International Journal of Environmental Chemistry
2024; 8(1): 12-17
http://www.sciencepublishinggroup.com/j/ijec
doi: 10.11648/j.ijec.20240801.12
ISSN: 2640-1452 (Print); ISSN: 2640-1460 (Online)

Effect of Intercropping of Different Varieties of Haricot Beans (*Phaseolus vulgaris L.*) and Maize (*Zea mays L.)* on Soil Fertility and Yield at Shashamene, Ethiopia

Abay Challa*, Mekonnen Workina, Kasahun Kitila

Oromia Agricultural Research Institute, Adami Tulu Agricultural Research Center, Ziway, Ethiopia

Email address:

abaychalla@gmail.com (Abay Challa)

*Corresponding author

To cite this article:

Abay Challa, Mekonnen Workina, Kasahun Kitila. (2024). Effect of Intercropping of Different Varieties of Haricot Beans (*Phaseolus vulgaris L.*) and Maize (*Zea mays L.*) on Soil Fertility and Yield at Shashamene, Ethiopia. *International Journal of Environmental Chemistry*, *8*(1), 12-17. https://doi.org/10.11648/j.ijec.20240801.12

Received: December 14, 2023; **Accepted**: January 3, 2024; **Published**: January 18, 2024

Abstract: Maize (Zea mays) - Haricot bean (Phaseolus vulgaris) intercropping is a recent practice at shashamane district, west-Arsi Zone of Oromia region and there is an inadequate information on its productivity and soil fertility management. Poor soil fertility and lack of financial resources to purchase mineral fertilizers have emerged as the greatest biophysical constraints to improve agricultural productivity in the study area. Therefore, a field experiment was conducted at Shashamane district during the 2020 and 2021 crop growing seasons to evaluate the effect of intercropping maize and haricot beans on soil fertility and yield improvement. The experimental materials were one maize hybrid (BH-546) and three haricot bean varieties (Dinknesh, SER-119 and Nasir). The experiment was laid out in a randomized complete block design with three replications. The soil analysis result showed intercropping of maize-haricot beans were highly influenced soil total nitrogen and available phosphorus. Improvement of soil total N was found in plots where haricot beans was grown in an intercrop with maize. In contrast available P content was reduced in post-harvest soils of all plots in which maize was intercropped with haricot beans. Higher grain yield of maize and haricot beans were obtained from sole cropping compared to intercropping. Intercropping of maize with haricot bean had total LER value greater than one which showed the benefit of intercropping over mono-crops. The combined yields obtained from intercrops were more profitable than sole haricot beans and maize. Therefore, intercropping agro-ecologically suitable haricot beans with maize are advantageous in terms of grain yield and soil nutrient improvement than the corresponding mono-crops.

Keywords: Maize, Intercropping, Haricot Bean, LER, Soil Fertility

1. Introduction

Soil degradation is expressed in quality and quantity of soil nutrients, physical and biological soil characteristics which are linked to stagnation and decline in yields in the most intensive agriculture [15]. The decline in soil properties is interrelated to the improper use of inorganic fertilizer and lack of organic fertilization, practices that are now widespread in the most intensive agriculture in developing countries [18]. The majority of farmers lack financial resources to purchase sufficient amounts of mineral fertilizers to replace soil nutrients removed through harvested crop products [11], crop residues, and through loss by runoff, leaching and as gases [4]. Consequently, poor soil fertility has emerged as one of the greatest biophysical constraints to increasing agricultural productivity, hence threatening food security [20]. Intercropping is advanced as one of the integrated soil fertility management practices consisting of growing two or more crops in the same space at the same time, which have been practiced over the years and achieved the soil fertility restorations and crops yield in agriculture [19]. Intercropping has some advantages over monocultures [12]. Intercropping supplies efficient resource utilization, reduces risk to the environment and production costs, and provides greater financial stability, making the system more suitable particularly for labor- intensive, small farmers [2]. Intercropping presents a large level of risk reduction for the smallholder. If one crop is entirely lost to pest or drought damage, the farmer may still harvest the other crop in the field.

In cereal-legume cropping systems, legumes play an important role in nitrogen fixation and are an important source of nutrition for both humans and livestock. According to [25], intercropping cereal and grain legume crops helps maintain and improve soil fertility, because crops such as cowpea, soybean and groundnuts accumulate from 80 to 350 kg nitrogen (N) ha^{-1}. Moreover, intercropping maize with soybean was reported to be profitable in terms of land utilization, in western Kenya [13].

In Ethiopia intercropping cereals and haricot beans is not a new practice. In Southern and Eastern parts of the country, intercropping haricot beans with maize and sorghum is widely practiced as means of income generation and important food crops for smallholder farmers [6]. In the Eastern highlands of Ethiopia, cereal and legume intercropping is also known for its soil fertility improvement [7]. But, there is no publication or research information with regard to the role of cereals and haricot bean intercropping on improvement of soil fertility and crop yield in West Arsi zone of Oromia region. In West Arsi Zone, in addition to mono-cropping culture, most farmers are not seen while they are using crop rotation and thus in turn affect the soil nutrient and crop productivity.

Therefore, by considering the environmental problems and risk of crop failure associated with current mono-cropping systems, the project was designed to evaluate the effect of intercropping maize and haricot beans on soil fertility and yield improvement in Shashamane District.

Specific objective:

1) To evaluate the effect of different varieties of haricot bean intercropping with maize on soil fertility
2) To evaluate the effect of different varieties of haricot bean intercropping with maize on yield of maize

2. Materials and Methods

2.1. Description of the Study Area

The experiments were conducted at two Farmer Training Center (FTC) of Shashamane district, West Arsi zone, of Oromia Region. Shashamane is located in West Arsi Zone, Oromia Regional State about 240 km south of Addis Ababa lying on the main road to Hawassa. The geographical extent of Shashamane district ranges from 7°0’50” to 7°22’45” N and 38°23'00" to 38°48'00" E. The area receives an annual rainfall of 800 – 1300 mm and has bimodal rainfall type. The altitude ranges between 1500 and 2000 meters above sea level. The area has an annual average minimum and maximum temperature of 12 and 28°C, respectively [23]. The dominant soil types of the area are: *Vitric Andosols, Eutric Vertisols, Mollic Andosols, Haplic Luvisols, Haplic Luvisols and Lithic Leptosols* [28].

2.2. Materials

Maize hybrid BH-546 and three haricot beans were used as an experimental crop. The selection of the crop is based on recommended agro ecology. So, for our experiment haricot beans which were recommended for all haricot beans production areas in Ethiopia such as Nasir, Dinkinesh and SER-119 were used.

2.3. Methods

Field activities and treatment application

The experiment was conducted during 2020 and 2021 at the rainy season. Experimental Fields were prepared by Oxen plough followed by manual work. The experiment had seven treatments with three replications designed in RCBD. The areas were 3 mx4 m for each plot. Maize (BH-546), which is the most commonly used by the farmers in the area, was used to evaluate the treatments.

The most commonly grown haricot beans in the area were used as intercropping with maize. The intercropping was done at a ratio of 1:1 (i.e. single row of haricot beans in between maize rows). Maize was planted at 75 cm space between rows and 30 cm within rows and at the time of intercropping haricot beans were planted at a plant spacing of 10 cm [1]. Each plot was separated by 1m walkways in order to reduce inter plot effect. Wedding and other agronomic practices such as hoeing were done according to recommendations. Fertilization, at the time of planting all plots received NPS at the rate of 100 kg ha^{-1} basal application. Nitrogen was applied in the form of urea (46 % N) at the rate of 100 kg ha^{-1} in split form in which one third application was done at knee height stage of maize, while the remaining two third was applied just before tasseling to all plots except the sole haricot bean assuming the bean would be benefited from the fixed nitrogen. Haricot beans were intercropped one month after planting of maize.

The treatments of the experiment were:-

T1: Single row of Nasir in between maize rows (1:1)
T2: Single row of Dinknesh in between maize rows (1:1)
T3: Single row of SER-119 in between maize rows (1:1)
T4: Sole maize (100 % maize)
T5: Sole Nasir
T6: Sole Dinknesh
T7: Sole SER-119

Figure 1. *Haricot Beans-Maize Intercropping Field Performance Picture July, 2020.*

Soil sampling and analysis

One composite soil sample per replication, each made from five sub-samples, was collected in a diagonal pattern from 0-20 cm soil depth before planting. Soil samples were also collected from every plot after harvesting to evaluate the effect of different varieties of haricot bean intercropping with maize on soil chemical properties like soil pH, CEC, total N, available P, and Organic Carbon using standard laboratory procedures.

Total N in the soil was determined by the Kjeldahl method [5]. Organic carbon content of the soil was determined by [30] method. Soil P^{H} was analyzed by (1:2.5 soils to water) method and available P was determined following the method of [22]. Cation exchange capacity (CEC) of soil was determined using ammonium acetate method at pH 7.0 [10]. All the above soil chemical properties were analyzed at Batu soil research center.

Data Collection and Measurements

Yield and yield components were collected after harvesting from all plots. Grain yield per plot (g/plot) was measured using electronic balance and then adjusted to 12.5% seed moisture content and converted to hectare basis.

Land equivalent ratio (LER)

The benefit of intercropping and the effect of competition between component crops were calculated by land equivalent ratio. LER which verifies the effectiveness of intercropping for using the resources of the environment compared to sole planting. The LER values were computed using the following formula described by [31].

$$\mathrm{LER} = \frac{\mathrm{Yab}}{\mathrm{Yaa}} + \frac{\mathrm{Yba}}{\mathrm{Ybb}}$$

Where, Yab and Yba are yield of maize and haricot bean in an intercropping system respectively and Yaa and Ybb are yield of maize and haricot bean in pure stand of each crop respectively.

Data Analysis

Analyses of variances for the data recorded were conducted using the SAS GLM procedure version 9.0. Least significant difference (LSD) test at 5% probability was used for mean separation when the analysis of variance indicates the presence of significant differences [8].

3. Results and Discussion

3.1. Soil Sample Collection and Laboratory Analysis

Table 1. *Soil chemical characteristics of experimental site before treatments application at Bute FTC.*

Soil characteristics	Value at Bute	value at Chabi
pH	5.79	6.09
OC (meq/100g soil)	2.07	2.43
Total nitrogen (%)	0.09	0.10
Available P (ppm)	27.78	9.60
CEC (meq/100g soil)	12.22	17.06

Table 2. *Soil chemical properties after harvesting at Bute and Chabi FTC.*

Treatments	At Bute FTC					At Chabi FTC				
	pH	TN (%)	OC (%)	CEC me/100g	P (ppm)	pH	TN (%)	OC (%)	CEC me/100g	P (ppm)
1	5.83a	0.11a	2.12a	14.91a	24.59ab	6.21a	0.19a	2.73a	17.42a	7.95bc
2	5.82a	0.12a	2.16a	15.45a	23.33b	6.12a	0.19a	2.80a	17.63a	7.86bc
3	5.86a	0.11a	2.13a	14.17a	26.5ab	6.14a	0.15b	3.36a	16.73a	7.83c
4	5.80a	0.08b	2.23a	15.75a	28.36a	6.08a	0.08c	2.35a	18.20a	9.56a
5	5.78a	0.12a	2.16a	13.14a	23.70b	6.07a	0.16ab	2.88a	19.43a	8.43bc
6	5.81a	0.11a	2.26a	15.12a	26.00ab	6.06a	0.18ab	3.16a	18.8a	8.58abc
7	5.83a	0.12a	2.25a	14.36a	25.6ab	6.12a	0.17ab	2.66a	17.91a	8.96ab
mean	5.82	0.11	2.19	14.27	25.44	6.11	0.16	2.85	18.02	8.45
CV (%)	1.27	11.12	5.37	17.76	6.55	2.17	12.55	30.0	8.76	7.34
LSD		0.02			4.32		0.036			1.10
P (<0.05)	ns	*	ns	ns	*	ns	*	ns	ns	*

Means with in same column followed by the same letter (s) are not significantly different at 5% level of significance

3.2. Effect of Different Varieties of Haricot Bean Intercropping with Maize on Soil Fertility

3.2.1. Effect on Soil pH

The soil-pH of both Bute and Chabi FTC before treatments application and after crop harvest is shown in Tables 1 and 2. The result showed that intercropping of haricot bean with maize did not significantly affect soil pH at both FTC (Table 2) indicating that the cropping systems of maize and haricot bean did not affect the pH values of the soil. Similarly, [3] reported that pH values of the rhizosphere soil continued fairly constant during the cropping cycles of intercropping maize with soybean. In contrast [24] have reported that pure stand of field beans had greater effect in raising the soil pH over pure maize.

3.2.2. Total Nitrogen (TN)

Before and after planting total soil nitrogen was not significantly different for sole maize, whereas nitrogen contents of the soil had shown significant ($p \leq 0.05$) difference before and after harvesting by interaction of maize-haricot bean intercropping and for sole haricot beans (Table 2). The improvement of soil N in experimental plots where haricot beans was grown in an intercrop and sole of haricot beans in the present study might be due to the decay of roots and nodules causing the release of N from the legume components into the rhizosphere during the cropping season [27]. It was agreed with works of [32] that reports, cereal-legumes intercropping patterns' effect on total soil N as significant. Exudates that produced by maize may stimulate nodulation in haricot beans which in turn lead to better N under intercropped treatments [26].

3.2.3. Soil Organic Carbon

The organic carbon contents of the soil did not significantly ($P \leq 0.05$) varied before and after planting among maize-haricot bean inter cropping and sole maize at both FTC (Tables 1 and 2). This was not in agreement with [21] who reported that, the soil organic carbon increase in the legume-cereal intercropping, while in mono-cropping cereal there was a small decrease.

3.2.4. Exchange Cation Capacity (CEC)

The Cation exchange capacity (CEC) of the soil was not affected by inter-cropping systems (Table 2). The unchanged in CEC might be due to the unchanged organic matter among treatments. In line with these finding [24] reported the non-significant variation on CEC in intercropping of maize with field beans.

3.2.5. Available Phosphorus (P)

Available phosphorus was significantly higher for sole maize than intercropped maize in both Bute and Chabi FTC (Table 2). The cause for the reduction of soil available phosphorous in intercropping might be due to intercropping exploits various soil phosphorous sources by different plant parts. Haricot beans have high phosphorous requirements for the process of N2 fixation and production of protein containing compounds. Thus, phosphorous concentration in haricot bean is generally much higher than that of cereals. The study result showed that available P content of the experimental soil before planting was higher than after harvesting both under sole and intercropping in both sites (Tables 1 & 2). Similarly report by [17] showed that available P content was reduced in post-harvest soils of all plots in which maize was intercropped with soybean and groundnut at varying row proportion compared to the initial and sole maize.

Table 3. *Maize Haricot bean Intercropping Relative Grain Yield Advantages and LER result of two FTC (Chabi and Bute).*

Treatments	Maize grain yield in kg/ha		Haricot bean Grain Yield (kg/ha)		RYT (M+HB=Kg/ha)		LER	
	Chabi	Bute	Chabi	Bute	Chabi	Bute	Chabi	Bute
BH560 vs Dinknesh	6112a	3828.7a	1152.3a	702.3a	7264.3	4531	1.63	1.36
BH560 vs Nasir	6016a	3733.4a	996.3a	760.2a	7012.3	4493.6	1.44	1.27
BH560 vs SER119	5428a	4171.6a	1126.8a	765.3a	6554.8	4936.9	1.65	1.64
Sole BH560	6195a	4183.3a						
mean	5743.7	3904	1091.8	742.6				
CV%	6.4	25	17.7	4.8				
Sole Dinknesh			2301.9ab	1855.1ab				
Sole Nasir			2992.6a	2427.8a				
Sole SER-119			1730.6b	1356.2b				
mean			2341.7	1879.7				
CV%			21	20.6				

Means with in same column followed by the same letter (s) are not significantly different at 5% level of significance

3.3. Effect of Maize Haricot Beans Intercropping on Grain Yield

The analysis of variance showed that the overall mean value for all the treatments were not significantly ($P>0.05$) affected by intercropping maize and haricot beans. Study by [29] also concluded that planting haricot beans in association had no appreciable effect on the yield of maize. Similarly, [14] indicated that although intercropping maize with beans tended to lower maize grain yield, the effects were not significant. Higher grain yield of maize (6195 kg/ha) and (4183.3 kg/ha) were obtained from sole cropping compared to intercropping both at Chabi and Bute FTC respectively (Table 3). Compare to other haricot beans intercrop, grain yield of maize intercropped with Dinknesh showed better at Chabi (which is low land area of the district) while grain yield of maize intercropped with SER-119 showed better at Bute (which is midland area of the district).

The analysis result revealed that there was a significant ($P<0.05$) difference among the sole haricot bean for the grain yield in the overall of the two locations. Sole Nasir showed better grain yield than sole Dinknesh and SER-119 at both Chabi and Bute sites. Hence, Nasir is more productive in both agro-ecology as a pure stand than both SER-119 and Dinknesh and less productive than the two as an intercropping in both sites (Table 3). In all sole planting haricot beans (SER- 119, Dinknesh and Nasir) planted as a pure stands recorded greater yield of 1730.6kg ha^{-1}, 2301.9 kg ha^{-1} and 2992.6kg ha^{-1} respectively at Chebi and 1356.2 kg ha^{-1}, 1827 kg ha^{-1} and 2427.8 kg ha^{-1} respectively at Bute than that produced from intercropped with maize at both site (Table 3). The higher grain yield of sole SER-119, Dinknesh and Nasir could be attributed to the least competition in sole haricot beans. In line with these finding [9] recorded higher yield of soybean form sole cropping than that produced from intercropped soybean due to the shading effect of maize over soybean.

Land equivalent ratio was more than one (1) for all intercrop treatments (Table 3), which indicates maize-haricot bean intercrop was productive. The highest LER was recorded for SER-119 haricot bean intercropping at both Chabi (1.65) and Bute (1.64) locations. The collective yields obtained from intercrops were more profitable than sole haricot beans and maize. The highest relative grain yield advantage was noted by Dinkinesh intercropping (7264.3 kg/ha) at Chabi and by SER-119 (4936.9 kg/ha) at Bute site (Table 3). In line with this [29, 16] reported that intercropping gave significantly higher combined yield than mono-cropping.

4. Conclusion and Recommendation

The results revealed that intercropping systems were more useful than monocultures of the components. The soil analysis result showed significant change in soil total nitrogen and available phosphorus for the cropping system after harvest. But, there was no significant difference in soil pH, organic carbon and CEC between intercropping and monocultures. The results of this study showed that productivity can be improved by intercropping haricot beans between maize plants as confirmed by high LER. The LER exceeded one in both farmers training centers (FTC) indicating that intercropping was beneficial due to higher utilization of the limited resources. The result indicates that haricot bean yield in the intercropping varies with the bean varieties used at different locations. Therefore, it is important to know that, Dinkinesh can go well to increase production in the haricot bean- maize intercropping at Chabi FTC area (in lowland area), while SER-119 is preferable to increase production in the haricot bean- maize intercropping at Bute FTC area (in midland area).

Acknowledgments

The authors would like to thank Oromia Agricultural Research Institute for funding the research and Adami Tulu Agricultural Research Center for providing all the necessary facilities required for the research. Moreover, all staff members of soil fertility improvement research team who were involved in data collection, monitoring and other stakeholders would be acknowledged. Our special thanks also go to Batu Soil Research Center for their soil sample analysis support.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Abuhay Takele and Jibril Mohammed, 2016. Time of Haricot Bean Intercropping into the Maize- Based Cropping Systems under Conservation Tillage in the Rift Valley of Ethiopia.

[2] Anil L, Phipps RH, 1998. Temperate intercropping of cereals for forage: a review of the potential for Growth and utilization with particular reference to the UK. *Grass and Forage Science*. 53: 301-317.

[3] Ariel C. E., Eduardo O. A., Benito G. E., Lidia G. 2013. Effects of two plant arrangements in corn (Zea mays L.) and soybean (Glycine max L. Merrill) intercropping on soil nitrogen and phosphorus status and growth of World J. Agric. Sci. 076 component crops at an Argentinean Argiudoll. American J. Agric and For., 1(2): 22-31.

[4] Bekunda, M. A., A. Bationo, and H. Ssali. 1997. Soil Fertility Management in Africa: A Review of Selected Research Trials, p. 63-79. In R. J. Buresh et al. (ed.) Replenishing soil fertility in Africa. SSSA Spec. Publ. 51. SSSA, Madison, WI.

[5] Dewis J. and Freitas, P. 1975. Physical and chemical methods of soil and plant analysis.

[6] EPPA (Ethiopian Pulses Profile Agency), 2004. Ethiopian Export Promotion Agency Product Development & Market Research Directorate Ethiopia.

[7] Gebrekidan, H., 2003 Grain Yield Response of Sorghum (Sorghum Bicolor) to Tied Ridges and Planting Methods on Entosols and Vertisols of Haramaya Area, Eastern Ethiopian Highlands. Journal of Agriculture and Rural Development in theTropics and SubTropics, 104, 113-128.

[8] Gomez A. and Gomez A. 1984. Statistical procedures for agricultural research. 2nd ed., Willey J. and Son I., New York, USA, PP: 97-107.

[9] Ijoyah MO. (2014) Maize-soybean intercropping system: Effects on striga control, grain yields and economic productivity at Tarka Benue State Nigeria. Int Lett Natl Sci 14.

[10] Jackson M. 1964. Chemical Composition of soils. In: Bear F. (2ed). Chemistry of the soil, New York. 71-141 PP.

[11] Jama, B., Palm, C. A. Buresh, R. J., Niang, A., Gachengo, C., Nziguheba, G., Amadalo, B., 2000.. Tithonia Diversifolia as a Green Manure for Soil Fertility Improvement in Western Kenya: a Review. Agroforestry Systems 49: 201–221. doi: 10.1023/A:1006339025728.

[12] Karadag Y, 2004. Forage yields, seed yields and botanical compositions of some legume- barley Mixtures under rain fed condition in semi-arid regions of Turkey. Asian Journal of Plant Science. 3: 295-299.

[13] Kipkemoi, P. L., Wasike, V. W., Ooro, P. A., Riungu, T. C., Bor, P. K., &Rogocho, L. M., 2001. Effects of intercropping pattern on soybean and maize yield in central Rift Valley of Kenya. Unpublished paper. Kenyan Agricultural Research Institute.

[14] Kimani, K. K., Gathua, R., Delu, D. J. T. and Cadish, G. (1999) Effects of Maize Bean Intercropping, Phosphorus and Manure Additions on Maize Production in the Central Kenya Highlands. Proceedings of the 6th Eastern and South Africa Regional maize Conference, Addis Ababa, 21-25 September 1998, 293-295..

[15] Ladha, J. K., Pathak, H., Tirol-Padre, A., Dawe, D. and Gupta, R. K.., 2003. Productivity Trends in Intensive Rice Wheat Cropping Systems in Asia. In: Improving the Productivity and Sustainability of Rice –Wheat Systems: Issues and Impacts, ASA Special Publication 65, 45 76. https://doi.org/10.2134/asaspecpub65.c3

[16] Lulie B, Worku W, Beyene S (2016). Determinations of Haricot Bean (Phaseolus vulgaris L.) Planting Density and Spatial Arrangement for Staggered Intercropping with Maize (Zea mays L.) at Wondo Genet, Southern Ethiopia. Acad. Res. J. Agri. Sci. Res. 4(6): 297-320.

[17] Mandal M. K., Banerjee M., Banerjee H., Alipatra A., Malik G. C. 2014. Productivity of maize (Zea Mays) based intercropping system during Kharif season under red and lateritic tract of west Bengal. The Bioscan, 9(1): 31-35.

[18] Masto, R. E., Chhonkar, P. K., Singh, D. and Patra, A. K., 2008. Alternative Soil Quality Indices for Evaluating the Effect of Intensive Cropping, Fertilisation Manuring for 31 Years in the Semi-Arid Soils of India. Environmental Monitoring and Assessment, 136, 419-435. https://doi.org/10.1007/s10661-007-9697-z

[19] Matusso, J., Mugwe, J. and Mucheru-Muna, M., 2014. Potential Role of Cereal- Legume Intercropping Systems in Integrated Soil Fertility Management in Smallholder Farming Systems of Sub-Saharan Africa. Journal of Agricultural and Environmental Management, 3, 162-174.

[20] Mugwe, J., Mugendi, D., Kung˝u, J. and Mucheru-Muna, M., 2007. Effect of Plant Biomass, Manure and Inorganic Fertilizer on Maize Yield in the Central Highlands of Kenya. African Crop Science Journal, Vol. 15, No. 3, pp. 111-126 ISSN 1021-9730.

[21] Nagar RK, Goud VV, Kumar R, Kumar R. 2016. Effect of organic manures and crop residue management on physical, chemical and biological properties of soil under pigeonpea based intercropping system 6(1), 101–113.

[22] Olsen S. and Dean L. 1965. Phosphorus in: Methods of Soil Analysis. In: Black C., (ed). American society of Agronomy. Madison, Wis. USA. pp 1035-1048.

[23] Oromia Regional State Finance and Economic Development Office (OFEDO), 2009. West Arsi zonal Map.

[24] Ossom EM, Rhykerd L 2007. Effect of corn (Zea mays L.) and grain legume associations on soil mineral nutrient concentration, soil temperature, crop yield, land equivalent ratio and gross income in Swaziland. African Crop Science Proceedings, 8: 225-230.

[25] Sanginga, N., &Woomer, P. L., 2009. Integrated soil fertility management in Africa: Principles, practices, and developmental process. CIAT.

[26] Santalla M., Rodino A., Casquero P. and Ron A. 2001. Interaction of bush bean intercropped with field and Sweet maize. European Journal of Agriculture, 15: 185-196.

[27] Szumigalski A. R., Van Acker R. C., 2006. Nitrogen yield and land use efficiency in annual sole crops and intercrops. Agron. J., 98: 1030-1040.

[28] Tadesse H., Kefyalew A., Tilahun F., 2016. Soil Fertility Assessment and Mapping at Shashamane District, West Arsi Zone, Oromia, Ethiopia. IJRIES, Vol 3 Issue No 5, ISSN 2394-1375.

[29] Tolera Abera, 2003. Effects of Nitrogen, Phosphorus, Farmyard Manure and population of Climbing Bean on the performance of Maize (Zea mays L) / Climbing Bean (Phaseolus vulgaris L) intercropping system in Alfisols of Bako. M.Sc. Thesis, Alemaya University, Alemaya, Ethiopia. 116p.

[30] Walkley A. and Black I. A. 1934. An examination of the Degtjareff method for determining soil organic method, and a proposed modification of the chromic acid titration method. soil Sci. 34: 29-38.

[31] Willey R. W. 1985. Evaluation and presentation of intercropping advantages. Experimental Agriculture 21: 119-133.

[32] Wiqar Ahmad, A., Farmanullah, B., Zahir Shah, B., Muhammad, J. B. and Kawsar, A. S. (2013) Recovery of Organic Fertility in Degraded Soil through Fertilization and Crop Rotation. Journal of the Saudi Society of Agricultural Sciences, 13, 92-99.