JOURNAL OF SOILSCAPE AND AGRICULTURE

Volume 3, Number 1, 2024
E-ISSN: 2963-7961
Journal Homepage: http://journal.unej.ac.id/JSA

Verification of Soil Test Crop Response Based Calibrated Phosphorus for Food Barely (*Hordeum Vulgare* L.) Production in Sinana District, Bale Zone, Oromia Region, Southeast Ethiopia

Mulugeta Eshetu[*a], Regassa Gosa[a], Tesfaye Ketema[a], Girma Getachew[a]

[a] Sinana Agricultural Research Center, Soil Fertility Improvement, Research Team, Bale-Robe, Ethiopia

ARTICLE INFO

Article History:
Received: 01 - 08 - 2024
Accepted: 23 - 09 - 2024

Keyword:
Blanket;
Optimum Nitrogen;
Phosporous critical;
phosphorus requirement factor;
Soil Test-based Fertilizer;

Corresponding Author:
Mulugeta Eshetu
[a]Sinana Agricultural Research Center, Soil Fertility Improvement, Research Team, Bale-Robe, Ethiopia
*email:
mulugeteshetu@mail.com

ABSTRACT

Nitrogen and phosphorus are the main variables restricting crop productivity in the soil of the study area, especially, in food barely productions. In the Sinana district, soil test-based phosphorus calibration studies were carried out in the past, and fertilizer 46 N kg ha^{-1}, P critical (20 ppm), and P requirement factor (4.60) were recommended for food barely production. To confirm the phosphorus critical (Pc) level and phosphorus requirement factor (pf) found during soil test crop response based phosphorus fertilizer calibration study for food barely production in 2022 bona (July to December) main cropping season, an on-farm field experiment was carried out in this study. The experimental setting comprised three treatments: (1) control (without fertilizer), (2) farmer practices as a blanket recommendation, and (3) soil test crop response-based phosphorus recommendation results. The improved food barely, Adoshe variety was used as a test using farmers as replication in seven sites with 10 m × 10 m plot sizes. Soil samples before planting were taken at 0 - 20 cm soil depth using a random sampling technique and analyzed using standard laboratory procedures. In contrast, the agronomic parameters were analyzed using R software 4.1.1 version. The results show soil sample analysis varied from 6. 03 to 6.25, 1.68 to 2.62%, and ranged from 1.01 to 3.30 mg/kg for soil pH (pH_H_2O), OM, and available phosphorus, respectively. The results revealed a significant ($p < 0.05$) difference between food yield and yield components. The soil test crop response-based phosphorus recommendation results yielded the highest grain yield (5682.43 kg ha^{-1}) with a marginal rate of return (4131.16%). Thus, for food barely production in Sinana District, the Pc (20 ppm) and pf (4.60) with optimal N (46 kg ha^{-1}) were verified from this study. It should be recommended that further demonstrate and scale up the application of soil test-based fertilizer recommendations, to extrapolate Pc and Pf for similar soil types, and to determine the adjusted NPS fertilizer rate using calibrated phosphorus for food barely production.

INTRODUCTION

Food barley (*Hordeum vulgare* L.) is one of the earliest cereal crops, crucial to the development of agriculture (Malla *et al*., 2021). Barley is one of the most significant cereal crops in the world, ranked fourth behind rice, wheat, and maize. For many smallholder farmers in the Ethiopian highlands, it is the most significant crop for food production, animal feed, and revenue (Bayeh and Berhane, 2011). However, several problems influence food barely production despite its great significance and utility for economic development and food security (Melle *et al*., 2015).

In the Ethiopian highlands, low soil fertility, inadequate agronomic techniques, and traditional production methods are the main causes of low barley yields and the most limiting factor for barley production (Abera *et al*., 2011; Lake and Bezabih, 2018; and Abera *et al*., 2018). Soil fertility issues, flooding, bug and pest infestations, inadequate crop management techniques, and lodging are the primary causes of decreased food barley production.

Due to erosion, leaching, and low nutrient recycling are the possible reasons for poor nutrient contents particularly those in the highlands of Ethiopia soils (Malla *et al*., 2021). In Ethiopia's highlands, one of the main problems restricting barley production is the depletion of soil fertility (Bayeh and Berhane, 2011, and Agegnehu *et al*., 2011). As a result, improving low soil fertility in the form of nutrient additions from various fertilizer sources is crucial for boosting soil productivity and sustained crop output. In large-scale agricultural regions, phosphorus and nitrogen are the two plant nutrients that are most limiting crop productivity. According to Ketema and Mulatu (2018), barley is highly responsive to nitrogen fertilization and extremely sensitive to low nitrogen levels.

Nonetheless, urea, diammonium phosphate (DAP), NPS, and other blended fertilizers are mainly based on a single blanket recommendation, particularly in the study area. This blanket recommendation often does not consider variations in resource soil types, climate risks, ideal agricultural productivity, and the economically significant. Thus, there is an urgent demand for crop response fertilizer recommendations based on soil testing.

The quantity of phosphorus in kilogram required to raise soil phosphorus by 1 mg kg^{-1} is the phosphorus requirement factor (Pf), and it aids in calculating the amount of P required per hectare to raise soil test levels by 1 mg kg^{-1} and supply available P levels above the critical level. The amount of phosphorus in the soil that provides the optimum yield response to P treatment is the critical P value (Pc). The critical P value (Pc) is the level of phosphorus in the soil that gives the optimal yield response to P application, but above this value causes a decrease, unpredictability, or zero yields. The critical value of soil P for optimum crop yield varies based on soil type, crop species, and environmental conditions (Mulugeta *et al.*, 2022).

As a result, the optimal nitrogen rate (46 N kg ha^{-1}), P critical (20 ppm), and P requirement factor (4.60) for food barely production from the 2019–2021 cropping season were determined by previously conducted soil test–based phosphorus calibration studies in Sinana District (Mulugeta *et al.*, 2022). Therefore, in the district's food barely producing areas, farmers' fields should be used for verification of these technologies before their dissemination, demonstration, and scaling up (Mulugeta *et al.*, 2022). Therefore, this study aimed to verify the critical phosphorus (Pc) and phosphorous requirement factor (Pf) for food barley production in the study area.

MATERIAL AND METHODS

Description of study Area

The experiment was conducted in the Sinana district, about 460 kilometers from the capital Addis Ababa. Geographically, the Sinana area is located between 6°53'20"N to 7°25'20"N and 39°54'40"E to 40°16'0"E. Topographically, the district consists of a gently undulating plain with an altitude of 1700 to 3100 above mean sea level (Figure 1).

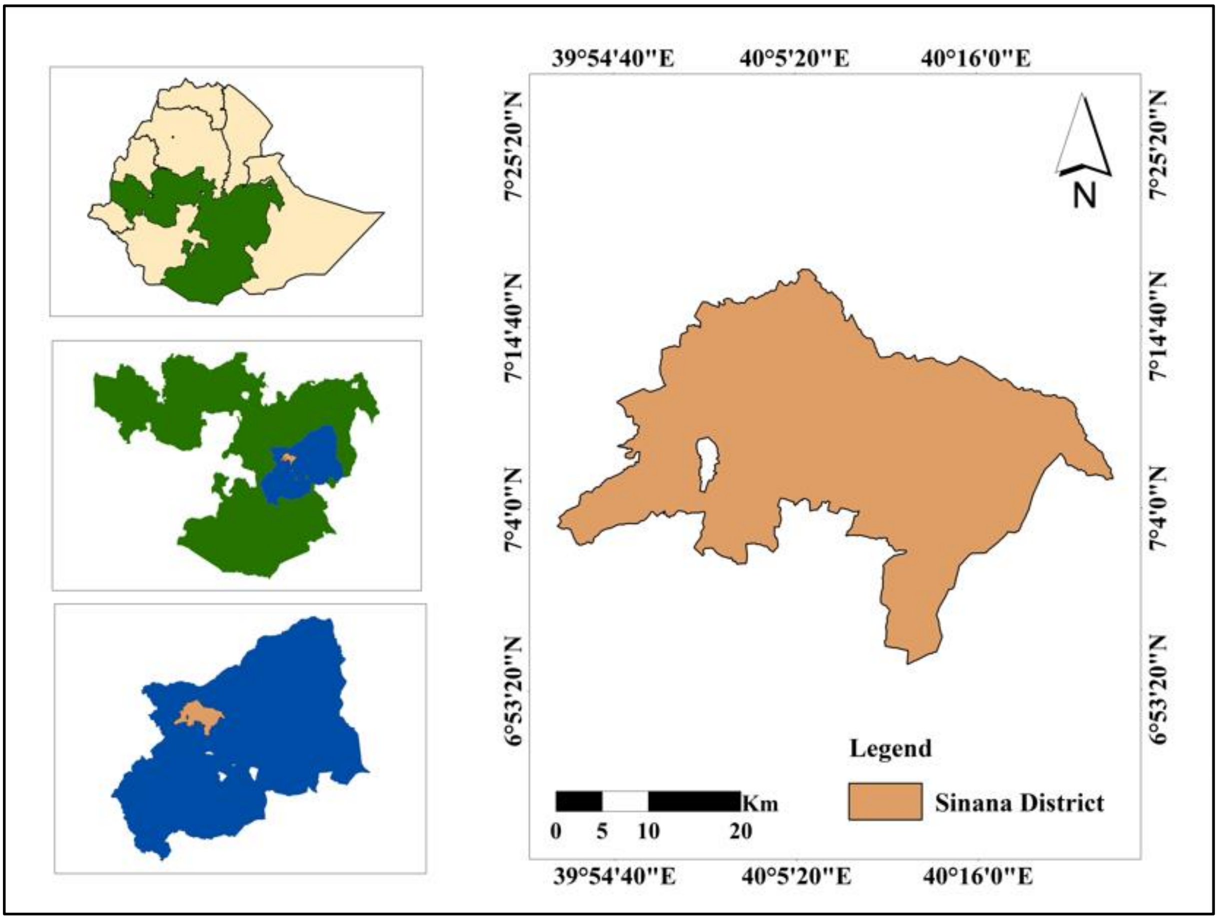

Figure 1. Map of the study area

Climate Characteristics

The area experiences bimodal rainfall patterns, with yearly totals varying from 453 mm to 1130 mm. Minimum temperatures varied between 6.8 and 10.1 °C, and maximum temperatures ranged from 21. 9 to 23. 5 °C (Figure 2). Crop farming is the primary source of subsistence income or economic activity. In this area, potatoes predominate among horticultural techniques, along with wheat, barley, faba beans, and field peas.

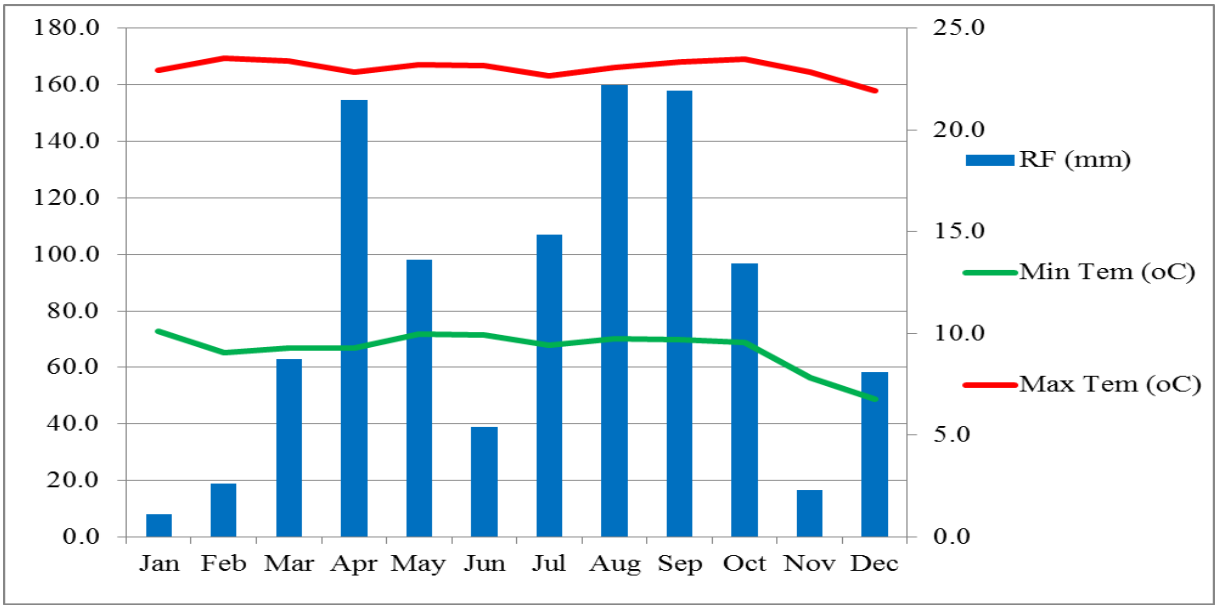

Figure 2. The Sinana district's average monthly rainfall (mm) and maximum and minimum temperatures (°C).

Design and Arrangement for Experimentation

The trial was conducted for a year during the main cropping season in 2022 on the farms of seven farmers. Three treatments were used in the experimental field: blanket recommendations, soil test-based P fertilizer recommendations with an optimal nitrogen rate of 46 kg ha^{-1}, and control (without fertilizer). Sources of fertilizer were urea and TSP for N and P, respectively, and 125 kg ha^{-1} rate of food barely Adoshe variety on 10 m x 10 m (100 m^2) plot size were used.

Phosphorus fertilizer rate (kg ha-1) = Pc- Pi)*Pf … (1)

Where, Pf = phosphorus requirement factor (4.60), Pi =initial available phosphorus, and Pc = phosphorus critical level (20 ppm) are for Sinana District

Soil Sampling and Laboratory Analysis

Before planting, soil samples were taken from the experimental sites using auger sampling points at 0 - 20 cm soil depth, and composites were prepared. The composite soil samples were labeled with the relevant information, air-dried, and crushed with a mortar and pestle through a 2 mm mesh sieve. The analyses were conducted at the Sinana Agricultural Research Center. A pH meter, was used to determine the soil's pH in the supernatant suspension of a 1: 2.5 soil-to-water ratio (Rhoades, 1982). According Walkley (1934) was used to determine the amount of organic carbon. The Olsen method was used to determine available P (Olsen *et al*., 2017).

Agronomic Data Collection and Analysis

Agronomic data related to food, such as plant height, the number of productive tillers, and the number of seeds per spike, above-ground biomass, and grain yield, were collected and subsequently subjected to statistical analysis. Using R version 4.1.1 software. The LSD at a 5% probability level test for mean separation for significant treatments (Gomez and Gomez, 1984).

Partial Budget Analysis

The economic viability of the treatment measures was conducted using a partial budget analysis (CIMMYT, 1988). The average grain yield was adjusted by 10% to reduce the possibility of overestimating the yield when converting a small plot of land's yield to hectares.

RESULT AND DISCUSSION

Selected Soils Chemical Properties before Planting

As shown in Table 1, the soil pH (pH_H_2O) values ranged from 6.03 to 6.25. According to Jone (2003) pH rate, the soil of the study area was classified as a slightly acidic medium. According to Table 1, the range of values for soil organic matter (OM) was 1.68 to 2.62%. According to Tekalign (1991), the OM was low to moderate class. The available phosphorus (Av. P) as established by the Olsen technique Cottenie, (1980), was very low, with values ranging from 1.01 to 3.30 mg/kg (Table 1). The very low category of these important soil plant nutrients might be caused by nutrient fixation, leaching, prolonged monocropping of cereals, poor or limited inputs of organic and inorganic fertilizers, and loss from soil erosion.

Table 1. Selected soils' chemical properties status of experimental sites of Sinana District.

Sites Name	pH (H_2O)	OM (%)	Av. P (mg/kg)
1	6.06	1.68	2.29
2	6.25	2.18	1.01
3	6.03	1.94	2.85
4	6.11	1.88	2.51
5	6.2	2.39	2.30
6	6.08	2.22	1.82
7	6.14	2.62	3.30

Where: OM = soil organic matter, Av. P = available phosphorus

Response of Food Barely Yield and Yield Components

Based on a statistical examination of all the agronomic data collected, the yield components and yield of food barely were significantly ($p \leq 0.05$) different between different fertilizer recommendations (Table 2). Accordingly, the highest yield components of food barely, namely plant height, spike length, seed per spike, number of tillers, biomass, and TKW were obtained from soil test-based crop response fertilizer recommendation followed by blanket recommendation, while the lowest from the control (without fertilizer) (Table 2). The responses on food barely grain yield revealed that the highest (5682.43 kg ha^{-1}) and the lowest (2033.00 kg ha^{-1}) grain yield was recorded from soil test-based crop response fertilizer recommendation and control, respectively. This result confirmed the findings of Mulugeta *et al* (2017); Temesgen and Chalsissa (2020); Dejene *et al* (2020) and Mulugeta *et al* (2022) stated that soil test-based site-specific optimum fertilizer recommended results the highest grain yield over blanket recommendation.

Table 2. Response of food barley production to verification of soil test crop response based Calibrated in Sinana District

Treatments	PH (cm)	SL (cm)	SPS	NT	BM (kg/plot)	GY (kg/ha)	TKW (g)
Control	69.4^{c}	3.41^{c}	34.71^{c}	1.97^{c}	45.73^{b}	2033.00^{c}	31.49^{c}
BK	82.6^{b}	5.05^{b}	44.63^{b}	3.69^{b}	65.21^{ab}	3410.14^{b}	33.86^{b}
STBFR	98.0^{a}	6.87^{a}	55.46^{a}	5.94^{a}	84.96^{a}	5682.43^{a}	36.19^{a}
Mean	83.33	5.11	44.93	3.87	65.30	3708.52	33.85
LSD $_{(0.05\%)}$	9.61	0.76	4.01	0.99	21.70	306.40	2.32
CV (%)	10.27	13.31	7.94	22.74	29.59	7.50	6.11

Where: BK = blanket recommendation, STBFR = soil test based crop response fertilizer recommendation, PH = plant height; SL = Spike length, SPS = seed per spike, NT = Number of productive tiller, BM = above ground biomass, GY = Grain yield, TKW = thousand kernel weight

Economic Analysis

Based on this result, the partial budget analysis indicated that the soil test-based P recommendation is economically feasible for food barely production in the district. Accordingly, the use of soil test-based crop response phosphorus recommendation is advisable having net benefit (150525.61 ETB) with acceptable MRR (4131.16%) for food barely production in the Sinana district.

Table 3. Partial budget analysis for verification of soil test crop response based Calibrated phosphorous for food barely production in Sinana District.

Treatment	UnGY (Kgha^{-1})	AGY (Kgha^{-1})	GB (Birrha^{-1})	TVC (Birrha^{-1})	NB (Birrha^{-1})	MRR (%)
Control	2033	1829.7	54891	0	54891	0
BK	3410.14	3069.126	92073.78	1450	90623.78	2464.33
STBFR	5682.43	5114.187	153425.61	2900	150525.61	4131.16

Where, BK = blanket recommendation, STBFR = soil test-based crop response fertilizer recommendation, AGY = adjusted grain yield, GB = gross benefit, UnGY = unadjusted Grain yield, TVC = total variable

Farmer technology evaluation and selection criteria

Farmers' evaluation the technology and selected soil test based crop responses based on their own knowledge and criteria as presented in Table 4. A total of 55 farmers, including 15 females were participated in the selection and ranking of the technology. The important selection criteria were, spike length, productive tiller, seed per spike, and grain yield (Table 4). Soil test based crop response was selected as the best soil fertility improvement and enhance bread wheat production in the study area, followed by farmer practices.

Table 4. Farmer's perception and selection criteria

Treatments	Rank	Reason for selection (criteria)
Control	3rd	Poor performances
BK	2nd	Low yield and yield parameter
STBFR	1st	Highest seed per spike, spike length, plant height, more productive tiller, good standing and high grain yield.

Where; BK = blanket recommendation, STBFR = soil test based crop response fertilizer recommendation cost, NB = net benefit, MRR = marginal rate of return.

CONCLUSION AND RECOMMENDATION

In conclusion, soil test crop response-based fertilizer recommendations significantly increased food barely production compared to blanket recommendations. As a result, the optimal nitrogen rate (46 $kgha^{-1}$), the critical value of P concentration (Pc) (20 ppm), and the value of the phosphorus requirement factor (Pf) (4.60) have been verified for food barely production in Sinana district, and extrapolate for similar soil types areas. The highest food barely grain yield (5682.43 kg ha^{-1}) with an economically feasible and acceptable marginal rate of return (4131.16 %) from a soil test-based fertilizer recommendation.

Therefore, verified optimum nitrogen (46 kg ha^{-1}), Pc (20 ppm), and Pf (4.60) should be advisable for food barely production in the Sinana district, and similar soil types. Based on these results, demonstrations, and scale-up of soil test-based fertilizer applications are needed. Further studies on determining adjusted NPS fertilizer rates using Pc and Pf based on calibrated phosphorus for food barely production should be encouraged.

ACKNOWLEDGMENTS

The Oromia Agricultural Research Institute provided logistical support for the entire activity, for which the author is grateful. We would especially want to express our gratitude to the Sinana Agricultural Research Center for establishing the logistical framework that allowed the study to be completed effectively. Lastly, we would especially want to thank the Sinana Agricultural Research Center's Soil Fertility Improvement Research Team.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

Abera, T., Molla, A., Feyissa, A., Liben, M., Woyema, A., Admassu, L., & Bekele, A. (2011). Research achievements in barley cultural practices in Ethiopia. Barley Research and Development in Ethiopia, 113.

Abera, T., Tufa, T., Midega, T., Kumbi, H., & Tola, B. (2018). Effect of integrated inorganic and organic fertilizers on yield and yield components of barley in Liben Jawi District. *International Journal of Agronomy*, *2018*, 1-7.

Agegnehu, G., Liben, M., Molla, A., Feyissa, A., Bekele, A., & Getaneh, F. (2011). Research achievements in soil fertility management in relation to barley in Ethiopia. *Barley research and development in Ethiopia*, 137.

Bayeh, M. and Berhane, L. (2011). Research achievements in barley cultural practices in Ethiopia. In: Mulatu, B. and Grando, S. (eds). Barley Research and Development in Ethiopia, Proceedings of the 2nd National Barley Research and Development Review Workshop. 28-30 November 2006, HARC, Holetta, Ethiopia. pp. 1-16.

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

Cottenie, A., (1980). Soil and plant testing as a basis of fertilizer recommendations. FAO soil bulletin 38/2. Food and Agricultural Organization of the United Nations, Rome.

Dejene Getahun, Dereje Girma, Abreham Feyisa, Ajema Lemma, and Lello Dejene. (2020). Verification of Soil Test Crop Response Based Phosphorus Recommendation on Bread Wheat (Triticum Aestivum L.) in Yaya Gulele District of North Shewa Zone, Oromia. *International Journal of Applied Agricultural Sciences*, 6 (3), 52-56.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedures for Agricultural Research. 2nd ed. John Wiley and Sons, New York, USA. P. 680.

Jones, J. Benton. (2003). Agronomic Handbook: Management of crops, soils, and their fertility. CRC Press, Washington, USA.

Ketema Niguse and Mulatu Kassaye. (2018). Response of Food Barley (Hordeum vulgare L.) Varieties to Rates of Nitrogen Fertilizer in Limo District, Hadiya Zone, Southern Ethiopia. *Journal of Natural Sciences Research*, 8 (15), 17–31.

Lake. M and Bezabih. W. (2018). Response of Food Barley (Hordeum Vulgare L.) to Various Levels of P Fertilizer", International Journal of Research in Agriculture and Forestry, 5 (2), 21-26.

Malla, M., Tesema, G., Tesema, S., Hegano, A. and Negash, S. (2021). Evaluation of blended fertilizer rates for improving production of food barley (Hordeum vulgare L.) in Semen Ari District, Southwestern Ethiopia. Int. *J. Agril. Res. Innov. Tech*. 11(2): 10-17.

Melle Tilahun, Asfaw Azanaw and Getachew Tilahun. (2015). Participatory evaluation and promotion of improved food barley varieties in the highlands of north western Ethiopia. *Wudpecker Journal of Agricultural Research*; 4(3): 050 – 053.

Mulugeta Eshetu, Daniel Abegeja, Regassa Gosa, Tesfaye Ketama, Girma Getachew, Tilahun Chibsa. (2022). Soil Test Based Crop Response Phosphorus Calibration Study for Food barely Production in Sinana District of Bale Zone, Southeastern Ethiopia. International Journal of Science and Qualitative Analysis. 8 (1), 1-12.

Mulugeta Eshetu, Shure Sebboka, Tilahun Chibsa, Chala Chimdessa, Negash Bedasso. (2017). Optimization of Fertilizer Recommendations for Food barely at Sinana District of Bale Zone, Southeastern Oromia, Ethiopia. International Journal of Science and Qualitative Analysis. 3 (6), 55-60.

Olsen, S. R., Cole, C. V., Watanabe, F. S., and Dean, L. A. (1954). Estimation of available phosphorous in soils by extraction with Sodium Bicarbonate. USDA Circular, 939: 1-19.

Rhoades JD. (1982). Soluble salts. In: Page AL, Millere RH and Page DT (eds) Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties, pp 167–180. Madison, WI: American Society of Agronomy.

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

Temesgen Chimdessa and Chalsissa Takele. 2020. Verification of Soil Test Based Phosphorous Calibration Study for Bread Wheat (Triticum Aestivum L.) Production in Horo District, Oromia Regional State, Ethiopia. *Advances in Biochemistry*, *8*(3), 52-56.

Walkley, A, Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science, 37: 29-37.