RJOAS: Russian Journal of Agricultural and Socio-Economic Sciences
ISSN 2226-1184 (Online) | Issue 2(146), February 2024

UDC 631

FINE-TUNING AND VALIDATION OF BLENDED FERTILIZERS: USING ETHIO-SIS FERTILITY MAPS IN SOUTHERN ETHIOPIA

Sigaye Melkamu Hordofa
Wondo Genet Agricultural Research Center, Ethiopian Institute of Agricultural Research, Shashemane, Ethiopia
E-mail: hordofa.mel@gmail.com

ABSTRACT
Field experiments were conducted to validate blended fertilizer to develop site- and crop-specific optimum rate recommendations based on the Ethio-SIS soil fertility map in Alaba and Silti districts of southern Ethiopia during the 2019 cropping season. The experiments consisted of six treatment levels: (1) control, (2) farmers' practice (100 kg ha^{-1} of NPSB + 50 kg ha^{-1} of urea) for maize and Teff at each district, (3) 100% of the recommended rates of N & P from TSP and urea, (4) 50% of the recommended rates of N & P from blended fertilizer and urea, (5) 100% of the recommended rates of N & P from blended fertilizer and urea and (6) 150% of the recommended rates of N & P from blended fertilizer and urea, and arranged in a randomized complete block design (RCBD) with three replications. Based on the study, the maximum grain yield (8,240 kg ha^{-1}), straw yield (18,435 kg ha^{-1}), and biomass yield (25,858 kg ha^{-1}) of maize were obtained from the application of 150% of the recommended rate of nitrogen and phosphorous from the NPSB blended fertilizer source at Alaba districts. Likewise, at Silti, the application of 150% of the recommended rate of nitrogen and phosphorous from the NPSB blended fertilizer source resulted in the maximum Teff grain yield (2,505 kg ha^{-1}), straw yield (5317 kg ha^{-1}) and biomass yield (7,822 kg ha^{-1}). The economic analysis indicated that the application of 150% of the recommended rate nitrogen and phosphorous from the NPSB blended fertilizer source gives a net benefit of 107, 113.50 ETB ha^{-1} with MRR of 9% 91, 645.70 ETB ha^{-1} with an MMR of 17% in maize and Teff production in Alaba and Silti districts, respectively. Consequently, based on the findings, I conclude that the application of the NPSB blended fertilizer source significantly improved maize and Teff yield and yield components and increased soil fertility by improving some essential soil nutrients at both sites. Finally, this is a seasonal result, so further study should be done for two years to confirm and for the applicability of the current finding.

KEY WORDS
Blended fertilizers, teff, maize, yield, Ethio-SIS.

Agriculture in Ethiopia is the primary source of employment for 85% of the population and contributes to 90% of the country's total export earnings. Furthermore, it supplies over 70% of the raw materials required by industries and accounts for 60% of gross domestic product (CSA, 2022). Consequently, agriculture plays a significant role in Ethiopia's economic growth and is projected to continue leading shortly. However, the agricultural sector in Ethiopia faces the serious and chronic challenge of food shortages due to low production per unit area and poor agricultural practices. One of the primary factors contributing to low crop productivity is the depletion of soil fertility, which is exacerbated by nutrient removal during harvest, tillage, weeding, runoff, soil erosion, soil degradation, and the use of unbalanced and inappropriate amounts and forms of fertilizer for specific sites and crops (Hussain *et al*., 2006).

Soil fertility preservation has become a major concern in tropical Africa, particularly with the rapid increase in population in recent decades (Smaling and Braun, 1996). Enhancing food production and soil resources in the smallholder farming sector of Africa has become an immense challenge (Dagne, 2016). Therefore, restoring soil fertility is a crucial prerequisite for increasing crop production (Brady *et al*., 2002). Inorganic fertilizers have played a vital role in addressing soil fertility issues and have contributed significantly to the increase in food production. However, the unbalanced use of fertilizers in pursuit of higher agricultural productivity has led to problems such as soil fertility depletion and imbalances in plant nutrients, including major and secondary macronutrients and micronutrients. Failure to replenish secondary macronutrients and micronutrients in intensive agriculture can result in deficiencies (Fageria and Baligar, 2001; Singh, 2011).

Recent soil analysis data in Ethiopia, as indicated by the soil fertility map, have revealed widespread deficiencies in several nutrients in Ethiopian soils, including nitrogen (86%), phosphorus (99%), sulfur (92%), boron (65%), Zn (53%), potassium (7%), copper, manganese, and iron (Ethio-SIS, 2016). Similarly, Asgelil *et al.* (2007) found that soil analyses and site-specific studies indicated the depletion of elements, such as potassium, sulfur, calcium, magnesium, and various micronutrients (Cu, Mn, boron, Mo, and Zn) in different parts of the country, leading to deficiency symptoms in major crops. To address this issue of nutrient deficiency, the use of soil fertility maps (soil fertility atlas) has been implemented, and district-level multi-nutrient balanced fertilizers containing nitrogen, phosphorus, potassium, sulfur, boron, and zinc in blended form have been introduced. These fertilizers aim to alleviate site-specific nutrient deficiencies and subsequently increase crop production and productivity in their respective areas.

Consequently, experiments have been conducted throughout the country to validate the use of blended fertilizers (formulas) for major crops across various soil types, comparing them with previously recommended fertilizer rates. Moreover, according to soil fertility maps (soil fertility atlas) and survey reports, the deficiency of nitrogen, phosphorous, sulfur, and boron was widely spread in Alaba and Siliti districts (Ethio-SIS, 2016). However, there is still a lack of sufficient information and limited studies on the validation of blended fertilizers for major crops and soil types, especially in low-potential areas such as the Alaba and Siliti districts. Additionally, the soil fertility maps indicated a widespread deficiency of nitrogen, phosphorous, sulfur, and boron in these districts. Therefore, it is necessary to improve the nutrient content of the fertilizer to suit the needs and the productivity of the crop and soil. However, information on the application of rate blended fertilizer NPSB, especially for maize and Teff, still needs to be determined in the study area. Therefore, these experiments were designed to validate blended fertilizers to develop site and crop-specific optimum rates for maize and Teff on yield and yield components based on the Ethio-SIS map recommendation of the following objectives: To enhance crop productivity and contribute to food security in the districts, To validate blended fertilizer recommendations (rates) based on the Ethio-SIS soil fertility map, and To determine agronomic and economic optimum blended fertilizer rates for maize and Teff on yield, yield component under different soil types in productive safety net program (PSNP) districts.

MATERIALS AND METHODS OF RESEARCH

The study was conducted during the main cropping season of 2022-2023 in the districts of Alaba and Siliti in Southern Ethiopia. The experimental sites in Alaba and Silti are located at 7°24'53.87"" N and 38°6'55.54" E, with an altitude of 1790 *m.a.s.l.,* and at 8°01'33.03" N and 38°23'85.80" E, at an altitude of 1850 *m a.s.l.,* respectively. In both the Silte and Alaba districts, the main crops cultivated were maize, wheat, sorghum, barley, teff, and pepper. To account for soil variation, a minimum distance of 500 m was maintained between the fields of different farmers.

The experiment was conducted using a randomized complete block design (RCBD) with three replicates. It consisted of six different treatment levels: (1) control (no input), (2) farmers' practice (applying 100 kg ha^{-1} of NPSB + 50 kg ha^{-1} of urea) for maize and Teff in each district, (3) applying 100% of the recommended rates of N and P from TSP and urea; (4) applying 50% of the recommended rates of N and P from blended fertilizer and urea; (5) applying 100% of the recommended rates of N and P from blended fertilizer and urea; and (6) applying 150% of the recommended rates of N and P from blended fertilizer and urea. The test crops used in this study were maize - BH-546 variety and Teff - Kuncho varieties. The trials were conducted in two farmers' fields per crop and district.

To minimize losses and increase use efficiency, blended fertilizer, and phosphorus-containing fertilizer from NPS and triple super phosphate (TSP), respectively, were applied once at sowing. Nitrogen fertilizer from urea was applied in two stages: half at sowing and the other half during the maximum growth stage, which was between the third and fourth weeks after sowing, and at the full-tillering stage for maize and Teff, respectively. All other agronomic management practices were implemented in accordance with the recommended guidelines for a specific variety. The necessary data were collected at appropriate times and crop growth stages.

Data collection involved gathering various parameters related to the crop yield and yield components for each test crops. These parameters included the number of effective tillers, height of the plants, length of the panicles, yield of the grains, yield of the biomass, yield of the straw, and 1000 seed weight, Soil samples were collected from each farmer's field at a depth of 0-20 cm before sowing and immediately after harvesting. These soil samples were then analyzed for various properties, such as texture, pH, organic matter, total nitrogen, total sulfur, available phosphorous, exchangeable potassium, cation exchange capacity, and boron were analyzed based on standard soil plant analysis procedure.

To determine the economic feasibility of different treatments, an economic analysis was conducted following the procedure outlined by CIMMYT (1988). This analysis includes partial budgets, dominance analysis, and marginal analysis. The average yield was adjusted by 10% to account for the difference between the experimental plot yield and the yield expected from the same treatment. Market prices for maize, Teff, straw, and the official prices of fertilizers were used in the analysis.

The collected data were analyzed using one-way analysis of variance (ANOVA) with the help of Statistical Analysis Software (SAS) version 9.4 (SAS, 2014). Whenever significant treatment effects were observed, mean separations were determined using the least significant difference (LSD) test at a probability level of $p \leq 0.05$, as determined by one-way ANOVA.

RESULTS AND DISCUSSION

The physicochemical properties of the soil at the experimental sites were assessed before sowing. The soil particle size distribution at the Alaba site was 63.1% sand, 21.3% silt, and 15.3% clay. Similarly, at Silti, the percentages were 55.6% sand, 14.1% silt, and 30.3% clay. Therefore, the soil textural class at the Alaba site was sandy loam, whereas that at the Silti site was sandy clay loam, according to the (Bieganowski *et al*., 2014). The proportion of clay in the soil at the Silti site was higher than that at the Alaba site, which is beneficial for stabilizing soil aggregates and reducing the risk of wind and water erosion in the surface soil layers. This could also indicate a higher water- and nutrient-holding capacity, resulting in increased crop productivity. The pH values of the soil were 6.1 at Alaba and 6.6 at Silti. Soil pH plays a crucial role in various chemical reactions that influence plant growth by affecting soil microorganism activity, solubility, and availability of essential plant nutrients, including micronutrients, such as Fe, Zn, B, Cu, and Mn (Sumner, 2000). The available phosphorus (P) content at Alaba and Silti districts was 11.2 and 16.2 ppm, respectively.

Table 1 – Soil physiochemical properties at Alaba prior to sowing

Parameters	Value	Rating	Reference
Sand (%)	63.1		
Silt (%)	21.6		
Clay (%)	15.3		
Textural class	Sandy Loam		(Bieganowski *et al.,* 2014)
pH (1:2.5 soil: water)	6.1		
Available P (mg kg^{-1})	11.2	Medium	Olsen *et al*. (1954)
Sulfur (mg kg^{-1})	2.8	Low	Don Ankerman and Richard (2015)
Total nitrogen (%)	0.12	Low	Tekalign (1991); Berhanu (1980)
Organic carbon (%)	1.5	Low	Tekalign (1991)
Cation exchange capacity (cmol (+) kg^{-1})	12.8	Moderate	London (1991); Hazelton and Murphy (2007)

According to the rating system of Olsen *et al*. (1954), the available P status at both sites falls under the medium-level category. The Silti site had a higher available P content than the Alaba site, which could be attributed to the higher clay content and enhanced nutrient retention capacity of the soil at Silti. The organic carbon content at Alaba and Silti sites was 1.5% and 1.4%, respectively, while the total sulfur (S) content was 2.8 ppm and 1.5 ppm, respectively. Both sites fall under the low category in terms of organic carbon and total sulfur content. The cation exchange capacities at the Alaba and Silti sites were 12.8 meq/100 g sample-1 and 17.6 meq/100 g sample^{-1}, respectively, indicating a medium status. The total nitrogen contents at the Alaba and Silti sites were 0.12% and 0.13%, respectively, and were categorized as medium and low, respectively (Tekalign, 1991; Berhanu, 1980).

Table 2 – Soil physiochemical properties at Silti before sowing

Parameters	Value	Rating	Reference
Sand (%)	55.6		
Silt (%)	14.1		
Clay (%)	30.3		
Textural class	Sandy clay loam		(Bieganowski *et al*., 2014)
pH (1:2.5 soil:water)	6.6		
Available P (mg kg^{-1})	16.2	Medium	Olsen *et al*. (1954)
Total sulfur (mg kg^{-1})	1.5	Low	Don Ankerman and Richard (2015)
Total nitrogen (%)	0.13	Moderate	Tekalign (1991); Berhanu (1980)
Organic carbon (%)	1.4	Low	Tekalign (1991)
Cation exchange capacity (cmol(+) kg^{-1})	17.6	Moderate	London (1991); Hazelton and Murphy (2007)

At the Alaba site, the utilization of NPSB-blended fertilizer had a significant impact on the available soil P level (Table 3). The maximum soil P level was achieved when 100% and 150% of the recommended N and P (RNP) were applied using NPSB and Urea sources. The results also indicated that the application of fertilizers did not have a significant effect on soil reaction (pH), sulfur, total nitrogen, or organic matter content of the soils at the experimental site in Alaba (Table 3). However, it was observed that the application of 100% and 150% RNP from NPSB and Urea sources resulted in improved total S, total N, and OC content of the soils.

Similarly, at the Silte site, the application of NPSB blended fertilizer in combination with urea had significant effects on the available soil P, total S, total N, and OC content of the soils (Table 4). However, there was no significant improvement in soil reaction (pH) (Table 4). Overall, as the level of NPSB application increased from 0 to 150%, there was a corresponding increase in the improvement of the soil chemical properties (Table 4). The greatest improvements were observed when 150% RNP from NPSB and urea were applied. Therefore, the application of balanced fertilizer not only increased crop yield but also enhanced the nutrient status of the soil.

Table 3 – Soil physiochemical properties pre-planting at Alaba

Treatments	pH (1:2.5 H_2O)	Av. P (ppm)	S (ppm)	% N	% OC
1	5.85	12.82^{b}	1.81	0.12	1.18
2	5.57	25.88^{a}	2.43	0.11	2.01
3	5.88	30.22^{a}	3.52	0.12	1.78
4	6.22	27.60^{a}	2.52	0.10	1.81
5	6.20	32.30^{a}	3.44	0.14	2.33
6	6.16	31.82^{a}	3.63	0.16	2.46
CV	7.2	19.8	29.4	17.1	25.5
lsd @0.05	ns	9.6	ns	ns	ns

The results obtained from the fields of the two farmers were consistent; hence, a combined analysis was performed. The measured variables of maize, including aboveground biomass, grain yield, straw yield, and harvest index, were significantly influenced by the application of different rates of NPSB-blended fertilizer ($p<0.01$). The aboveground biomass, grain yield, and straw yield ranged from 11,758 to 25,858 kg ha^{-1}, 3,421 to 8,240 kg ha^{-1}, and

8,337 to 18,435 kg ha^{-1}, respectively (Table 5). The analysis indicated that the highest aboveground biomass (25,858 kg ha^{-1}), grain yield (8,240 kg ha^{-1}), and straw yield (18,435 kg ha^{-1}) were achieved when 150% of RNP was applied from NPSB and urea fertilizers. Similarly, statistically equivalent biomass and straw yields were obtained from the application of 100% RNP from TSP and urea and 100% RNP from NPSB and urea fertilizers (Table 5).

Table 4 – Soil physiochemical properties pre-planting at Silti

Treatments	pH (1:2.5 H_2O)	Av. P (ppm)	S (mg/kg)	% N	% OC
1	6.21	13.16^{c}	1.41^{d}	0.12^{bc}	1.17^{b}
2	5.92	26.39^{ab}	2.84^{bcd}	0.13^{abc}	1.58^{ab}
3	6.22	19.51^{bc}	2.70^{cd}	0.12^{c}	1.28^{ab}
4	5.71	22.10^{b}	3.88^{bc}	0.12^{bc}	1.44^{ab}
5	5.97	25.28^{ab}	4.37^{b}	0.15^{ab}	1.76^{ab}
6	6.26	29.89^{a}	7.25^{a}	0.16^{a}	2.06^{a}
CV	25.4	17.5	23.1	12..5	30.1
lsd @0.05	ns	7.2	1.6	0.03	0.9

Furthermore, the results showed no significant difference in most yield and yield components between the application of 100% RNP from TSP and Urea (as per the previous recommendations), and 100% RNP from NPSB blended and urea fertilizers (Table 5). The lowest yield and yield components were observed in the control and unfertilized plots. Applying 150% of RNP from NPSB blended with urea fertilizers resulted in a higher grain yield of 36%, 34%, and 21% compared to the farmers' practice, application of 100% of RNP from TSP and Urea, and application of 100% of RNP from TSP and Urea fertilizers, respectively. The yield advantage relative to the control (unfertilized) treatment was 58% (Table 5), indicating depletion of the soil and its strong response to fertilizer application. This can be attributed to the optimal application of N, P, and S and their roles in providing energy for seed formation and grain filling. Therefore, it is crucial to apply balanced fertilizers based on soil tests (crop response) to enhance soil fertility and crop yield.

Corn harvesting mainly relies on the accessibility of necessary nutrients for plants, which are obtained with fertilizers (Adediran, *et al*. 2003). Dagne (2016) also found similar results in their experiment, with the highest average grain yield (8,400 kg ha^{-1}), stover yield (8,553 kg ha^{-1}), and total biomass yield (16,868 kg ha^{-1}) from blended fertilizers, whereas the lowest yields were obtained from the control group. Abebaw and Hirpa (2018) also noted that the application of blended fertilizer at a rate of 200 kg ha^{-1}, along with 63.91 kg ha^{-1} of urea, resulted in the highest Teff grain yield compared to the control group and the NP-recommended rates.

Table 5 – Polled means biomass yield, straw yield, grain yield, and harvest index of maize crop as influenced by different rates of NPSB fertilizer in the Alaba district

Treatments (kg ha^{-1})	AGBM (kg ha^{-1})	SY (kg ha^{-1})	GY (kg ha^{-1})	HI%
Control	11758.0^{c}	8337.0^{c}	3421.3^{d}	29.2^{abc}
Farmers Practice	19900.0^{b}	14421.0^{b}	5479.2b^{c}	27.4^{abc}
100% of RNP (from TSP and Urea)	23013.0^{ab}	16494.0^{ab}	6518.6^{b}	29.2^{abc}
50% of RNP (from NPSB and Urea)	15433.0^{c}	10196.0^{c}	5236.9^{c}	34.4^{a}
100% of RNP (from NPSB and Urea)	24917.0^{a}	17619.0^{ab}	6481.6^{b}	26.3^{c}
150% of RNP (from NPSB and Urea)	25858.0^{a}	18435.0^{a}	8239.5^{a}	32.2^{ab}
CV	16.7	19.1	17.1	15
lsd @0.05	3881.1	3395.1	1181.0	5.9
Site*treatment	ns	ns	ns	ns

Note: AGBM, SY, GY, and H are above-ground biomass, straw yield, grain yield, and harvest index, respectively.

The analysis of variance indicated that the application of different rates of NPSB blended fertilizer had a significant ($p<0.01$) impact on all measured variables. The yield and yield components of Teff achieved by the application of 150% RNP from NPSB and Urea fertilizers were superior to those of the other treatments. Application of 150% RNP from NPSB and Urea fertilizers resulted in the highest biomass (7,822 kg ha^{-1}), grain (2,505 kg ha^{-1}), and straw (5,317 kg ha^{-1}) yields. Additionally, the longest spike length (41 cm) and the highest number of tillers (360 m-1) were obtained with the application of 150% of the recommended nitrogen and phosphorus fertilizer from the NPSB blended fertilizer source. Conversely, the control (unfertilized) treatment yielded inferior results in terms of the yield and yield attributes. The grain yield obtained from the application of 150% RNP from NPSB and Urea was 34%, 27%, and 20% larger than the farmers' practices, application of 100% RNP from TSP and Urea, and 100% RNP from NPSB and Urea fertilizers, respectively (Table 6). This enhanced yield can be attributed to the application of balanced and appropriate mixes of fertilizer, which can increase crop yield; improve the physical, chemical, and biological conditions of the soil; and increase revenue from fertilizer application. Similarly, Fayera *et al*. (2014) discovered that Teff had the highest productive tillers when 200 kg ha^{-1} (NPKSZnB) blended fertilizer and 23 kg N ha^{-1} were applied.

Table 6 – The polled mean of yield and yield attributes of Teff as influenced by different rates of NPSB fertilizer in Silti District

Treatments (kg ha^{-1})	SL (cm)	NT (m^3)	AGBM (kg ha^{-1})	SY (kg ha^{-1})	GY (kg ha^{-1})	HI %
Control	15.2^c	108.8^c	1959.0^e	1305.6^d	653.4^d	33.9^b
Farmers Practice	34.7^b	248.6^b	3719.6^c	2077.8^{bc}	1641.8^b	45.1^a
100% of RNP (from TSP and Urea)	34.8^b	264.9^b	4242.1^{bc}	2416.7^b	1825.4^b	43.0^a
50% of RNP (from NPSB and Urea)	17.7^c	133.7^c	2697.2^d	1555.6^{cd}	1141.7^c	42.3^a
100% of RNP (from NPSB and Urea)	33.6^b	237.9^b	4382.1^b	2388.9^b	1993.2^b	45.5^a
150% of RNP (from NPSB and Urea)	40.8^a	359.9^a	7821.6^a	5316.7^a	2504.9^a	32.2^b
CV	10.6	20.1	11.1	22.8	19.2	16.1
lsd @0.05	3.1	56.0	549.4	684.7	372.4	7.7
Site*treatment	ns	ns	ns	ns	ns	ns

Note: SL, NT, AGBM, SY, GY, and HI are the spike length, number of tillers, above-ground biomass yield, straw yield, grain yield, and harvest index, respectively.

Table 7 – Economic analysis of the effect of NPSB-blended and conventional NP fertilizer application on maize production in Alaba District

Treatments	AGY (kg ha^{-1})	TVC (Birr)	GFB (Birr)	NB (Birr)	MRR (%)
Control	3421.3	1375.00	45851.9	44476.9	
Farmers Practice	5479.2	3825.00	75054.6	71229.6	10.9
100% of RNP (from TSP and Urea)	6518.6	7325.00	92066.8	84741.8	3.9
50% of RNP (from NPSB and Urea)	5236.9	3911.75	71991.5	68079.7	D
100% of RNP (from NPSB and Urea)	6481.6	6448.5	90709.3	84260.8	6.4
150% of RNP (from NPSB and Urea)	8239.5	8985.25	116098.8	107113.5	9.0

Note: (1) AGY, TVC, GFB, NB, MRR, and D are adjusted grain yield, total variable costs, gross field befit, net befit, and marginal rate of return (%) and dominated, respectively; (2) Price of Urea, TSP, and NPSB were =15.5, 19, and 16.5 birr kg-1, respectively;(3) Price of maize grain was 13 birr kg^{-1}.

Table 8 – Economic analysis of the effect of NPSB-blended and conventional NP fertilizer application on Teff production in Silti District

Treatments	AGY (kg ha^{-1})	ASY (kg ha^{-1})	TVC (Birr)	GFB (Birr)	NB (Birr)	MRR%
Control	653.4	1305.6	562.2	25090.3	23784.7	
Farmers Practice	1641.8	2077.8	3012.2	63554	60354	D
100% of RNP (from TSP and Urea)	1825.4	2416.7	4002.2	70598.5	66408.5	12.5
50% of RNP (from NPSB and Urea)	1141.7	1555.6	2085	44445.7	42161.1	D
100% of RNP (from NPSB and Urea)	1993.2	2388.9	3607.8	76969.4	73150.2	12.0
150% of RNP (from NPSB and Urea)	2504.9	5316.7	5130.6	96999.5	91645.7	17.0

Note: (1) AGY, ASY, TVC, GFB, NB, MRR and D are adjusted grain yield, adjusted straw yield, total variable costs, gross field befit, net befit, and marginal rate of return (%) and dominated, respectively; (2) Price of Urea, TSP, and NPSB were =15.5, 19 and 16.5 birr kg^{-1}, respectively;(3) Price of Teff grain and straw were 38 and 0.20 birr kg^{-1}

Similarly, the application of nitrogen with the addition of sulfur nutrients has a positive or synergetic effect (Marschner, 2002). This positive interaction is crucial for boosting crop yields. Sulfur is necessary to produce chlorophyll, phosphorus, and other essential nutrients. Sulfur is as important as nitrogen in optimizing crop yield and quality (Marschner, 2002). In line with this finding, Lemlem *et al*. (2015) observed a significant effect on Teff yield and yield components when a blended fertilizer was applied. Tekle and Wassie (2018) also reported significantly higher yield and yield components of Teff compared to conventional N and P fertilizers owing to the application of blended fertilizer. Klikocka *et al.* (2016) documented the synergetic effect of N and S fertilization and the subsequent increase in yield and yield components of the crop. Additionally, greater responses to S application have been observed when abundant amounts of N were applied (Zhao *et al*., 1999). Zada and Afzal (1997) found that the application of 4 kg ha^{-1} boron increased the number of tillers per plant, spikes per square meter, and grain yield of wheat.

Economic analysis demonstrated that the application of 150% RNP from NPSB blended fertilizer and urea resulted in relatively high net benefits. Therefore, these rates could be considered the most suitable for maize and teff production in the Alaba and Silti districts, respectively (Tables 7 and 8). The highest economic return in maize production was obtained through farmers' practices, followed by the application of 150% RNP from NPSB fertilizer (Table 7). The application of 150% RNP from NPSB-blended fertilizer resulted in the highest economic return for Teff production. For every unit of investment in NPSB fertilizer application, an additional return of 17 birr could be earned from Teff production (Table 8). The highest net benefit of (61,634) Birr ha^{-1} was obtained from the combined application.

CONCLUSION, RECOMMENDATIONS AND LIMITATIONS

In Ethiopia, maize and Teff production and productivity have been limited mainly due to declining soil fertility, unbalanced application of plant nutrients, application of fertilizer without soil test-based and crop response, and use of inappropriate fertilizer recommendations. Based on the results of the current study on the yield and yield components of maize and Teff, the following recommendations can be made: Based on the results of this study, the maximum grain yield (8,240 kg ha^{-1}), stover yield (18,435 kg ha^{-1}), and biomass yield (25,858 kg ha^{-1}) of maize were obtained from the application of 150% of the recommended rate of nitrogen and phosphorous from an NPSB blended fertilizer source in Alaba district. Likewise, in the Silti district, 150% of the recommended rate of nitrogen and phosphorous from the NPSB blended fertilizer source yielded the maximum Teff grain yield (2,505 kg ha^{-1}), stover yield (5317 kg ha^{-1}), and biomass yield (7,822 kg ha^{-1}).

The economic analysis indicated that the application of 150% of the recommended rate of nitrogen and phosphorous from the NPSB blended fertilizer source gives net benefits of 107, 113.50 ETB ha^{-1} with MRR of 9% 91, 645.70 ETB ha^{-1} with an MMR of 17% in maize and Teff production in Alaba and Silti districts, respectively. Therefore, 150% of the recommended rate of nitrogen and phosphorous from NPSB-blended fertilizer sources could be recommended for different wealthy groups of farmers. Generally, the application of NPSB-blended fertilizer significantly improved maize and Teff of the yield and yield components, improved soil fertility, and increased some essential soil nutrients. Finally, this is a one-season result, so further study should be conducted for two years to confirm and widen the applicability of the current findings.

The decision to limit the data presentation to one year in the research paper was multifaceted. Initially, the primary objective was to validate the accuracy and reliability of the newly introduced ETHIO-SIS fertility maps while simultaneously fine-tuning recommendations for blended fertilizers. This focused approach ensured a thorough assessment of the maps' efficacy in guiding fertilizer applications within a realistic agricultural setting.

Additionally, practical constraints such as limited resources and logistical challenges necessitated a concise timeframe for data collection and analysis. However, it's important to note that this singular year of data serves as a foundational step, offering valuable insights into immediate applications and adjustments. Looking ahead, future research endeavors have the potential to delve into longer-term trends, allowing for a more comprehensive validation of findings and the refinement of agricultural practices over time.

The original contributions presented in the study are included in the article; further inquiries can be directed to the corresponding author.

FUNDING

This research was conducted with funds from of Ethiopian Institute of Agricultural Research and National Soil and Water Research Division.

ACKNOWLEDGMENTS

We would like to acknowledge the Ethiopian Institute of Agricultural Research, and Wondo Genet Agricultural Research Center for providing the necessary facilities to carry out this work.

REFERENCES

1. Adediran, J. A. and J. O. Kogbe, 2003. Influence of nitrogen, phosphorus, and potassium application on the yield of maize in the savanna zone of Nigeria. African J. Biotech. 2: 345-349.
2. Abebaw Tadele Alem and Hirpa Legese. 20118. 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. (2018).5(7):1-14.
3. Asgelil D., Taye B., and Yesuf A. 2007. The status of Micro-nutrients in Nitisols, Vertisols, Cambisols, and FLuvisolss in major Maize, Wheat, Teff, and Citrus growing areas of Ethiopia. In Proceedings of Agricultural Research Fund. pp 77-96.
4. Berhanu Debele, 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.
5. Bieganowski A., Ryzak M., “Soil Texture: Measurement Methods.” Springer, Encyclopedia of Earth Sciences Series, 978-90- 481-3584-4, 2014.
6. Brady, N.C. and Weil, R.R. 2002. The Nature and Properties of Soils.13th edition. Pearson Education Ltd, USA.
7. CIMMYT. 1988. From agronomic data to farmer’s recommendations: economics training manual. Completely revised edition, CIMMYT, Mexico. D.F. 79 pp.
8. CSA (Central Statistical Agency). 2022. Agricultural Sample Survey for the crop season. Vol. 5 report on Area and production Statistical Bulletin 578. FDRE/CSA, A.A, Ethiopia.
9. Dagne C.2016. Blended fertilizers effects on maize yield and yield components of Western Oromia, Ethiopia. Agriculture, Forestry and Fisheries 5(5):151-162. DOI: 10.11648/j.aff.20160505.13.
10. Don Ankerman, B.S. and Richard Large, 2015 Agronomy handbook. Soil and Plant Analysis Midwest Laboratories, Inc pp. 35.
11. Ethio-SIS (Ethiopia Soil Fertility Status). 2016. Fertilizer Recommendation Atlas of the Southern Nations, Nationalities and Peoples’ Regional State, Ethiopia. pp 81.
12. Fageria, N. K. and V. C. Baligar. 2001. Improving nutrient use efficiency of annual crops in Brazilian acid soils for sustainable crop production. Commun. Soil Sci. Plant Anal. 32:1303–1319.
13. Fayera Asefa, Adugna Debela and Muktar Mohammed. 2014. Evaluation of Teff [Eragrostis Teff (Zuccagni) Trotter] Responses to Different Rates of NPK Along with Zn and B in Didessa District, Southwestern Ethiopia. World Applied Sciences Journal, 32 (11): 2245-2249.
14. Hazelton, P., and B. Murphy, 2007. Interpreting soil test results: What do all the numbers mean. 2nd Edition. CSIRO Publishing. 152p.

15. Hussain N, Khan M.A and Javed M.A. 2006. Effect of foliar application of plant micronutrient mixture on growth and yield of wheat (Triticum aestivum L.). Pak. J. Bio. Sci. 8:1096-1099.
16. Landon, J.R. 1991. Booker Tropical Soil Manual Handbook for soil survey and agricultural land evaluation in the tropical and sub-tropics. Long man scientific and technical, ESSXEX, New York.474p.
17. Marschner H. 2002. Mineral nutrition of higher plants .2nd ed. Academic Press: London.674p.
18. SAS (Statistical Analysis System Institute). 2014. SAS Version 9.4 © 2002-2012. SAS Institute, Inc., Cary, North Carolina, USA.
19. Singh J, Bisen S, Bora DK, Kumar R, Bera B (2011). Comparative study of organic, inorganic and integrated plant nutrient supply on the yield of Darjeeling tea and soil health. Field Crop Research 58:58-61.
20. Smaling, E. M. and A. R. Braun, 1996. Soil fertility research in sub-Saharan Africa: new dimensions, new challenges. Commun. Soil Sci. and Plant Anal. J. 27: 365-386.
21. Sumner, M.E. 2000. Handbook of Soil Science, CRC Press, Boca Raton, FL.
22. 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.
23. Tekle L, Wassie H (2018). Response of Teff (Eragrostis Teff (Zucc.) Trotter) to blended fertilizers in Tembaro, Southern Ethiopia. Journal of Biology, Agriculture and Healthcare 8(13):34-39.
24. Zada K. and Afzal M. 1997. Effects of boron and iron on yield and yield components of wheat. Kluwer Academic Publishers. pp 35-37.
25. Zhao, F.J., Salmon S.E., Withers P.J.A., Monaghan J.M., Evans E.J., Shewry P.R. and McGrath S.P., 1999. Variation in the bread making quality and mineralogical properties of wheat in relation to sulfur nutrition under field conditions. Journal of Cereal Science 30(1): 19-31.