Original Research Article||

Evaluation of different blended fertilizer types and rates for better production of bread wheat (*Triticum aestivum L.*) at Adiyo District, South Westhern Ethiopia

Ute Guja[1]*, Konjit Abreham[1], Tatek Mekuria[1], Henok Tsegaye[1]

[1]*Southern Agricultural Research Institute, Bonga Agricultural Research Center, Bonga, Ethiopia*

Abstract

Bread wheat (*Triticum aestivum* L.) is an important food crop and source of income for farmers. It is the most responsive crop to fertilizer applications. A field experiment was carried out on farmers' fields in 2016/17 and 2017/18 main cropping seasons to evaluate the response of bread wheat to different types and rates blended fertilizers at Adiyo district, South Western Ethiopia. Eight treatments: Control (T1), four rates of NPSB: (46 N,54 P_2O_5,10 S, 1.07 B (T2); 69 N, 72 P_2O_5, 13 S, 1.4 B (T3), 92 N, 90 P_2O_5, 17 S, 1.7 B (T4) and 92 N, 36 P_2O_5, 7 S, 0.71 B (T5)) and three rates of NPSB+Cu: T2+Cu (T6), T3+Cu (T7), T4+Cu (T8), were laid out in randomized complete block design with three replications. Cupper was supplemented in the treatments as foliar application. Crop parameters measured were analyzed using proc GLM procedures in the SAS version 9.3 for Windows. Analysis was also performed to investigate the economic feasibility of the fertilizers for wheat production. Results indicated that application of both types and three rates of each fertilizer significantly ($p<0.05$) affected all tested parameters except thousand seed weight, which was improved by only T4. The highest biomass (14.80 ton ha-1) and grain yield (6.537 ton ha-1) were obtained from the application of the highest rate of NPSB+Cu (T8) whereas the lowest biomass (9.36 ton ha-1) and grain yield (3.66 ton ha-1) were obtained from the control (untreated soil). The application of NPSB+Cu (T8) also gave the highest net benefit of Birr 46637 and the acceptable MRR% was 151.02%. Hence farmers at study area and elsewhere with similar agro-ecologies could use NPSB+Cu at a rate (92 N, 90% P_2O_5, 17 S, and 1.7 B) and 600 g ha^{-1} Cu as a foliar application or NPSB = 92, 90, 17, 1.7. However, further verification study is needed to give a reliable and consistent recommendation.

Key words: Economic benefit, Foliar application, NPSB, NPSBCu, Wheat, Yield

***Corresponding author's address:** Ute Guja, Email: fekaduguja100@gmail.com
Coauthors: kojitaberham@gmail.com, mekuriatatek@gmail.com, henoktsegaye66@gmail.com

INTRODUCTION

Wheat is one of the major cereal crops grown in the highlands of Ethiopia and which is regarded as the largest wheat producer in Sub-Saharan Africa (Efrem et al., 2000). Wheat is considered as highly responsive crop to starter fertilizers, particularly phosphorus and nitrogen (Ruiz, 2016). Wheat productivity in Ethiopia is low (2.67 ton ha^{-1}) (CSA, 2017) due to depleting soil fertility, low levels and imbalanced use of chemical fertilizers, limited knowledge on time and rate of fertilizer applications, and the unavailability of other modern crop management inputs (Anderson and Schneider, 2010). Therefore, the management of nutrients should be given adequate attention to increase yields and sustain productivity.

Fertilizer management is a key to wheat production and the responsiveness of wheat crop to the application of different fertilizer nutrients is studied extensively (Franzen *et al*., 2008; Knight *et al*., 2012; Abebaw and Hirpa, 2018; Diriba *et al*., 2019). Most researches focus on NP requirements of crops, and limited information is available on various sources of fertilizers potassium, sulfur, zinc and boron and other micronutrients. Therefore, application of other sources of nutrients beyond urea and DAP, especially those containing K, S, Zn and other micro-nutrients increase crop productivity (CSA, 2011). Balanced fertilizers containing N, P, K, S, Zn and B in blend form have been recommended to ameliorate site specific nutrient deficiencies and thereby increase crop productivity.

The results of a recent study on the Ethiopian soil map indicated that there is a wide spread of nutrient deficiencies (EthioSIS, 2016). The recent national soil inventory data revealed that S, B and Zn deficiencies are widespread in Ethiopian soils. Some soils are also deficient in K, Cu, Mn and Fe (ATA, 2016), all of which potentially hold back crop productivity. However, fertilizer trials involving multi-nutrient blends that include micronutrients are rare. In recent times, soil test-based fertilizer recommendation and calibration efforts have been tried by Ethiopian Agricultural Research Institute (EIAR) and Regional Agricultural Research Institutes (RARIs), but only limited to a certain location and crop types (ATA, 2016).

According to EthioSIS (2016) fertilizer type recommendation map, eight types of fertilizer blends are identified for Southern Nations Nationalities and Peoples' Regional State. Similarly, three and two types of fertilizer blends were identified for Adiyo Woreda and Boka Kebele, respectively. But this needs validation for the fertilizer types and determination of rates for the identified fertilizer types for specific crops. Therefore, this study was initiated with the objectives of (1) Evaluating the relative influences of NPSB and NPSB+Cu on wheat production and (2) determining the optimum rate of the selected blended fertilizer type for the production of wheat in Adiyo woreda.

MATERIALS AND METHODS

Description of the Experimental Area

A field experiment was carried out on three farmers' lands during the main cropping seasons for two years (2016/17 and 2017/18) at Boka Kebele, Adiyo Woreda of Kaffa Zone, Southern Nations, Nationalities and Peoples' Regional State (SNNPRS), Ethiopia. The altitude of the study areas ranged from 2435 to 2550 m.a.s.l. with latitude of 07º15 471' N and longitude of 36º25 112' E. The area received 600-1800 mm rainfall annually in a bimodal pattern and temperature ranged from 15-20ºC. Topographically, the area consists of a gently undulating plain with an average slope gradient of 6%. Crop produced in the area are mostly cereals, pulses and tubers. Wheat is extensively grown followed by faba bean (AWANDRDO, 2017). The dominant soil type of the area is Nitisols, with a textural class of clay loam (FAO, 1998).

Experimental Details and Treatment Set-ups

The treatments were laid out in Randomized Complete Block Design (RCBD) replicated three times on each of the three farmerss' fields. Eight treatments: Control (T1), four rates of NPSB: (46N, 54P_2O_5, 10S, 1.07B or 150 kg NPSB + 41 kg urea top dressing (T2); 69N, 72P_2O_5, 13S, 1.4B or 200 kg NPSB + 72 kg urea top dressing (T3), 92N, 90P_2O_5, 17S, 1.7B or 250 kg NPSB + 102 kg urea top dressing (T4) and 92N, 36P_2O_5, 7S, 0.71B or 100 kg NPSB + 161 kg urea top dressing (T5)) and three rates of NPSB+Cu: T2+Cu (T6), T3+Cu (T7), T4+Cu (T8), were used. Additional 600 g Cu ha^{-1} for three treatments; and 100 kg KCl for all treatments were applied.

The plot size was 3 x3 m (9 m2) and the spacing between rows was 20 cm. The improved wheat variety (Danda'a) was received from Sinana Agricultural Research Center and used as a test crop. Urea was used as a source of N in addition to NPSB and NPSB+Cu blends. Blended and KCl fertilizers were applied at planting; whereas remaining N from urea was top dressed after 45 days of planting (Table 1). The CuSO4 used as a source of Cu by foliar application was applied 45 days after germination. The test crop was planted by drilling and other crop management practices were applied as per the recommendations for the area.

Table 1. Treatments used in the study

Treatment	Fertilizer types and rates					Cu (g)
	Fertilizer in blended form and Urea	Fertilizer in nutrient form (total, kg)				
	NPSB, NPSBCu and Urea	N	P_2O_5	S	B	
T1	Control	0	0	0	0	0
T2	150 kg NPSB + 41 kg urea top dressing	46	54	10	1.07	0
T3	200 kg NPSB + 72 kg urea top dressing	69N	72P_2O_5	13S	1.4B	0
T4	250 kg NPSB + 102 kg urea top dressing	92N	90P_2O_5	17S	1.7B	0
T5	100 kg NPSB + 161 kg urea top dressing	92N	36P_2O_5	7S	0.71B	0
T6	T2 + Cu	46	54	10	1.07	600
T7	T3 + Cu	69N	72P_2O_5	13S	1.4B	600
T8	T4 + Cu	92N	90P_2O_5	17S	1.7B	600

N.B: *Basically, blended NPSB fertilizer contain full nutrient PSB; and nearly half N (fertilizer in nutrient form) in each treatment case. All PSB rates were applied at planting. N was applied by split application; nearly half* *at planting with blends and the remaining by top dressing from urea after 45 days of planting. Cu was applied 45 days after germination by foliar application.*

Soil Sampling and Analysis

Representative composite surface soil samples were collected from 0-20 cm depth at each experimental unit just before sowing. After manual homogenization, the samples were ground to pass through sieves (2 mm for soil pH, texture, cation exchange capacity and available phosphorus; 0.5 mm for total nitrogen and organic carbon analysis) and analyzed for texture, pH, organic carbon, total nitrogen, cation exchange capacity and available phosphorus.

Agronomic Data Collection

The yield and yield components: plant height (cm), spike length (cm), number of tillers per plant, thousand seed weight (g), biomass yield (ton), and grain yield (ton) were collected and subjected to analysis of variance (ANOVA). The grain yield was determined from each experimental plot and adjusted to constant moisture levels of 12%.

Economic Analysis

A partial budget analysis was carried out to determine the net benefit and percent marginal rate of return (%MRR) of specific fertilizer type and rate. Wheat grain yield was valued at an average open market value of the local market price of Birr 900 per 100 kg whereas the average price of urea and NPSB fertilizers were Birr 10 and 14 per kg, respectively. The price of copper sulfate was Birr 1625 per kg. The cost of other production practices like, seed and weeding were assumed to remain the same among the treatments. The grain yield was down adjusted to reflect the situation in actual production by farmers (CIMMYT, 1988).

Data Analysis

The data obtained from the field were subjected to combined analysis of variance (ANOVA) over years after confirmation of homogeneity of error variance using SAS, version 9.3, using the general linear model (GLM) procedure (SAS Institute, 2011). A significant difference between and among treatment means was assessed using the least significant difference (LSD) test at 0.05 level of probability.

RESULTS AND DISCUSSION

Physico-chemical Properties of Soil

Soil samples collected before planting from the study area was analyzed in the laboratory. The analysis results indicated that the experimental sites soil textural class was clay loam with the proportion of 37% sand, 35% clay, and 28% silt. The soil pH value of the area was 5.1 and classified as strongly acidic as per the pH rating category suggested by Tekalign (1991).

The organic matter content for soils of the experimental site was 7.3% and is classified in the highest range as rating of Tekalign (1991). In most highly acidic soils, microbial activity is low, slowing down the decomposition rate and results in accumulation of organic matter. The total nitrogen value of the experimental soil was 0.4% which is rated high based on Tekalign (1991). Generally, the high total nitrogen content of the soil might be due to the highest organic matter content of the area. The available phosphorus content of the experimental site was 12.5 ppm, which makes the soil rated as having low P (Jones, 2003). Masresha (2014) reported low amount of available phosphorus content on soils that are cultivated repeatedly due to P fixation and P mining. Habtamu, *et al*. (2015) also reported that low content of available phosphorus was due to fixation problems. The CEC of the site was 5.6 cmol (+) kg^{-1}. According to Landon *et al.*, (1991) the cation exchange capacity of the site was found to be in the lower range.

Table 2. Selected physico-chemical properties of the Study area soil before planting

Soil properties	Unit	Values
pH-H_2O (1:2.5)	-	5.1
Sand	%	37%
Clay	%	35%
Silt	%	28
Organic Matter	%	7.3
Total Nitrogen	%	0.4
Available phosphorus	ppm	12.5
Cation Exchange Capacity	cmol $_{(+)}$ kg^{-1}	5.6

Texture	-	Clay loam

Yield and Yield Components of Wheat as influenced by Types and Rates of Blended Fertilizer

Data analysis indicated that a year by treatment effects did not occur, so data are averaged across years. Average wheat yield and yield components are presented in Table 1 and 2. In general, application of both fertilizer types and rates significantly ($p<0.05$) improved yield and yield components of wheat in comparison to control. Mean biomass and grain yield of both years and combined over years were significantly affected by different fertilizer types and rates (Table 1). The grain yields significantly increased as the rates of the two blended fertilizer rates increased. However, averaged over years, significantly highest biomass (14.80 ton ha^{-1}) and grain yield (6.5 ton ha^{-1}) of wheat were obtained by application of NPSB + Cu at a rate 250 NPSB + 600 Cu ($CuSO_4$) and 102 kg urea top dressing (92 N, 90 P_2O_5, 17 S, 1.7 B + Cu). All yield components except thousand seed weight were affected by fertilizer types and rates in similar trend with grain yields increasing with application rates of the fertilizers (Table 2).

Table 3: Combined mean grain and biomass yield of bread wheat as influenced by blended fertilizer types and rates at Adiyo district

Treatment	Biomass yield ton/ha	Grain yield ton/ha
1. Control	9.364^{d}	3.657^{f}
2. NPSB = 46, 54, 10, 1.07	12.353^{c}	5.229^{e}
3. NPSB = 69, 72, 13, 1.4	13.525^{b}	5.839^{c}
4. NPSB = 92, 90, 17, 1.7	13.537^{b}	6.203^{b}
5. NPSB = 92, 36, 7, 0.71	13.654^{b}	5.852^{c}
6. NPSBCu = Tr2 + Cu	12.506^{c}	5.472^{de}
7. NPSBCu = Tr3 + Cu	12.864^{bc}	5.765^{cd}
8. NPSBCu = Tr4 + Cu	14.80^{a}	6.537^{a}
Mean	12.83	5.569
LSD (0.05%)	1.08	0.31
CV%	9.51	8.62

LSD (0.05%): least significant difference at 5% level; CV: coefficient of variation; ; means in a column followed by the same letters are not significantly different at 5% level of significance.

Applications of different types of blended fertilizers at varying rates increased biomass yield of bread wheat by 31.91-58.04% over the control. This might be due to better crop nutrition enhanced through blended micronutrients (B and Cu) with macronutrients (N, P, and S), which might have resulted in improved vegetative growth of crops. In agreement with this finding Fayera *et al.,* (2014) reported that above ground dry biomass yield of teff was significantly increased by the application of blended fertilizers.

The significant increase in wheat yield with the application of the different types and rates of blended fertilizers (NPSB and NPSB+Cu) was 42.98 to 78.75% improvement over the control (Table 3). Mulugeta, *et al.* (2017) reported that the application of some macro and micro nutrients significantly increased grain yield and yield components of bread wheat as compared to the control.

The response of wheat yield to blended fertilizer types and rates showed variation between treatments; indicating that the application of higher NPSB rate with copper was vigorous for wheat crop production. The higher wheat grain yield was recorded by application of 92 N, 90 P2O5, 17 S, 1.7 B + 600 g Cu when compared with that of 92 N, 90 P2O5, 17 S, 1.7B. It suggests that the inclusion of Cu is important fertilizer management practice for wheat production at the study area. This result is in line with that reported by Noabur and Jeff (2020), who showed that wheat responses to copper was effective in correcting deficiency limitation for growth of wheat. Increasing the application of blended fertilizer (NPSB) rates on the bread wheat production constantly increased the amount of yield in the experimental site. Diriba et al., (2019) also reported that increasing rate of blended fertilizers increased the grain yield of wheat.

Table 4. Combined mean yield components of bread wheat as influenced by types and rates of blended fertilizers at Adiyo district

Treatment	PH (cm)	SL (cm)	TPP	TSW (g)
Control	84.2^{c}	7.0^{c}	3.9^{d}	49.1^{b}
NPSB = 46, 54, 10, 1.07	93.7^{b}	7.8^{b}	5.4^{abc}	49.9^{b}
NPSB = 69, 72, 13, 1.4	93.8^{b}	7.9^{b}	5.2^{bc}	50.1^{b}
NPSB = 92, 90, 17, 1.7	96.2^{ab}	8.0^{b}	5.0^{c}	56.5^{a}
NPSB = 92, 36, 7, 0.71	96.7^{ab}	8.0^{b}	5.6^{ab}	49.4^{b}
NPSBCu = Tr2 + Cu	93.6^{b}	8.0^{ab}	5.3^{bc}	50.5^{b}
NPSBCu = Tr3 + Cu	94.0^{ab}	8.1^{ab}	5.8^{a}	49.6^{b}
NPSBCu = Tr4 + Cu	97.5^{a}	8.4^{a}	5.8^{a}	49.3^{b}
Mean	93.72	7.9	5.26	50.55
LSD (0.05%)	3.61	0.39	0.47	4.10
CV%	5.85	7.44	13.43	12.25

N.B*: *LSD (0.05%): least significant difference at 5% level; CV: coefficient of Variation; PH: plant height; SL: spike length; TPP: number of tillers per plant; TSW: thousand seed weight; Means in a column followed by the same letters are not significantly different at 5% level of Significance

Partial Economic Analysis

Partial economic analysis also indicated that application of NPSB + Cu at rate 250 kg NPSB + 600gm Cu and 102 kg top dressing (92N, $90P_2O_5$, 17S, 1.7B + 600gm Cu) gave the highest net benefit and inclusion of Cu in NPSB blend gave 151.02% MRR. Thus it could be recommended that farmers at the study and similar AEZ could apply 250 kg NPSB + 600gm Cu and 102 kg urea top dressing ha^{-1} for optimum wheat production. Application of NPSB at rate 250 kg NPSB with 102 kg urea top dressing gave modest wheat grain yield and could be optionally used in the absence of Cu blends and lower NPSB rates might be accepted on the farmer yield goal.

Table 5. Partial budget and dominance analysis for blended fertilizers on bread wheat at Adiyo district

No.	Treatment	GY (kg ha^{-1})	Adjusted GY (kg ha^{-1})	FC (ETB ha^{-1})	AC (ETB ha^{-1})	TVC (ETB ha^{-1})	GB (ETB ha^{-1})	NB (ETB ha^{-1})	MRR%
1	Control	3657.4	3291.66	0	0	0	29624.94	29624.94	
2	NPSB = 46,54,10, 1.07	5229.0	4706.10	2469	450	2919	42354.9	39435.90	
5	NPSB = 92, 36, 7, 0.71	5851.9	5266.71	2849	406.5	3255.5	47400.39	44144.89	
6	NPSBCu = Tr2 + Cu	5472.2	4924.98	3444	550.2	3994.2	44324.82	40330.62	D
3	NPSB = 69, 72, 13, 1.4	5839.5	5255.55	3448	598.1	4046.1	47299.95	43253.85	D
7	NPSBCu = Tr3 + Cu	5765.4	5188.86	4423	698.5	5121.5	46699.74	41578.24	D
4	NPSB = 92, 90, 17, 1.7	6203.7	5583.33	4418	819.1	5237.1	50249.97	45012.87	
8	NPSBCu = Tr4 + Cu	6537.0	5883.30	5393	919.6	6312.6	52949.70	46637.10	

Table 6. Analysis of net benefit and MRR% of blended fertilizers on bread wheat after removal of dominated treatments

No.	Treatment	GY (kg ha^{-1})	Adjusted GY (kg ha^{-1})	FC (ETB ha^{-1})	AC (ETB ha^{-1})	TVC (ETB ha^{-1})	GB (ETB ha^{-1})	NB (ETB ha^{-1})	MRR%
1	Control	3657.4	3291.66	0	0	0	29624.94	29624.94	
2	NPSB = 46,54,10, 1.07	5229.0	4706.10	2469	450	2919	42354.9	39435.90	336.1
5	NPSB = 92, 36, 7, 0.71	5851.9	5266.71	2849	406.5	3255.5	47400.39	44144.89	1399.4
4	NPSB = 92, 90, 17, 1.7	6203.7	5583.33	4418	819.1	5237.1	50249.97	45012.87	43.8
8	NPSBCu = Tr4 + Cu	6537.0	5883.30	5393	919.6	6312.6	52949.70	46637.10	151.02

N.B: *Yield adjustment: 10%, ETB: Ethiopian Birr, GY: grain yield, FC: fertilizer cost, AC: application cost, TVC: total variable cost, GB: gross benefit, NB: net benefit, D: indicates dominated treatments that are rejected, MRR: marginal rate of return*

CONCLUSION AND RECOMMENDATION

Based on the results of this study, it is generally concluded that, application of blended fertilizer types and rates revealed considerable difference of biomass yield and grain yield over untreated soil at the study area. Application of blended fertilizer types and rates significantly affected plant height, spike length, number of tiller per plant, thousand seed weight, biomass yield and grain yield. In conclusion, application of NPSBCu at a rate of 250 kg NPSB + 600gm Cu and 102 kg urea top dressing (92N, 90P2O5, 17S, 1.7B + 600gm Cu) significantly improved bread wheat yield and gave high net benefit and %MRR. Both the highest net benefit and MRR% was obtained by application of 92N, 90P2O5, 17S, 1.7B + 600 gm Cu at Adiyo district. Hence the application of NPSBCu: 92N, 90P2O5, 17S, 1.7B + 600 gm Cu predominantly or as option NPSB: 92N, 90P2O5, 17S, 1.7B can be used for bread wheat productivity in the study area. However, to reach at a conclusive recommendation, the experiment should be repeated with multi-locations and soil types in different agro-ecologies for wider use.

Acknowledgements

The authors would like to thank the Southern Agricultural Research Institute, Natural Resource Research Directorate for the financial support to this study; and Bonga Agricultural Research Center (BARC) both for valuable collaboration work, evaluation and monitoring of the activity on the field through.

REFERENCES

Abebaw T. and Hirpa L., 2018. Effects of Fertilizer Rate (Blended) and Sowing Methods on Yield of Bread Wheat (Triticum Aestivum) and Its Economic Profitability in Western Ethiopia. Int. J. Compr. Res. Biol. Sci. 5(7):1-14. [Scholar Google]

Adiyo Woreda Agricultural and Natural Resource Development Office (AWANRDO). 2017. Annual Report for the year 2017-2018. Adiyo Woreda Agricultural and Natural Resource development Office. Adiyo Kaka, Ethiopia.

Anderson L. and Schneider K., 2010. Yield Gap and Productivity Potential in Ethiopian Agriculture: Staple Grains & Pulses. Evans School Policy Analysis and Research (EPAR) Brief No. 98. [Scholar Google]

ATA (Agricultural Transformation Agency, Ethiopian). 2016. Soil Fertility Status and Fertilizer Recommendation Atlas of the Southern Nations, Nationalities and Peoples' Regional State, Ethiopia, Pp. 301.

CIMMYT, 1998. From agronomic data to farmer recommendations. An Economics Training Manual. Completely Revised Edition. CIMMYT, Mexico, D.F.,Mexico. 79 pp.

CSA (Central Statistical Agency), 2011. Agricultural Sample Survey Report on area and production of major crops, 1, Addis Ababa.

CSA (Central statistical agency), 2017. Agricultural sample survey 2016/2017. Volume I. Report on area and production for major crops (private peasant holdings, meher season). Central Statistical Agency. Addis Ababa, Ethiopia.

Diriba, S., Rut-Duga D. and Wogayehu W., 2019. Effects of Blended Fertilizer Rates on Bread Wheat (Triticum Aestivum L.) Varieties on Growth and Yield Attributes. Journal of Ecology & Natural Resources 3(3): 000170. [Scholar Google]

Efrem, B., Hirut K. and Getachew B., 2000. Durum wheat in Ethiopia: An old crop in an ancient land. Institute of Biodiversity Conservation and Research. Addis Ababa, Ethiopia 68. [Scholar Google]

EthioSIS (Ethiopian Soil Fertility Status, Ethiopian Soil Information System). 2016. Fertilizer Recommendation Atlas of the Southern Nations Nationalities and Peoples' Regional State, Ethiopia.

FAO, 1998. World Reference Base for Soil Resources, by ISSS–ISRIC–FAO. World Soil Resources Report No. 84. Rome.

Fayera A., Adugna D. and Muktar M., 2014. Evaluation of Teff [Eragrostistef (Zuccagni) Trotter] Responses to Different Rates of NPK Along With Zn and B in Didessa District, Southwestern Ethiopia, World Appl. Sci. J., 32 (11): 2245-2249. [Scholar Google]

Franzen D. W., McMullen M. and Mossett D. S., 2008. Spring wheat and durum yield and disease responses to copper fertilization of mineral soils.

Agronomy Journal 100:371-375. [Scholar Google]

Habtamu A., Heluf G., Bobe B., and Enyew A., 2015. Effects of Organic and Inorganic Fertilizers on Yield and Yield Components of Maize at Wujiraba Watershed,Northwestern Highlands of Ethiopia. Ame J Plant Nutrition Fertilization Technol 5(1): 1-15. [Scholar Google]

Jones J. B., 2003. Agronomic Handbook: Management of Crops, Soils, and Their Fertility. CRC Press LLC, Boca Raton, FL, USA. 482p. [Scholar Google]

Knight S., Kightley S., Bingham I., Hoad S., Lang B., Philpott H., Stobart R., Thomas J., Barnes A. and Ball B., 2012. Desk study to evaluate contributory causes of the current 'yield plateau' in wheat and oilseed rape. AHDB Cereals & Oilseeds Project Report No. 502. [Scholar Google]

Landon J. R., 1991. Booker Tropical Soil Manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics. John Wiley & Sons Inc., New York.

Masresha M., 2014. Response of Maize (Zea mays L.) to Application of Mineral Nitrogen Fertilizer and Compost in Godere District, Gambella Region, Southwestern Ethiopia. Haramaya University,Ethiopia. [Scholar Google]

Mulugeta E., Shure S., Tilahun C., Chala C. and Negash B., 2017. Optimization of Fertilizer Recommendations for Bread Wheat at Sinana District of Bale Zone, Southeastern Oromia, Ethiopia. Int J Sci Qualitative Analysis 3(6): 55-60. [Scholar Google]

Noabur R., and Jeff S., 2020. Response of wheat, pea, and canola to micronutrient fertilization on five contrasting Prairie soils. Department of Soil Science, University of Saskatchewan, Saskatoon, SK, Canada. [Scholar Google]

Ruiz D., 2016. Seeding, Planting, and Nutrient Management. Department of Agronomy, Kansas State University.

SAS Institute. 2011. SAS Institute, SAS/IML 9.3 user's guide. Inc., Cary, NC, USA.

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