American Journal of IT and Applied Sciences Research
Vol. 3(1), pp. 1-9, March, 2023

ISSN: 2831-4840
https://www.mprijournals.com/

Full Length Research

Evaluation of Maize Common Bean Intercropping and Phosphorus Critical Level Rate Based on Calibrated Phosphorus in the Maize Based Farming System of Bedele District, Ethiopia.

[1]DAGNE Chimdessa and [2]GEDEFA Sori
[1, 2]Oromia Agricultural Research Institute (IQQO),
Bedele Agricultural Research Center (BeARC),
Bedele, P. O. Box, 167, Ethiopia.
Corresponding Author Email:dagnechim@gmail.com

Accepted March, 10, 2023

Abstract: Inclusion of legumes in cropping systems is essential for sustainable management of farming systems. A field experiment was conducted at Bedele district of south western Ethiopia during the 2020 and 2021 crop growing seasons to evaluate maize common bean intercropping and phosphorus critical level(Pc) rate for optimum maize common bean productivity and profitability. Treatments consisted of factorial combinations of three (without, single and double) rows of common bean between maize rows and four rates of phosphorus critical level (Pc %) (0,50,75 and 100 %)kgha^{-1}, where Pc = phosphorus critical level determined for maize in the district. A sole crop maize with recommended fertilizer rate of 92/100 % N/Pc ha^{-1} was used as a control treatment. The treatments were laid out in a randomized complete block design with three replications. Results indicated that the intercrop system was more productive relative to the sole crop. Common bean when associated with maize showed significant differences on maize grain yield. Maize common bean single row inter crop fertilized with (75% Pc ha^{-1}) increased maize grain yield as compared to sole crop maize. Moreover, maize common bean single row intercropping with (75% Pc ha^{-1}) was the most profitable with marginal rate of return (11.62%).Results from this study indicated that smallholders in the Bedele district can achieve higher maize grain yield productivity and profitability through the implementation of simultaneous intercropping of maize with common bean under inorganic fertilizer application.
Keywords: Common Bean: Intercropping: Maize: Phosphorus: Critical Level.
Cite this Article as: Dagne, C. & Gedefa, S. (2023). Evaluation of Maize Common Bean Intercropping and Phosphorus Critical Level Rate Based on Calibrated Phosphorus in the Maize Based Farming System of Bedele District, Ethiopia. American Journal of IT and Applied Sciences Research, 3(1): 1-9.

1.0 Background of the Study

Low soil fertility is one of the bottlenecks to sustain agricultural production and productivity in Ethiopia. Anthropogenic factors such as inappropriate land use systems, mono cropping, nutrient mining and inadequate supply of nutrients are aggravated the situation (Olusesi & Joshua, 2022; Owhe-Ureghe et al., 2022). To alleviate the problem, Intercropping of legumes in association with non-legumes is an option as it utilizes available resources by component crops (Sarkar et al., 1995). Intercropping is defined as the growing of two or more crops simultaneously on the same field with crop intensification in both time and space dimensions and crops interact during all or part of crop growth and farmers manage more than one crop at a time in the same field (Chu *et al.*, 2004). Increased nutrient uptake in intercropping systems can occur spatially and temporally.

Spatial nutrient uptake can be increased through the increasing root mass, while temporal advantages in nutrient uptake occur when crops in an intercropping system have peak nutrient demands at different times (Rao *et al.,* 1999). In the species that have different rooting and uptake patterns, such as cereal/legume intercropping system, more efficient use of available nutrients may occur and higher N-uptake in the intercrop have been reported, compared mono crops (Li *et al*, 2002; Abdulkadir et al., 2022; Gebeyehu et al., 2022; Ukonu et al., 2022).

Other advantages of intercropping include: insurance against crop failure thereby minimizing risk, better use of resources by plants of different heights, rooting depths and nutrient requirements and a more equal distribution of labour through the growing season (Sanginga & Woomer, 2009). Moreover, intercropping systems more efficiently used the growth factors because they capture more radiation and make better use of the available water and nutrients, reduce pests, diseases incidence and suppress weeds (Addo *et al.*, 2011). And favor soil-physical conditions, particularly intercropping cereal and legume crops which also maintain and improve soil fertility (Akande *et al.,* 2006*)*. This cropping system increased total productivity per unit land, per unit time and improves the judicious utilization of the land and other resources on farm (Okpara *et al.,* 2004). It is mainly practiced to cover the risk of failure of one of the component crops due to vagaries of weather or pest and disease incidence. Yield advantages in intercropping system are mainly because of differential use of growth resources by component crops. The complementarily will occur when the growth patterns of component crops differ in time (Sharma & Choubey, 1991; Egan & Bamfo-Agyei, 2023).

Intercropping of legumes in association with non-legumes helps in utilization of nitrogen being fixed by legumes in the current growing season, but also helps in residual build up of nutrients in soil (Sarkar et al., 1995). Maize -haricot bean has been considered as the best component in most of intercropping system (Susan & Mini, 2005). Haricot bean is known for its soil nitrogen enrichment, rotational advantages and cheaper cost of production. In its roots, there are numerous nodules containing Rhizobium bacteria which form symbiotic association with the plants (Ayua et al., 2023; Abdulkadir & Ajagba, 2022). They fix atmospheric nitrogen into ammonium. Ammonium is then converted into amino acids like glutamine and asparagine which is exported to the plant. In exchange, the plant supplies the bacteria with carbohydrates in the form of organic acids. However, in the study areas, research work regarding intercropping role of common bean and inorganic fertilizer on yield and yield components of maize is very limited. Therefore, the objective of this experiment was to evaluate maize common bean intercropping and phosphorus critical level (PC) rates for optimum maize common bean productivity and profitability in Bedele district.

2.0 Materials and Methods of the Research

2.1 Description of the Study Area

A study was conducted to evaluate maize common bean intercropping and Phosphorus critical level rates in 2020 and 2021 cropping seasons at Bedele district, south western Ethiopia on farmers' fields. Bedele district is located at 08º14’28.6” to 08º37’52.8”N and 036 º13’22.0” to 036 º35’09.1” E with altitude ranging from 1013 to 2390 masl. The 18 years weather information at nearby study area (Ethiopian Meteorology Agency Bedele District Branch) indicated that a uni-modal rainfall pattern with average annual rain fall of 1945 mm. The rainy seasons cover April to October and the maximum rainfall is received in the months of June, July and August. The minimum and maximum annual air temperatures are 12.9 and 25.8.0°C, respectively. The predominant soil type in southwest and western Ethiopia in general and the study area in particular, is Nitisols according to the (FAO, 2001) soil classification system. Its vernacular name is “*Biyyee Dimmaa*” meaning red soil. On the average, the soil is deep and relatively highly weathered, well drained, clay in texture and strongly to moderately acidic in reaction. Nitisols are highly weathered soils in the warm and humid areas of the west and southwest Ethiopia (Mesfin, 1998)

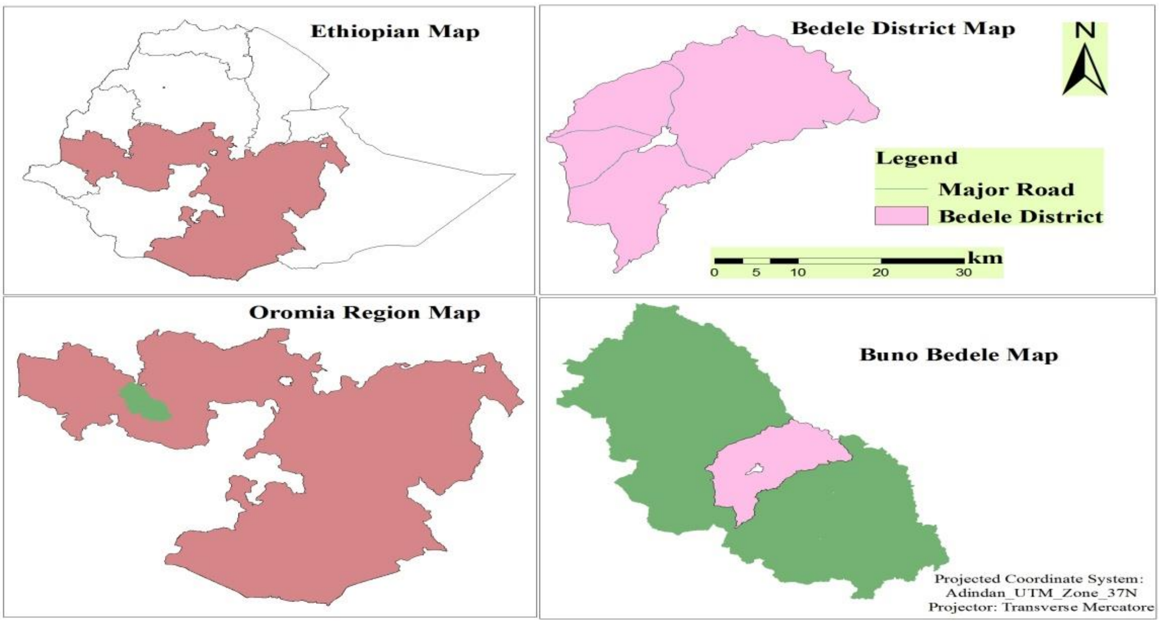

Figure 1. Map of the study area (Bedele District)

2.2 Soil Sampling and Analysis

Composite surface soil samples (0-20) cm depth were collected from each experimental sites before planting to analyze soil pH (H_2O), available P and (%OC), The collected soil samples were prepared and analyzed following standard laboratory procedures at soil analysis laboratory of, Bedele Agricultural Research Center. Soil analysis indicated that the soils in the experimental site are generally strongly acid in reaction (pH 4.6–5.0) and very low in available phosphorus (< 2.3 mg kg^{-1} soil). Total nitrogen is low (< 0.2 %) and organic carbon ranges low (< 2 %). The low contents of available P observed in the study area agreed with the results of similar study (Eylachew, 1999). The low available P in most Ethiopian soils can be attributed to P fixation, crop harvest. Soil erosion and low rate of P sources application. The OC content of the soil was low (Berhanu, 1980). Most cultivated land soils of Ethiopia are poor in their organic matter content due to the low amount of organic materials applied to soil and complete removal of biomass from farm land (Yihenew, 2002). As a result, the major source of organic matter in cultivated soils below ground plant biomass has little contribution to increasing OM (Olson *et al.*, 2014).

2.3 Treatments

Treatments consisted of factorial combinations of three (without, single and double) rows of common bean between maize rows and four rates of phosphorus critical level (Pc %) (0,50,75 and 100 %) $kgha^{-1}$, where Pc = phosphorus critical level determined for maize in the district. A sole crop maize with recommended fertilizer rate of 92/100 % N/Pc ha^{-1} was used as a control treatment.

3.0 Experimental Design and Procedures

A randomized complete block design (RCBD) with three replications was used in a factorial arrangement. Treatment combinations were assigned to each plot using randomization. The gross plot size was $12m^2$ (3m x4m) that accommodated five maize plant rows. Maize variety (BH 661) which is high yielder as compared to other improved maize varieties in the study area was used as a test crop in the district, that was planted in rows with spacing of 80 cm between rows and 25 cm among plants within a row. Common bean variety (Nasir) was planted between maize rows at a spacing of (40 c m × 10cm) between rows and within rows, respectively. Two seeds were planted in each hole. These were thinned down to one seed per hole after two weeks of emergence.

Phosphorus rate was calculated and applied according to the formula, P (kg ha^{-1}) = (Pc – Po)*Pf, where Pc= Phosphorus critical level, Po = initial soil Phosphorus in the soil and Pf= Phosphorus correction factor. Recommended N; (92 kg N ha^{-1}) determined during Phosphorus calibration study for maize in Bedele district was used as source of N. The experimental fields were prepared by using oxen plow in accordance with conventional farming practices followed by the farming community in the area. Where, the fields were plowed four times. Full dose of phosphorous as per the treatment and one-third of N was applied at sowing. The remaining two-third of N was top dressed at 35 days after planting in the form of urea. The field was kept free of weeds by hand weeding during the period of the experiment. All other recommended agronomic management practices disease and insect pest control was done. Finally, maize and common bean grain yields were collected. The collected data was subjected to analysis of variance using SAS software. Mean separation was done by LSD.

Costs that vary among treatments were also assessed using the CIMMYT partial budget analysis (CIMMYT, 1988). The cost of DAP,UREA, the cost of labor required for the application of fertilizer, and cost for shelling were estimated by assessing the current local market prices. The price of, DAP (1997 ETB 100 kg-^{1}), UREA (1394 ETB 100 kg-^{1}), daily labors (35 ETB per one person day based on governments' current scale in the study area) and the cost of maize and common bean shelling (1 ETB $kg^{-1)}$) were considered to get the total cost that vary among the treatments. Time elapsed during each treatment activity was recorded to calculate daily labor required for one hectare. One person per day was estimated based on eight working hours per day. Maize and common bean grain yields were valued at an average field price of ETB 15 and 8 $kg^{-1,}$, respectively, However, other non-varied costs were not included since all agronomic managements were equally and uniformly applied to each experimental plot. Before calculating gross revenue, maize and common bean grain yields obtained from each experimental plot were adjusted down by 10%. Finally, gross revenue was calculated as total yield obtained multiplied by field price that farmers receive for the sale of the crop. The net benefit and the marginal rate of return (MRR) were also calculated as per standard manual (CIMMYT, 1988).

4.0 Results and Discussion

4.1 Effect of Inter Cropping System on Performance of Maize Grain Yield,

There was significant (P<.0.05) effect of cropping system on maize grain yield (Table 1). The highest (9447.9 $kgha^{-1}$) maize grain yield was recorded for the treatment combination of maize common bean double rows inter crop and fertilized with (100% Pc ha^{-1}).However, this treatment was at par with maize common bean single row inter crop and fertilized with (75% Pc ha^{-1}) in maize grain yield. Moreover, maize common bean single row inter crop and fertilized with (75% Pc ha^{-1}) increase in production of 66.5 $kgha^{-1}$as compared to sole crop maize. Maize grain yield increased under intercropping in association with maize common bean compared to that obtained under sole crop maize with inorganic fertilizer application. The cereal based cropping systems in Ethiopia is less efficient compared with intercropping (Bogale *et al.*, 2002) due to continuous cropping. Common bean had a positive effect on associated maize. The conditions that made this type of response possible are mainly due to the maize common bean intercropped decreased inter specific competition between the associated crops for nitrogen use through N2 fixation, especially at low N concentration, that accelerated growth as well as the additional N input generated by the common bean (Suárez *et al., 2021)* that likely impacted on greater photosynthetic activity and C gain by maize (Omoto *et al., 2012)* which translated into increases in grain production (Rao *et al.,*1999). At the level of planting pattern design, the double row arrangement of maize had an impact on weed reduction and therefore facilitated better maize growth (Alemayehu *et al.*, 2018). Results from this study are in agreement with previous studies (Odedina *et al.*, 2014).

Table 1. Interactions effect of maize common bean intercropping on maize grain yield

	Phosphorus critical level (Pc%) ha^{-1}			
Maize common bean intercropping	**0**	50	75	100
	Maize grain yield (kg ha^{-1})			
Sole crop MZ	515.1^{d}	5795.7^{c}	7600.7^{b}	8985.0^{a}
Mz + CB single row	636.6^{d}	6357.1^{c}	9051.2^{a}	9447.9^{a}
Mz + CB double rows	606.5^{d}	6303.3^{c}	8200.2^{b}	9142.4^{a}
Mean	6053.4			
CV(%)	15.0			
LSD	737.9			

Where, means followed by the same letters are not significantly different at (P≤0.05), CB= common bean, MZ=maize,, Pc= phosphorus critical level, ha=hectare, , kg=kilogram, , CV= Coefficient of variation, LSD= Least significant differences, trt= treatment

4.2 Effect of Cropping System on Performance of Common Bean Grain Yield

There was significant (P<.0.05) difference of common bean-maize inter cropping on common bean grain yield (Table 2).The highest (1064.8 kgha^{-1}), followed by (937.5 kgha^{-1}) common bean grain yield was recorded for the treatment combination of maize common bean intercropping single row. Common bean grain yields in maize common bean single row association were greater than that obtained under the double row with inorganic fertilizer application. This could be due to common bean intercropped with maize decreased inter specific competition for nitrogen use through N2 fixation. Intercropping of maize common bean is the possibility of increasing nitrogen (N) use efficiency by the cereal (Bedoussac & Justes, 2010**)** due to its association with the N-fixing legume (Nassary *et al.*, 2020).The change in the microclimatic condition within the intercrop (Alemayehu *et al.,* 2018) could improve and stabilize the yield of the associated crops.(Lithourgidis *et al.*, 2006)

Table 2. Effect of maize common bean intercropping on grain yields of component crops

Trt	Maize common bean intercropping	Pc%	MZ grain Yield(kgha^{-1})	CB grain Yield (kgha^{-1})
1	Sole crop MZ	0	515.1^{d}	-
2	Sole crop MZ	50	5795.7^{c}	-
3	Sole crop MZ	75	7600.7^{b}	-
4	Sole crop MZ	100	8985.0^{a}	-
5	Mz + CB single row	0	636.6^{d}	821.8^{bc}
6	Mz + CB single row	50	6357.1^{c}	798.6^{bc}
7	Mz + CB single row	75	9051.2^{a}	937.5^{ab}
8	Mz + CB single row	100	9447.9^{a}	1064.8^{a}
9	Mz + CB double rows	0	606.5^{d}	706.0^{cd}
10	Mz + CB double rows	50	6303.3^{c}	532.4^{d}

11	Mz + CB double rows	75	8200.2^{b}	671.3^{cd}
12	Mz + CB double rows	100	9142.4^{a}	694.5^{cd}
Mean			6053.4	521.7
CV(%)			15.0	30.7
LSD			737.9	213.9

Where, means followed by the same letters are not significantly different at ($P \leq 0.05$), CB= common bean, MZ=maize,, Pc= phosphorus critical level, ha=hectare, , kg=kilogram, , CV= Coefficient of variation, LSD= Least significant differences, trt= treatment

5.0 Economic Returns from Maize Common Bean Intercropping

Intercropping of maize common bean in single row fertilized with (75% Pc ha^{-1}) was the most profitable with high marginal rate of return(11.62% ha^{-1}) (Table 3).The financial advantage ranged from 1.29%ha^{-1} to 11.62% ha^{-1} with 100%Pc ha^{-1} and75%Pc ha^{-1}in maize common bean single row inter crop, respectively.

Table 3. Summary of partial budget analysis for economic profitability

trt	P_2O_5 (*kgha^{-1}*)	Adj.MZGy (kgha^{-1})	Adj.CBGy (kgha^{-1})	FC (birr)	HTBC (birr)	TVC (birr)	GB (birr)	NB (birr)	MRR (%)
1	0	463.59	-	0	1097.16	1097.16	6953.85	5856.69	-
9	0	545.85	635.40	0	2795.62	2795.62	13270.95	10475.30	2.72
5	0	572.94	739.62	0	3106.39	3106.39	14511.06	11404.70	2.99
2	48.30	5216.13	-	3847.20	12344.84	16192.04	78241.95	62049.90	3.87
10	48.30	5672.97	479.16	3847.20	14560.04	18407.24	88927.83	70520.60	3.82
6	48.30	5721.39	718.74	3847.20	16241.64	20088.84	91570.77	71481.90	0.57
3	72.45	6840.63	-	5770.80	16189.49	21960.29	102609.45	80649.20	4.90
7	72.45	8146.08	843.75	5770.80	18275.93	24046.73	128941.20	104894.00	11.62
11	72.45	7380.18	604.17	5770.80	18896.30	24667.1	115536.06	90869.00	D
4	96.60	8086.5	-	7694.40	18138.05	25832.45	121297.50	95465.10	D
8	96.60	8503.11	958.32	7694.40	19092.05	26786.45	135213.21	108427.00	1.29
12	96.60	8228.16	625.05	7694.40	20952.60	28647.00	128422.80	99775.80	D

Adj.MZGy = adjusted maize grain yield, Adj.CBGy = adjusted common bean grain yield, D=dominated, D.A = dominance analysis, FC=fertilizer cost, GB = gross benefit, HTBC= harvesting, trashing and bagging costs, trt= treatments, trt= treatment

6.0 Conclusion and Recommendation

Intercropping of legumes with cereals as maize showed many benefits. Results indicated that maize common bean intercropping with inorganic fertilizer produced greater grain yield than sole maize crop. Intercropping of maize common bean in single row with (75% Pc ha^{-1}) was the most profitable with high net returns and marginal rate of return relative to maize. Thus, the use of simultaneous intercropping can improve grain production per unit area. Therefore, farmers can benefit financially by practicing maize common bean intercropping in maize based cropping system of Bedele district.

7.0 References of the Research

Addo-Quaye, A. A., Darkwa, A. A. & Ocloo, G. K. (2011). Yield and Productivity of Component Crops in a Maize-Soybean Intercropping System as Affected by Time of Planting and Spatial Arrangement. *Journal of Agriculture and Biological Sciences*, 6(9): 50-57.

Akande, M. O., Oluwatoyinbo, F. I., Kayode, C. O. & Olowokere, F. A. (2006). Response of Maize (*Zea Mays*) and Okra (*Abelmoschus Esculentus*) Intercrop Relayed with Cowpea (*Vigna Unguiculata*) to different Levels of Cow Dung Amended Phosphate Rock. *World Journal of Agriculture Sciences*, 2(1): 119-122.

Ayua, G. T., Magomya, A. M. & Etim, E. E. (2023). A Technical Report of Student Industrial Work Experience Scheme (SIWES) on Oracle Business Conglomerate Feeds Proximate Analysis Lab. *American Journal of Multidisciplinary Research in Africa*, 3(1): 1-12. DOI: https://doi.org/10.58314/2667TYO

Abdulkadir, B. & Ajagba, G. C. (2022). Cassava Grating Machines, Designs and Fabrication: A Review of Related Literature. *American Journal of Multidisciplinary Research in Africa*, 3(1): 1-11. DOI: https://doi.org/10.58314/908876

Abdulkadir, B., Ajagba, G. C. & Joshua, F. J. (2022). Empirical Investigation on the Design and Fabrication of Cassava Grating Machine of 4.5kw. *American Journal of IT and Applied Sciences Research*, 1(4): 1-10. https://doi.org/10.58314/278975

Abebe, M. (1998). Nature and Management of Ethiopian Soils. Alemaya University of Agriculture, Ethiopia. 272p.

Alemayehu, D., Shumi, D. & Afeta, T. (2018). Effect of Variety and Time of Intercropping of Common Bean (Phaseolus Vulgaris L.) with Maize (Zea Mays L.) on Yield Components and Yields of Associated Crops and Productivity of the System at Mid-Land of Guji, Southern Ethiopia. *Adv. Crop. Sci. Tech.* 6, 324–335.

Bedoussac, L. & Justes, E. (2010). Dynamic Analysis of Competition and Complementarity for Light and use to Understand the Yield and the Protein Content of a Durum Wheat-Winter Pea Intercrop. *Plant Soil*, 330, 37–54.

Bhatti, I. H., Ahmad, R., Jabbar, A., Nadeem, M., Khan, M. M. & Vains, S. N. (2013). Agronomic Performance of Mash Bean as an Intercrop in Sesame Under Different Planting Patterns. *Emirates Journal of Food and Agriculture*, 25: 52-57.

Bogale, T., Debele, T., Gebeyehu, S., Tana, T., Geleta, N. & Workayehu, T. (2002). Development of Appropriate Cropping Systems for Various Maize Producing Regions of Ethiopia. In Enhancing the Contribution of Maize to Food Security in Ethiopia: Proceedings of the Second National Maize Workshop of Ethiopia, 12–16 November 2001, Addis Ababa, Ethiopia (Eds M. Nigussie, D. Tanner & S. Twumasi-Afriyie), Pp. 61–70. Addis Ababa, Ethiopia: CIMMYT.

CIMMYT (1988). From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely Revised Edition. (International Maize and Wheat Improvement Center). Mexico, DF. 79p

Chu, G. X., Shen, Q. R. & Cao, J. L. (2004). Nitrogen Fixation and N Transfer From Peanut to Rice Cultivated in Aerobic Soil in Intercropping System and its Effect on Soil N-Fertility. *Plant Soil*, 263, 17–27.

Debele, B. (1980). The Physical Criteria and their Rating Proposed for Land Evaluation in the Highland Region of Ethiopia. Land Use Planning and Regulatory Department, Ministry of Agriculture, Addis Ababa, Ethiopia.

Egan, C. A. & Bamfo-Agyei, E. (2023). The Influence of Temperature Control on Labour Productivity on Masonry Work. *American Journal of IT and Applied Sciences Research,* 3(1): 1-13. https://doi.org/10.58314/23456H

FAO (2001). Lecture Notes on the Major Soils of the World. Driessen, P., J. Deckers, and F. Nachtergaele, (Eds.). Food and Agricultural Organizations, Rome, Italy. 334p.

Gebreselssie, Y. (2002). Selected Chemical and Physical Characteristics of Soils of Adet Research Center and its Testing Sites in Northwestern Ethiopian. Society of Soil Science. *Ethiopian J, Natura. Resource.* 4: 199-215.

Gebeyehu, C., Gedefa, S., Dagne, C. & Garoma, F. (2022). Performance Evaluation of Bread Wheat (Triticum Aestivum L.) Varieties for Grain Yield in BunoBedele, South West Oromia, Ethiopia. *American Journal of IT and Applied Sciences Research*, 1(4): 1-11. https://doi.org/10.58314/467900

Li, L., Tang, C., Rengel, Z. & Zhang, F. S. (2002). Chickpea Facilitates Phosphorous Uptake by Intercropped Wheat From an Organic Phosphorus Source. *Plant and Soil,* 248: 297-303.

Lithourgidis, A. S., Vasilakoglou, I. B., Dhima, K. V., Dordas, C. A. & Yiakoulaki, M. D. (2006). Forage Yield and Quality of Common Vetch Mixtures with Oat and Triticale in two Seeding Ratios. *Field Crops Res*., 99, 106–113.

Nassary, E. K., Baijukya, F. & Ndakidemi, P. A. (**2020).** Productivity of Intercropping with Maize and Common Bean over Five Cropping Seasons on Smallholder Farms of Tanzania. *Eur. J. Agron.* 113, 125964.

Odedina, J. N, Fabunmi, T. O., Adigbo, S. O., Odedina, S. A. & Kolawole, R. O. (2014). Evaluation of Cowpea Varieties (*Vigna Unguiculata*, L Walp) for Intercropping with Okra (*Abelmoschus Esculenta*, L Moench). *Journal of Research Communication*, 2(2): 91-108.

Okpara, D. A., Awurum, A. N. & Okeke, A. I. (2004). Effect of Planting Schedule and Density on Cowpea/Maize Intercropping in South Eastern Nigeria. *Journal of Tropical Agricultural Research*, 11: 59-67.

Olson, K., Ebelhar, S. A. & Lang, J. M. (2014) Long-Term Effects of Cover Crops on Crop Yields, Soil Organic Carbon Stocks and Sequestration. *Open Journal of Soil Science*, 4, 284-292.

Omoto, E., Taniguchi, M. & Miyake, H. (**2012)**. Adaptation Responses in C4 Photosynthesis of Maize Under Salinity. *J. Plant Physiol.*, 169, 469–477.

Olusesi, A. & Joshua, F. J. (2022). An Empirical Investigation of Automatic Streets Lighting Systems Design and Implementation for Crime Prevention in Residential Areas. *American Journal of IT and Applied Sciences Research*, 1(4): 1-10. https://doi.org/10.58314/262690

Owhe-Ureghe, U. B., Okorie, E. C., Olunaike, J. H. & Okhani, P. (2022). Empirical Analysis of Enteric Pathogens in Raw Milk Sold at Aduwawa, Agbor, Asaba, Auchi and Warri, Nigeria. *American Journal of Information Technology and Applied Sciences Research*, 1(3): 1-12. https://doi.org/10.58314/235509

Rao, I. M., Borrero, V., Ricaurte, J. & Garcia, R. (1999). Adaptive Attributes of Tropical Forage Species to Acid Soils. V. Differences in Phosphorus Acquisition from Less Available Inorganic and Organic Sources of Phosphate. *Plant Nutrition,* 22: 1175-1196.

Sanginga, N. & Woomer, P. L. (2009). Integrated Soil Fertility Management in Africa: Principles, Practices and Development Process. (Eds.). Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture. Nairobi. Pp: 263.

Sarkar, R. K., Shit, D. & Chakraborthy, A. (1995). Yield and Economics of Pigeonpea Based Intercropping System on Rainfed Upland of Chotanagpur Plateau. *Indian Journal of Agronomy*, 40: 30-34.

Sharma, R. S. & Choubey, S. D. (1991). Effect of Maize Legume Intercropping Systems on Nitrogen Economy and Nutrient Status of Soil. *Indian Journal of Agronomy,* 9(3): 36: 60-63.

Suárez, J. C., Polanía, J. A., Anzola, J. A., Contreras, A. T., Méndez, D. L., Vanegas, J. I., Noriega, J. E., Rodríguez, L., Urban, M. O. & Beebe, S. (**2021)**. Influence of Nitrogen Supply on Gas Exchange, Chlorophyll Fluorescence and Grain Yield of Breeding Lines of Common Bean Evaluated in the Amazon Region of Colombia. *Acta Physiol. Plant,* 43, 1–15.

Susan, A. J & Mini, C. (2005). Biological Efficiency of Intercropping in Okra (*Abelmoschus Esculentus,* L. Moench). *Journal of Tropical Agriculture,* 43(1-2): 33-36.

Ukonu, C. U., Lasisi, H. O., Adewole, E. A. & Olunaike, J. H. (2022). Empirical Analysis of Hydrogen Cyanide in Streams used for Commercial Fermentation of Cassava. *American Journal of IT and Applied Sciences Research,* 1(3): 1-9. https://doi.org/10.58314/456890

Zewdie, E. (1999). Selected Physical, Chemical and Mineralogical Characteristics of major Soil Soccurring in Chercher Highlands, Eastern Ethiopia. Ethiopian Society of Soil Science. *Ethiopian J .Natural Resource,* 1: 173-185.