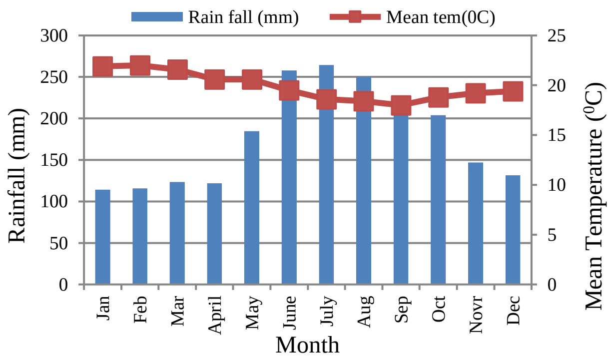

Figure 1 Monthly rainfall and temperature during 2015-2017 in the study area

Soils of the Study Area

Soil samples were collected from the experimental site just before planting using auger for post planting soil characterization. The soil was characterized as strongly acidic (Tekalign, 1991) with pH-H_2O and pH-KCl value of 5.2 and 4.1, respectively. Textural class of the soil was sandy loam. The observed organic matter and total N content could be rated as moderate (4.7 and 0.12%), respectively (Tekalign, 1991). The soil cation exchange capacity was 10 $Cmol_c$/kg soil is low (Hazelton and Murphy 2007). The soil was also characterized by available P content of 3.5 mg/kg which can be rated as very low (Olsen et al., 1954). Unlikely, exchangeable acidity of the study area was considerable (6.5 $Cmol_c$/kg soil).

The lime requirement was determined by the Shoemaker, McLean, and Pratt, (SMP) single buffer method (Shoemaker et al., 1961) to raise the soil pH value of 5.2 to the targeted pH values of 6.0 was 2.5 ton/ha at Horticoop Ethiopia soil, water and plant analysis laboratory.

Experimental Materials

The current experimental materials as soil amendment *i.e.*, coffee husk charcoal (CHC) and coffee husk ash (CHA) were collected from Qeqer dry coffee processing industry located nearby Mizan Tepi University (Mizan campus). Diammonium phosphate as source of P and agricultural lime (AL) or $CaCO_3$ as conventional liming material were obtained from Gatimo Kebele. Local variety of faba bean was used as a test crop.

Characterization of the Soil Amendments

Major nutrient contents in the CHC and CHA were determined by wet digestion (using inductively coupled plasma optical emission spectrometry (ICP-OES) method (Tormen et al., 2011). Wet digestion (Kjeldahl distillation) procedure was followed for determination of N content (Nelson and Sommers, 1980). All of the aforementioned analyses were carried out at Horticoop Ethiopia Soil, Water and Plant Analysis Laboratory, Debrezeit.

Table 1 Chemical characteristics of the coffee husk (CHA) ash and coffee husk charcoal (CHC)

Parameters	Characteristics	
	CHA	CHC
pH	10.90	10.08
Ca (%)	3.09	0.82
Mg (%)	0.97	0.23
K (%)	23.53	4.00
P (%)	2.31	0.90

Treatments and Experimental Design

Total of twelve treatments (Table 2) were given below. Since the 46 kg /ha of sole P_2O_5 had been commonly practiced by farmers of the study area only the 100% and 50% below of it were considered for their efficiency when integrated with the soil amendments.

Table 2 List of treatments for field experiment

No	Treatments
1	Control
2	23 kg P_2O_5
3	46 kg P_2O_5
4	2.5 ton AL
5	7.5 ton CHC
6	7.5 ton CHA
7	AL+23 kg P_2O_5
8	CHA+23 kg P_2O_5
9	CHC+23 kg P_2O_5
10	AL+46 kg P_2O_5
11	CHA+46 kg P_2O_5
12	CHC+46 kg P_2O_5

The experiment was laid down in randomized complete block design with three replications. Size of the experimental plot was 2.4 m × 2.4 m (5.76 m^2). The blocks and plots were put 1 m apart.

Field Operations

The experimental field was prepared following the conventional farmers' tillage practice (oxen driven plough). The soil amendments (AL, CHA, and CHC) were incorporated one month before planting. The seed and fertilizer were distributed in rows at intra-row and inter-row spacing of 10 and 40 cm, respectively.

Post-Harvest Soil Sampling and Analysis

Surface soil samples (0-20 cm depth) were collected from each plots treated with the same treatments in composited manner in treatment base. The chemical characteristics such as pH-H_2O, pH-KCl, EA, CEC, OM, total N, and available P were analysed.

Soil pH was determined using a pH meter with combined glass electrode in water (H_2O) at 1:2.5 soil: water ratio as described by Jackson (1973). The Blake (1965) wet digestion method was used to determine soil organic carbon content and percent soil OM was obtained by multiplying percent soil organic carbon by a factor of 1.724 following the assumptions that OM is composed of 58% organic carbon. Total N was analysed using the Kjeldahl digestion, distillation and titration method as described by Jackson (1958) by oxidizing the OM in concentrated sulfuric acid solution (0.1N H_2SO_4). Available soil P was analysed by extracting following the Olsen procedure as described by Olsen et al. (1954) extraction method. Then absorbance of the extracts was analysed using spectrophotometer which further related with the concentration of P (mg kg^{-1}).

Soil CEC was measured by treating the soil sample with ammonium acetate extracted (ammonium ion saturated) then leaching with 10% sodium chloride solution. The amount of ammonium ion in the percolate was determined by the Kjeldahl procedure and reported as CEC (Hesse, 1972). Exchangeable acidity was determined by saturating the soil samples with potassium chloride solution and titrating with sodium hydroxide as described by USDA (1984).

Data Collection

The grain yield per hectare was measured after sun drying until constant weight was attained. the seed samples for the hundred seeds weight were picked randomly from the well dried up to constant weight was achieved and then measured using by sensitive balance. Agronomic efficiency of P (AE-P) was calculated by using the following formula (Fageria et al., 2013).

$$AE\text{-}P = (GY_f - GY_u)/P_a$$

Where Gf is the grain yield of the P fertilized plot, Gu is the grain yield of the unfertilized plot, Pa is the quantity of P applied.

Statistical Analysis

The data were subjected to analysis of variance using statistical analysis software SAS version 9.3. The treatment means were compared using the least significant difference test at $P \leq 0.05$ significance level.

Result and Discussion

Effects of the Treatments on Soil Characteristics

Postharvest soil analysis result showed that characteristics of the soil were affected by the soil amendments. (Table 3), soil pH, organic matter total N, available P content and cation exchange capacity exhibited an increasing trend as compared to their respective pre-plating soil test results. Considerable change was observed from an experimental plot treated with AL where the maximum values for the aforementioned soil characteristics were 5.81 (increased by 11.7%), 5% (increased by about 10%), 0.18% (increased by 50%), 6.83 mg/kg (increased by 95%) and 16 $Cmol_c$/kg soil (increased by 60%), respectively.

The momentous increase in soil pH changed it from strongly acidic to moderately acidic range. It is clear that relatively positive outcome obtained regarding characteristics of the soil due to application of the AL, CHA and CHC with their importance increasing with order in which the materials are put. There is no doubt that AL and organic materials are commonly used for reclaiming acid soil. However, Ulrich (1991) argues that the addition of organic matter in the soil impact the saturation rate in bases in the root zone negatively and consequently decreases the pH. Effect of the current soil amendments completely contradicts with the aforementioned thought the fact that CHA and CHC were found increasing soil pH as compared to the control or sole application of P_2O_5 and revealing their soil acidity reclaiming potential. This is most probably due to the materials were already processed through burning so that no further decomposition process undertaking that would produce carbon dioxide. The mechanisms postulated for explaining effect of the CHA and CHC on soil pH include (complexation) of the acid forming ions (H^+ and Al^{3+}) with the materials because of their colloidal nature (Tipping, 2002). Moreover, the materials have high pH, contain considerable amount of minerals such as K, Ca, Mg, and sodium (Table 1).

Effect of The Treatments on The Grain Yield and Agronomic Efficiency

As it can be observed from Table 4 treating soil of the current study area with CHA, CHC or AL had affected the grain yield and agronomic efficiency of the P fertilizer. Hence, the result showed that higher mean grain yield of 1947, 1963 and 2265 kg/ha were observed due to application of 46 kg P_2O_5 in integration with CHC, CHA or AL, respectively. Yet, application of the sole P_2O_5 even at 46 kg/ha showed insignificant yield advantage over the control.

Table 3 Effects of the treatments on soil characteristics

Plots treated with	pH	Total N (%)	Ava. P (mg/kg)	CEC ($Cmol_c$/kg)
None	5.2	0.25	3.5	10
23 kg P_2O_5/ha	5.1	0.25	3.4	10
46 kg P_2O_5/ha	5.2	0.25	3.5	10
7.5 t/ha CHC	5.4	0.29	6.36	13
7.5 t/ha CHA	5.5	0.29	6.53	16
2.5 t/ha AL	5.8	0.31	6.83	16.3

AL= agricultural lime; CHA= coffee husk ash; CHC = coffee husk charcoal; t= tons; ha = hec

The positive yield responses due to the soil amendments might be attributed to the modified soil pH and increased exchangeable cations such as Ca^{2+} and K^{+}. Likely, this situation could be enhanced availability of the P fertilizer. This is in agreement with the finding of Endalkachew et al. (2018) where integrated application P fertilizer with organic materials and lime in acid soils of north western highlands of Ethiopia gave significant grain yield advantage over the control as well as solely applied P fertilizer. On the other hand, improved N availability due to enhanced nodulation and P uptake might contribute to betterment of grain yield. It is also known that P is crucial for enzyme system involving in the synthesis of other foods from carbohydrate (Ahmed and El-Abagy, 2007).

Table 4 Mean value estimates of grain yield and agronomic efficiency

Treatments	GY (kg)	AE-P
AL+46 kg P_2O_5/ha	2265.40[a]	14.604[a]
CHA+46 kg P_2O_5/ha	1963.37[b]	8.038[b]
AL+23 kg P_2O_5/ha	1947.37[b]	14.858[a]
CHC+46 kg P_2O_5/ha	1935.3[b]	7.691[b]
2.5.t AL/ha	1830.90[c]	-
CHA+23 kg P_2O_5/ha	1818.63[c]	10.074[b]
CHC+23 kg P_2O_5/ha	1806.03[c]	9.236[b]
7.5 t/ha CHA	1688.40[d]	-
7.5 t /ha CHC	1669.27[de]	-
46 kg P_2O_5/ha	1640.47[de]	2.323[c]
23kg P_2O_5/ha	1623.73[ef]	2.160[c]
Control	1580.27	-
LSD (0.05)	51.54	2.4996
CV (%)	1.6%	16.7%

AL= agricultural lime; CHA= coffee husk ash; CHC = coffee husk charcoal; t= tons; ha = hectare

The agronomic efficiency values presented by Table 4 above clearly indicates that the maximum values of 14.86,14.60 and 10.07 were observed from the experimental plots treated with AL+23 kg P_2O_5, AL+ 46 kg P_2O_5 and CHA+23 kgP_2O_5, respectively. These observations revealed the vitality of such amendments for soils of the environment in which this research was conducted. The reason why the integrated use of fertilizers with the soil amendments resulted higher agronomic efficiency is most probably due to the fact that the materials (CHC, CHA and AL) are alkaline in nature. As a result they interfered to improve reaction of the soil from strongly acidic medium to at least moderate medium. Application and incorporation of such substance competing with the phosphate ion for adsorption sites within the soil could increase the availability of P. Thus, sorption of P that would limit its availability to the plant leading to low grain yield of crop has been inverted due to the modification of pH of the soil. Report by Huck et al. (2014) had also revealed effects of pH modification (usually by lime application to acid soils) on P availability.

Conclusion

Result obtained from the current study showed that integrated use of P fertilizer with the three soil amendments (AL, CHA and CHC) affected the yield and agronomic efficiency of the fertilizer significantly. The highest grain yield of 2265 kg/ha was resulted from experimental plots treated with AL+46 kg P_2O_5. Also 1963 and 1947 kg/ha of grain yields were obtained due to integrated use of the 46 kg P_2O_5/ha with that of CHA and CHC, respectively. Unlikely, highly greater agronomic efficiency of the P fertilizer (14.86 kg/kg) had been observed by integrated use 23 kg P_2O_5 kg/ha with AL. Followed by AL+46 kg P_2O_5/ha, CHA+23 kg P_2O_5/ha and CHC+23 kg P_2O_5/ha with the observed values of 14.60, 10.07 and 9.23 kg/kg, respectively. Enhanced agronomic efficiency means increased yield per unit applied fertilizer which is important indicator of nutrient availability to the plant. Therefore, integrated application of 46 kg P_2O_5/ha fertilizer with at least 2.5 ton AL/ha or 7.5 ton CHA/ha or 7.5 ton CHC/ha should be advised to the soil of Masha district. Considering the local availability advantage of the substrate, use of CHA and CHC should be promoted.

Acknowledgement

The authors would like to appreciate Mizan Tepi University for funding this research with its limited budget.

References

Abay Ayalew. 2018. Review of Soil Fertility Improvement and Crop Responses to Application of Fertilizers in the Southern Ethiopia. Journal of Natural Sciences Research, Vol.8, No.7.

Ahmed MA, El-Abagy HMH. 2007. 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.; 3:408–20

Blake GR. 1965. Methods of soil analysis.Agron. Part I, No. 9.Am. Soc. Agron. Madison, Wisconsin, USA.

Abdenna D, Negassa CW, Tilahun G. 2007. Inventory of Soil Acidity Status in Crop Lands of Central and Western Ethiopia. "Utilisation of diversity in land use systems: Sustainable and organic approaches to meet human needs" Tropentag, October 9-11, 2007, Witzenhausen.

Asnakech T, John D, Julia S, Asnake F. 2016. Participatory assessment of production threats, farmers' desired traits and selection criteria of faba bean (*Vicia faba* L.) varieties: opportunities for faba bean breeding in Ethiopia. Indian J. Agric. Res., 50 (4): 295-302.

CSA. 2017. Central Statistical Agency, Agricultural sample survey. Report on area and production for major crops (private peasant holdings, meher season). Addis Ababa: Statistical Bulletin.

Endalkachew F, Kibebew K, Asmare M, Bobe B. 2018. Yield of faba bean (Viciafaba L.) as afected by lime, mineral P, farmyard manure, compost and rhizobium in acid soil of Lay Gayint District, northwestern highlands of Ethiopia. Agric & Food Secur 7:16.

Hazelton P, Murphy B. 2007. Interpreting soil test results: What do all the numbers mean? 2nd Edition. CSIRO Publishing. 152p.

Hesse P. 1972. A textbook of soil chemical analysis. John Murry Limited, London, Great Britain. 470p.

Jackson ML. 1958. Soil chemical analysis.Prentice- Halls Inc., Englewood Cliffs, N.J. 582p.

Huck YCh, Osumanu HA, Nik MM. 2014, "Improving Phosphorus Availability in an Acid Soil Using Organic Amendments Produced from Agroindustrial Wastes," The Scientific World Journal, vol. 2014, Article ID 506356, 6 pages. https://doi.org/10.1155/2014/506356.

Jackson ML. 1973. Soil chemical analysis. Practical Hall of Indian pvt. Ltd., New Delhi. P.498.

Jafer D, Gebresilassie H. 2017. Application of Lime for Acid Soil Amelioration and Better Soybean Performance in SouthWestern Ethiopia. Journal of Biology, Agriculture and Healthcare; Vol.7, No.5.

Mesfin A. 2007. Nature and Management of Acid Soils in Ethiopia.

Fageria NK, Knupp AM, Moraes MF. 2013. Phosphorus Nutrition of Lowland Rice in Tropical Lowland Soil, Communications in Soil Science and Plant Analysis, 44:20, 2932-2940, DOI: 10.1080/00103624.2013.829485.

Nelson DW, Sommers LE. 1980. "Total nitrogen analysis for soil and plant tissues", J. Assoc. Off. Anal. Chem. 63, 770-778, Environ.

Olsen S, Cole C. Watanabe F, Dean L. 1954. Estimation of available P in soils by extraction with sodium bicarbonate. USDA circular 939.1-19p.

Shoemaker HE, McLean EO, Pratt PF. 1961. Buffer methods for determining lime requirement of soils with appreciable amounts of extractable aluminum. Soil Sci. Soc. Am. Proc. 25:274-277.

Tekalign T. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa, Ethiopia.

Tipping E. 2002. Cation binding by humic substances. Cambridge University Press, Cambridge, 434 pp.

Tormen L, Placido TD, Maria DI, Araujo RGO, Frescura VLA, Jose CA. 2011. Rapid assessment of metal contamination in commercial fruit juices by inductively coupled mass spectrometry after a simple dilution, J Food Compos. Anal., 24: 96-102.

USDA. 1984 United States Department of Agriculture, Agriculture Handbook No. 8-11, Vegetables and Vegetable Products. USDA, Washington DC.

Wang J, Raman H, Zhang G, Mendham N, Zou M. 2006. Aluminum tolerance in barely (*Horidium vulgarie* L.): Physiological mechanisms, genetics and screening methods. Journal of Zhejiang University Science. 7: 769-787.

Wassie H, Shiferaw B, Kelsa K. 2010. Integrated Soil Fertility management options for sustainable crop production: Review of Research Findings from Southern Regional State of Ethiopia. Pp 163-175. *In:* Improved natural Resources management Technologies for Food Security, Poverty eduction and Sustainable Development. Proceedings of the 10th Conference of the Ethiopian Society of Soil Science . 25-27 March 2009, EIAR, Addis Ababa, Ethiopia.