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Research Article

Soil Test Crop Response Based NPS Fertilizer Rates Determination for Maize (Zea mays L.) Production at Sibu Sire District, Western Oromia Region

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Abstract

The use of improper fertilizer type and amount, the cultivation of unimproved, low-yielding varieties and poor soil fertility are among the main obstacles limiting the productivity of maize in Ethiopia in general and in the study area in particular. A field trial was therefore initiated to identify economically justifiable amount of NPS fertilizer in Sibu Sire district. The treatments consist of 100% Pc from TSP and 100, 75, 50, 25% Pc from NPS fertilizer with all recommended N fertilizer and control (no fertilizer application). The experimental design was a randomized complete block design (RCBD) with three replications. Limu seed variety was used for the trial. The results of soil samples collected before sowing showed a deficiency in soil chemical properties. Results of agronomic data showed that all Pc rates significantly increased the plant height, cob length, Seeds per cob and grain yield over control. Phosphorus critical level rate of 100% Pc from NPS gave grain yield (7057 kg ha^{-1}), which is not statistically not different from the application of 50, 75 and 100 % Pc from NPS and also 100% Pc from TSP. The application rate of 75% Pc from NPS offered net return of 130045 ETB ha^{-1} which was substantially greater than the rest of the fertilizer application. Hence, fertilizer application rate of 75% Pc from NPS is more economically beneficial and recommended for maize production in Sibu Sire district. It is important to deal with further awareness creation and demonstrating of the technology for wider popularization.

Keywords

Fertilizer, Maize, P-Critical Level, Rate and Soil

1. Introduction

Cereals are the most widely grown crops and comprise about 79.44% of total grain production in Ethiopia [9]. The dominant cereal crops in Ethiopian agriculture are maize, teff, sorghum, barley and wheat. Currently, maize is the cereal with the largest production in volume, number of growers (about ten million farmers in the 2021 production season) and second in production area, after teff [1, 10]. In the last three years 7,823,311 tons of maize had been produced per annum on average [7-10].

At the national level, maize productivity is about 4.24 tons ha^{-1} and currently ranks 1st compared to the other cereals in the total national production [9]. Maize grows in wide ranges

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of agroecologies such as moisture stress areas to high rainfall areas and from lowlands to the highlands of Ethiopia [35]. There is growing evidence on the role of crop diversification as an effective farm-level response to agroecology variability [4] In Oromia Region, among the total land size of 5,860,125.82 ha planted by all cereals, maize covered 1,207,526.12 ha, which is 20.6% of the production area covered by all cereals. It is the first major crop in the region. The regional productivity of maize is about 4.41 t ha^{-1} [9].

Agro ecology of Eastern Wollega zone are an ideal condition for maize production. In the Zone maize crop is widely produced for the purposes of both consumption and marketing. The zones' mean productivity of maize is about 4.65 t ha^{-1} and ranks 1^{st} compared to the other cereals production in the zone [9]. The maize variety, limu is the most widely grown in Sibu Sire district of Eastern Wollega Zone, which is currently under production. The district's mean productivity of maize is too low and even less than half of the potential productivity of maize that could be obtained through using improved maize varieties [30]. There are several factors that hampered maize production in this district. Among others, unwillingness of farmers to accept new improved maize varieties, inappropriate management practices and soil degradation leading to low soil fertility are the most important factors that limit maize production potential of this district [2]. Particularly for maize, a staple food in rural Ethiopia, intensification efforts through use of inorganic fertilizer, combined with improved farming practices, have been a policy priority [5].

Major plant nutrients like N, P and S are among nutrients limiting plant growth but depleted in alarming rate. Moreover, the soil fertility mapping project in Ethiopia reported the deficiency of K, S, Zn, B and Cu in addition to N and P in major Ethiopian soils and thus recommend application of customized and balanced fertilizers [16]. Moreover, [20, 22, 19] reported that S content in the soils they studied were found to be very low in some Ethiopian soils. Different blended fertilizers at different rates significantly contributed to growth and yields of crops [14]. The need for S fertilization should be particularly related to the amount of N being applied since both nutrients are required for protein formation. There are increasing reports that application of S in combination with N and P increases crop yields, suggesting an increased need for inputs of these nutrients as N and P deficiencies are alleviated [32, 34]. Due to these, new fertilizers such as NPS (19% N, 38% P_2O_5 and 7% S) are currently being used by the farmers in Ethiopia including the study area. Critical phosphorus level of 10 ppm, Phosphorus requirement factor of 20.63 ppm and economically optimum N of 138 kg h^{-1} were recommended for bread wheat production at Jima Arjo district [25]. However, fertilizer trials involving multi-nutrient blends of NPS fertilizer were not conducted in the study area. Therefore, it needs calibration of the NPS fertilizer rate based on soil tests in the study area to increase bread maize production and productivity in the study area.

Objective/s:

To determine NPS fertilizer rate based on soil test crop response based P calibration study for maize production in Sibu Sire districts.

2. Materials and Methods

2.1. Description of the Study Area

The study area, Sibu Sire District, is located about 270 km west of the capital city of Ethiopia, Addis Ababa. It lies between 8°56' to 9°23'N latitudes and 36°35' to 36°56' E longitudes and the study area (Figure 1). The altitude of the District varies from 1336 to 2500 meters above sea level. It has an estimated area of 1,132.51 km. About 74.2% of its surface area belongs to Mid-altitude 7.53% of the land is highland agro climate and the remaining 18.27% is classified as low land agro climate. The mean annual temperature and mean annual rain fall is 250 ^{O}C and 1050 mm, respectively [27].

The terrain is generally undulating to rolling plains. The major soil types are generally described as Nitisols according to FAO soil classification system [18]. This soil is characterized as deep, well-drained, red, tropical soils with diffuse horizon boundaries and a clay-rich nitic subsurface horizon. In general this soil is highly weathered, well drained, clay in texture and strongly to moderately acidic in reaction [24] The major annual and perennial crops grown in the study area are maize (Zea mays L.), sorghum (Sorghum bicolor L.), teff (Eragrostis tef), hot pepper (Capsicum frutescence L.), sweet potato (Ipomoea batatas L.), coffee (Coffe arabica L.), and sugarcane (Saccharum officinarum L.) [26].

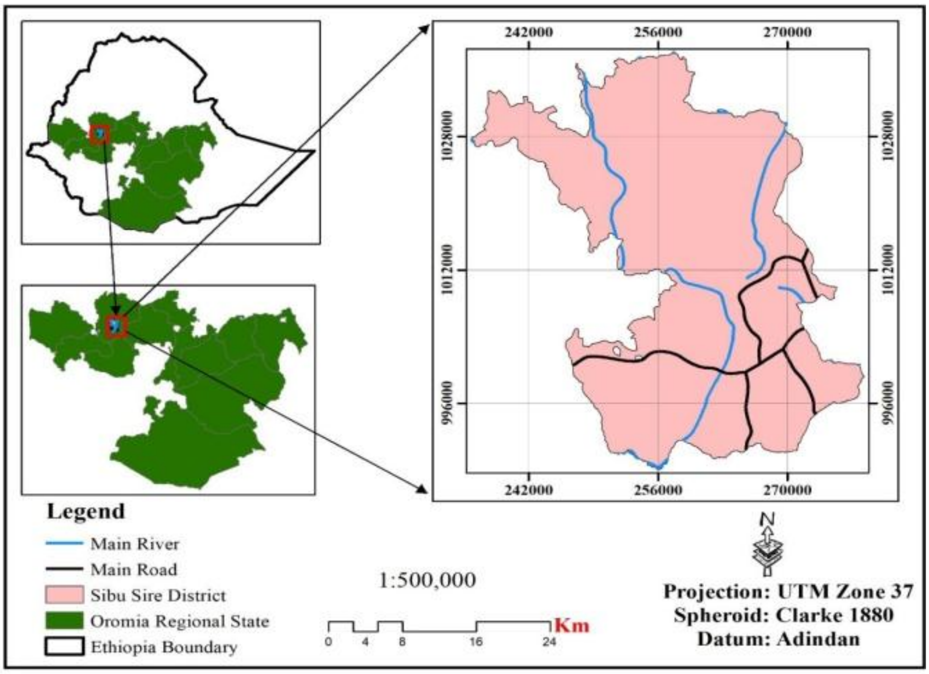

Figure 1. *Location map of the study area.*

2.2. Experimental Materials, Treatments, and Design

The study was conducted in 2022/23 year during the main cropping seasons at Sibu Sire district, East Wollega Zone, Oromia region. Sibu Sire district was selected for the implementation of the trial due to its potential for maize production. The study was conducted on four experimental sites/farmers' fields across the district. Those fields were selected based on farmers' willingness to provide land for the experimental purpose, initial phosphorous soil test value (less than P critical level), best performing farmers in maize production and accessibility to the road. Composite soil samples before planting were collected from all experimental sites. Important soil chemical analysis for available phosphorus, pH, Organic Carbon and Total Nitrogen were done.

The experiment design was a randomized complete block design (RCBD) with three replications. The spacing and plot size used were 75*30 cm and 5 m *4.8 m respectively. The treatments consisted of five (0, 25, 50, 75 and 100%) P critical levels (Pc) calculated from NPS fertilizer and one previously recommended P critical level (100% Pc) calculated from TSP fertilizer was included, which was used as check, that means the total number of treatment were six. Economically optimum N fertilizer was applied to all treatments except control. Spacing between blocks and plots of the experiments were 1 m and 0.5 m, respectively. Maize variety of *Limu* was used.

2.3. Data Collection

Agronomic data like Plant height, cob length, seeds per cob and grain yield were collected. Harvesting was done at physiological maturity. Grain yields were measured based on plant samples taken from each plot at full maturity stage. Grain yield recorded on plot basis was converted to kg ha^{-1} for statistical analysis.

2.4. Economic Analysis

The average open market price (Birr kg^{-1}) for maize during the harvesting time and the official prices of fertilizers during planting time were used for economic analysis. The dominance analysis procedure was used to select potentially profitable treatments from the range that was tested as detailed in [12]. The selected and discarded treatments using this technique are referred to as un dominated and dominated' treatments respectively. For each pair of ranked treatments, a marginal rate of return (MRR %) was calculated. The % MRR between any pair of undominated treatments denotes the return per unit of investment in fertilizer expressed as a percentage. Grain yield was adjusted down by 10% in order to minimize the effect of trial managed on small plots that may vary from the yield level on farmer's fields [21]. The optimum level of blended NPS fertilizer rate was determined for bread wheat production in the district.

2.5. Data Analysis

All data recorded and collected were subjected to the procedure of analysis of variance (ANOVA) using SAS software program [29]. The comparisons among treatment means were employed by using of Least Significance Difference (LSD) at 5% significant level.

3. Results and Discussions

3.1. Soil Reaction, Available Phosphorus, Organic Carbon and Total Nitrogen

The laboratory analysis results of the sites as indicated in table 1 below, the soil pH were ranged from very strongly acidic to slightly acidic in reaction [11]; available P content ranged from very low to low [13] and OC contents ranged from low to medium [31].

Soil pH result clearly indicated that the value was below the described range and the soil was not suitable for acid susceptible crop production with regard to pH. For optimum such crop production, the soil pH should be adjusted to the desired range through management intervention. The low contents of available P observed in the study area agreed with the [17] of study results. The low available P in most western Oromia soils can be attributed to P fixation, crop harvest, soil erosion and low rate of P sources application. The low organic carbon content of the soil might be due to low input of organic sources such as animal manure, compost and household wastes. Farmers of the area also remove crop residues from the cultivated fields for fuel and animal feeds. Thus, crop residues incorporation into soil is almost null. As a result, the major source of organic matter in cultivated soils below ground plant biomass has little contribution to increasing OM [28]. This low organic carbon contents of the study area were comparable with the findings of [36].

Table 1. *Selected experimental soil properties before planting in Sibu Sire District.*

Sites	pH (H_2O)	Av. P (ppm)	OC (%)	TN (%)
1	5.19	2.42	1.98	0.17
2	5.75	3.92	1.63	0.14
3	6.29	8.46	1.42	0.12
4	5.55	8.57	1.28	0.11

Where Ph = power of hydrogen; Av. P = Available phosphorus; ppm = parts per million; OC = Organic Carbon and TN =total Nitrogen

3.2. Responses of Yield and Yield Related Parameters of Maize to the Treatments

ANOVA indicated that overall maize height, cob length, seed number per cob and grain yield was highly and significantly affected by Pc based application of fertilizers. The result showed that most of recorded parameters increased with an increasing of NPS fertilizer rate application. Most of the traits of maize obtained from the application of 50, 75 and 100 % Pc from NPS and also 100% Pc from TSP were not statistically different among each other. The highest grain yield (7057 kg ha^{-1}) which was 4.6% over the 100% Pc from TSP was obtained by 100% Pc from NPS supplemented with recommended Nitrogen. While the lowest (2871.3 kg ha^{-1}) was recorded from control (without fertilizer). Among the treatments received fertilizers, application of 25% Pc from NPS relatively produced significantly the lowest grain yields (Table 2). This could be attributed due to efficient utilization of P applied.

The increment in those parameters might be due to increase in cell elongation, improved root growth and better growth which enhanced yield components and yield of crops. Different nutrient content of fertilizer containing NPS and the increasing of sulfur content caused a significant increase in maize root and shoot growth as well as nutrient uptake. This result is in lined with different authors' like [3, 6, 15, 23] results [33] works result also agreed with this result which investigated photosynthesis, respiration, energy storage and transfer of plants were enhanced by availability of P to plants.

Table 2. *Treatment influences on mean grain yields and selected yield related traits of maize in Sibu Sire for 2022/23 cropping season.*

Treatment	PH (cm)	CL (cm)	SPC (no)	GY (kg/ha)
Control (with out fertilizer)	135.67^{b}	9.58^{b}	285.17^{c}	2871.3^{c}
25% of Pc from NPS + rec. N	210.08^{a}	16.08^{a}	458.31^{b}	5399.7^{b}
50% of Pc from NPS + rec. N	212.92a	16.02^{a}	513.35^{ab}	6083.8^{ab}
75% of Pc from NPS + rec. N	222.08^{a}	15.92^{a}	525.23^{ab}	6809.4^{a}
100% of Pc from NPS + rec. N	218.92^{a}	14.57^{a}	527.35^{ab}	7057.0^{a}
100% of Pc from TSP + rec. N	220.67^{a}	15.87^{a}	534.29^{a}	6734.9^{a}
PV	<0.0001	<0.0001	<0.0001	<0.0001

Treatment	PH (cm)	CL (cm)	SPC (no)	GY (kg/ha)
LSD (0.5)	21.29	2.25	72.86	1104.6
CV (%)	5.88	8.62	8.64	10.59

Where PH = Plant height; CL = Cob length; SPC = Seeds per Cob; GY = Grain yield; PV = Probability value, LSD = Least significance difference and CV = Coefficient of variation.

Figure 2. Photo taken during the implementation.

3.3. Partial Budget Analysis

The partial budget analysis showed that the highest net income (131004.5 ETB ha^{-1}) with the marginal rate of return (MRR) (183.6 %) was obtained from the fertilizer application of 75% Pc from NPS fertilizer with recommended Nitrogen fertilizer (138 kg N ha^{-1}) (Table 3). Therefore, application of NPS fertilizer at the rate of 75% Pc from NPS fertilizer with supplemented recommended nitrogen fertilizer (138 kg N ha^{-1}) for the production of maize was more economically beneficial and recommended for Sibu Sire district.

Table 3. Economic analysis for maize production in Sibu Sire district.

Treatments	GY (qt/ha)	AGY (qt/ha)	GFB (ETB/ha)	TVC (birr/ha)	NB (birr/ha)	MRR (%)
Control (with out fertilizer)	28.71	25.8	77517.0	12919.5	64597.5	
25% of Pc from NPS + rec. N	53.99	48.6	145773.0	39255.0	106518.0	159.2
50% of Pc from NPS + rec. N	60.84	54.8	164268.0	45935.0	118333.0	176.9
75% of Pc from NPS + rec. N	68.09	61.3	183843.0	52838.5	131004.5	183.6
100% of Pc from NPS + rec. N	70.57	63.5	190539.0	57514.0	133025.0	43.2
100% of Pc from TSP + rec. N	67.35	60.6	181845.0	59428.0	122417.0	D

Where: GY = Grain yield; AGY = Adjusted Grain Yield; qt/ha = Quintal per hectare; GFB = Gross field benefit; TVC =Total variable cost; NB = Net benefit and MRR = Marginal rate of return. While the unit price of maize at farm gate during harvesting time, urea, NPS and TSP during the planting time were 30, 38, 43.5 and 41.50 birr/kg respectively.

4. Conclusions

Maize is one of the most important staple foods and one of the most important crops for food security in Ethiopia. However, the maize yield in Ethiopia and in the study area is low compared to the achievable yield, as maize production is limited by poor soil fertility, cultivation of unimproved low-yield varieties and use of unsuitable type and amount of fertilizer. Moreover, the optimum productivity of any cropping system depends on an adequate supply of plant nutrients. Soil test crop response based fertilizer rate recommendation has been conducted across the country. However, fertilizer trials involving multi-nutrient NPS fertilizer were not conducted in many areas. Therefore, for increasing maize production and productivity it need calibration of NPS fertilizer rate based on soil test crop response based. The study was conducted to determine economically optimum NPS fertilizer rate based on phosphorus calibration study done previously for maize production in Sibu Sire District.

Laboratory analysis results of soil samples collected before sowing showed a deficiency in soil chemical properties. ANOVA results of the study indicated that there were significant increase of grain yields and other important agronomic characters of maize for 100% Pc from NPS treatments which is statistically not different from 50, 75, 100% pc from NPS and 100% Pc from TSP with recommended nitrogen (138 kg ha^{-1}). Preferably, reasonable marginal rate of return was recorded for the treatment of 75% of Pc from NPS with recommended nitrogen (138 kg ha^{-1}).

5. Recommendations

Hence, 75% Pc from NPS with recommended nitrogen (138 kg ha^{-1}) is recommended for maize production in Sibu Sire districts of East Wollega zones of western Oromia Region. Obviously the technology could be new for farmers used blanket fertilizer recommendations for long time. Indeed, it is important to deal with further awareness creation and demonstrating of the technology for wider popularization. The awareness creation and demonstrating of NPS fertilizer rates based on calibrated phosphorus for maize production in the respective district require research and extension efforts.

Abbreviations

AGY	Adjusted Grain Yield
ANOVA	Analysis of Variance
Av. P	Available Phosphorus
CL	Cob Length
CV	Coefficient of Variation
FAO	Food and Agricultural Organization
GFB	Gross Field Benefit
GY	Grain Yield
LSD	Least Significance Difference
LSD	Least Significant Different
MRR	Marginal Rate of Retarn
NB	Net Benefit
OC	Organic Carbon
Pc	Phosphorus Critical
Pf	Phosphorus Requirement Factor
Ph	power of Hydrogen
PH	Plant Height
ppm	Parts Per Million
PV	Probability Value
qt	Quintal
RCBD	Randomized Complete Block Design
SPC	Seeds Per Cob
TN	Total Nitrogen
TSP	Triple Supper Phosphate
TVC	Total Variable Cost

Author Contributions

Temesgen Chimdessa: Methodology, Software, Writing – original draft

Mintesinot Desalegn: Formal Analysis, Supervision, Writing – review & editing

Chalsissa Takale: Conceptualization, Project administration

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Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Abate, T., Shiferaw, B., Menkir, A., Wegary, D., Kebede, Y., Tesfaye, K., Menale, K., Gezahegn, B., Berhanu, T. and Keno, T. (2015). Factors that transformed maize productivity in Ethiopia. Food Security, 7(5), 965-981.

[2] Abdenna Deressa, Wakene Negassa, Fite Getaneh and Kefyalew Negisho. 2014. Optimum NP Fertilizers Rate For Wheat Production on Alfisols of Arjo and Shambu Highlands, Western Ethiopia. *Journal of environment and human,* 1: 2.

[3] Abebaw Tadele and Hirpa Legese. 2018. Effects of Fertilizer Rate (Blended) and Sowing Methods On Yield And Yield Components Of Bread Wheat (Triticum Aestivum) In Western Ethiopia, Int. J. Compr. Res. Biol. Sci. (2018). 5(6): 1-16.

[4] Asfaw, S., Scognamillo, A., Di Caprera, G., Sitko, N., and Ignaciuk, A., 2019. Heterogeneous impact of livelihood diversification on household welfare Cross-country evidence from Sub Saharan Africa. World Development, 117, 278–295.

[5] Assefa, B. T., Reidsma, P., Chamberlin, J., and van Ittersum, M. K., 2021. Farm-and community level factors underlying the profitability of fertiliser usage for Ethiopian smallholder farmers. Agrekon, 60(4), 460-479.

[6] Bizuwork Tafes. 2018. Growth, Yield and Grain Quality of Durum Wheat (Triticum turgidum L. var. durum) as Influenced by Rates of Blended NPSB and N Fertilizers at Debre Zeit, Central Ethiopia. MSc Thesis, Haramaya University.

[7] Central Statistics Agency (CSA)., 2018. Agriculture Sample Survey 2017/2018 (2010 E. C.). Statistical Bulletin, Report on Farm Management Practices (Private Peasant Holdings, Meher Season). CSA: Addis Ababa, Ethiopia. 153 153.

[8] Central Statistics Agency (CSA)., 2019. Agriculture Sample Survey 2018/2019 (2011 E. C.). Statistical Bulletin, Report on Farm Management Practices (Private Peasant Holdings, Meher Season). CSA: Addis Ababa, Ethiopia.

[9] Central Statistics Agency (CSA). (2021). Agriculture sample survey 2020/2021 (2013 E. C.). Statistical bulletin 590, report on farm management practices (private peasant holdings, Meher season).

[10] Central Statistics Agency (CSA). 2020. Agriculture sample survey 2019/2020 (2012 E. C.). Statistical bulletin, report on report on area and production of major crops (private peasant holdings, Meher season). Addis Ababa: CSA.

[11] Chude, V. O., Jayeoba, O. J. and Oyebanyi, O. O. 2005. Hand book on soil acidity and use of agricultural lime in crop production. Published by *NSPFS Nigeria.* Pp 7-24.

[12] CIMMYT (International Maize and Wheat Improvement Center), *An Economic Training Manual: From Agronomic Data Recordation*, CYMMT, Mexico City, MX, USA, 1988.

[13] Cottenie, A. 1980. Soil and plant testing as a basis of fertilizer recommendations. FAO soil bulletin 38/2. Food and Agriculture Organization of the United Nations, Rome.

[14] Diriba-Shiferaw, G. and Tilaye-Batu, G., 2020. Effects of Different Rates of NPS, NPSB and NPSZn Blended Fertilizers on Growth and Yields of Potato (Solanum tuberosum L.). *Discovery Agriculture*, *6*(16), pp. 184-192.

[15] Doberman, A. and Fairhurst, T., 2000. Nutriments Disorders and Nutriments Management. International Plant Nutrition Institute.

[16] Ethio-SIS (Ethiopian Soil Information System), *Soil Analysis Report Agricultural Transformation Agency*, EthioSIS (Ethiopian Soil Information System), Addis Abeba, Ethiopia, 2014.

[17] Eylachew Zewdie, 1999. Selected physical, chemical and mineralogical characteristics of majorsoil soccurring in Chercher highlands, Eastern Ethiopia. Ethiopian Society of Soil Science. Ethiopian J. Natural Resource 1: 173-185.

[18] FAO (1986) The Ethiopian highlands reclamation study (EHRS). vol 1, In: Main Report. Food and Agriculture Organization of the UN, Rome.

[19] Habtamu, A., Heluf, G., Bobe, B., & Enyew, A. (2014). Fertility status of soils under different land uses at Wujiraba Watershed, North-Western Highlands of Ethiopia. *Agriculture, Forestry and Fisheries*, *3*(5), 410-419.

[20] Habte, M., Hiluf, G. & Haile, W. (2013). Decomposition and nutrient release of selected green manure species at different stages of growth on Alisols at Areka, southern Ethiopia. *International Journal of Natural Sciences Research*, *1*(5), 30-42.

[21] International Maize and Wheat Improvement Center (CIMMYT), 1998. "From Agronomic data to Farmer Recommendations", An Economic work Book. Mexico, D. F.: CIMMYT, 1988.

[22] Laekemariam, F. (2015). Soil spatial variability analysis, fertility mapping and soil plant nutrient relations in Wolaita zone, Southern Ethiopia. *Haramaya University Ethiopia*.

[23] Melesse H. 2017. Response of bread wheat (Triticum aestivum L.) varieties to N and P fertilizer rates in Ofla district, Southern Tigray, Ethiopia. African Journal of Agricultural Research 12(19): 1646-1660.

[24] Mesfin Abebe. 1998. Nature and management of Ethiopian soils. Alemaya University of Agriculture. Alemaya, Ethiopia. 272p.

[25] Mintesinot, D., Chalsissa, T., Temesgen, Ch., Rafissa, L., Chaltu, R.., Firaol, G. and Amanuel, T. (2021). Soil Test Crop Response Based Phosphorous Calibration Study for maize in Sibu Sire District, Western Oromia, Ethiopia. Proceedings of Review Workshop on Completed Research Activities of Natural Resource Research Directorate Held at Batu Fishery and Other Aquatic Life Research Center, Batu, Ethiopia, 23-27 December 2021.

[26] Negassa, W., Price, R. F., Basir, A., Snapp, S. S. and Kravchenko, A., 2015. Cover crop and tillage systems effect on soil CO_2 and N_2O fluxes in contrasting topographic positions. *Soil and tillage research*, *154*, pp. 64-74.

[27] Ngigi S (2003) Review of irrigation development in Kenya. International Water Management Institute Colombo Sri Lanka 35-37.

[28] Olson, K., Ebelhar, S. A. and Lang, J. M. 2014. Long-Term Effects of Cover Crops on CropYields, Soil Organic Carbon Stocks and Sequestration. Open Journal of Soil Science, 4, 284-292.

[29] SAS Institute Inc., 2002. SAS/STAT® 9.3 user's guide. Cary, NC: SAS Institute Inc.

[30] Sibu Sire District Agricultural Office (SSDADO). 2023. Annual Report for the year 2022-2023. (unpublished report). Sibu Sire District Agricultural Development Office. Sire, Ethiopia.

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

[32] Tilahun Abera and Tamado Tana. 2019. Growth, yield component and yield response of durum wheat (Triticum turgidum L. var. Durum) to blended NPS fertilizer supplemented with N rates at Arsi Negelle, Central Ethiopia. Vol. 13(1), pp. 9-20, January 2019.

[33] Tisdale, S. T., W. L. Nelson, J. D. Beaton. 2002, Soil fertility and fertilizers 4th edition, Macmillan publishing company, New York.

[34] Wilkinson, S. R., D. L. Grunes, and M. E. Sumner. 2000. Nutrient interactions in soil andplant nutrition. In: Handbook of soil science, M. E. Sumner, Ed., Boca Raton, FL: CRCPress.

[35] Wondesen T, Sheleme B. (2011) Identification of Growth Limiting Nutrients in Alfisols: Soil Physico-chemical Properties, Nutrient Consentrations and Biomass Yield of Maize. Ame. J. Plant. Nutri. Fertili. Technolo. 1. (1). pp. 23-35. https://doi.org/10.3923/ajpnft.2011.23.35

[36] Yihenew Gebreselssie, 2002. Selected chemical and physical characteristics of soils of AdetResearch Center and its testing sites in Northwestern Ethiopian. Society of Soil Science. Ethiopian J, Natural. Resource. 4: 199-215.

Research Fields

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