Asian Journal of Plant Sciences

ISSN 1682-3974

OPEN ACCESS Asian Journal of Plant Sciences

ISSN 1682-3974
DOI: 10.3923/ajps.2022.130.138

Research Article
Effect of Blended Fertilizer on Yield, Nutrient Uptake and Economy of Maize (*Zea mays* L.) in Assosa District, Western Ethiopia

[1]Bakala Anbessa, [2]Girma Abera and [3]Sofiya Kassas

[1]Ethiopia Institute of Agricultural Research, Assosa Agricultural Research Center, Assosa Ethiopia
[2]Hawasa University College of Agriculture, Hawassa Ethiopia
[3]Ethiopia Institutes of Agricultural Research, Addis Ababa, Ethiopia

Abstract
Background and Objective: Soil fertility depletion and soil acidity are critical problems for maize (*Zea mays* L.) production in western Ethiopia. Because of this, a field experiment was conducted on acidic Nitisols of the Assosa area to investigate the response of maize to different blended fertilizer rates and types. **Materials and Methods:** The treatments consists of control, three rates of N and P (92/46, 115/57 and 138/69 N/P_2O_5 kg ha^{-1}) and two blended fertilizers with three rates (100 kg NPSB+73.9 kg N ha^{-1}, 150 kg NPSB+110.8 kg N ha^{-1}, 200 kg NPSB+147.8 kg N ha^{-1}, 100 kg NPSZnB+75.1 kg N ha^{-1}, 150 kg NPSZnB+112.6 kg N ha^{-1}) and 200 kg NPSZnB+150.2 kg N ha^{-1}. The experiment was laid out as a Randomized Complete Block Design with three replications. **Results:** The results revealed that fertilizer types and rates significantly ($p<0.01$) affected grain yield, stover yield and harvest index. However, there was no significant difference between the two blended fertilizer types (NPSB and NPSZnB). The highest grain yield (7056.2 kg ha^{-1}) was recorded with 200 kg NPSZnB+150.2 kg N ha^{-1} application. Blended fertilizers had improved nutrient concentration and uptake of maize. Application of 150 kg NPSB+110.8 kg N ha^{-1} recorded the highest marginal rate of return and net benefit. **Conclusion:** The study demonstrates high improvement in grain and stover yield and nutrient uptake of maize in response to blended fertilizers implying that N, P, S, Zn and B are deficient in Assosa soils, hence external application of these nutrients are vital as a blend for sustainable maize production.

Key words: Agronomic efficiency, blended fertilizers, nutrient uptake, partial budget analysis

Citation: Anbessa, B., G. Abera and S. Kassa, 2022. Effect of blended fertilizer on yield, nutrient uptake and economy of maize (*Zea mays* L.) In Assosa District, Western Ethiopia. Asian J. Plant Sci., 21: 130-138.

Corresponding Author: Bakala Anbessa, Ethiopia Institute of Agricultural Research, Assosa Agricultural Research Center, Assosa Ethiopia

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The soils of western Ethiopia are acidic attributed to their high rainfall condition. In acid soils, most crop nutrients can be leached, while available P would be limited due to its fixation to Al and Fe oxides. Despite this fact, crop response experiments are limited in the Assosa areas of western Ethiopia. Because of this, it is crucial to assess the soil fertility status to apply the required nutrients for sustainable crop production[1].

In recent years, crop productivity in Ethiopia in general and in the Benishangul Gumuz region, in particular, has shown a declining trend, despite the best use of improved varieties. The most possible causes of the decline in crop production are soil fertility depletion and the continuous use of the traditional fertilizer, which have limited number of essential plant nutrient. In addition, due to high rainfall, soil erosion is a severe problem in sloping areas where vegetative cover is very low.

Among cereals, maize (*Zea mays* L.) ranks third after wheat and rice in the world[1]. It is one of the most important cereal crops used for the human diet in large parts of the world, besides served as an important feed component for livestock. In terms of total world production, maize outranked paddy rice and wheat. Despite the large area under maize, the national average yield of maize is about 3.387 t ha^{-1}. This is by far lower than the world's average yield which is about 5.21 t ha^{-1} and also lower than the average national research centre based yields (8 t ha^{-1}) in Ethiopia[2]. These are attributed to many factors: lack of access to seeds of improved varieties, poor soil fertility and diseases and insect pests.

Low soil fertility is one of the bottlenecks to sustain agricultural production and productivity in Ethiopia. The problem is aggravated by several factors which include among others, soil erosion, nutrient mining, soil acidity and low level of application of nitrogen and phosphorus. Furthermore, unbalanced application of plant nutrients may aggravate the depletion of other important nutrient elements in soils such as K, Mg, Ca, S and micro-nutrients[3]. Thus, maize is one of the heaviest feeders of nutrients to produce high and quality yields among cereals. This is because it produces higher grain and straw yields than other cereals. Hence the application of balanced fertilizers is the basis to produce more crop output from the existing land under cultivation as nutrient needs of crops is according to their physiological requirements and expected yields[4]. Most of the fertilizer experiment in Ethiopia focus on N and P requirements of crops, hence limited information is available on various sources of nutrients such as K, S, Zn and B and other micronutrients. However, recently blended fertilizers were introduced to Ethiopia to combat the limitations of various essential nutrients in crop production. Therefore, it is paramount important to assess maize response towards different blended fertilizers such as NPSB and NPSZnB, besides the conventional fertilizers N and P fertilizers application.

Actual nutrient uptake will vary with crop yield and variety. The nutrient requirement of the crop can be met by nutrients available in the soil and by nutrient additions. Nutrient uptake by the plant is affected mainly by environmental conditions, management practices, the concentration of nutrients and the form in which nutrients are present in the soil[5]. Nutrient use efficiency is the ability of a plant to utilize soil available nutrients to result in measurable yield[6]. Agronomic efficiency (AE), uptake efficiency (RE), constitutes a set of simple indices and could be used in agronomic research to appraise the applied fertilizer efficiency particularly to assess the short-term response of the crop to a nutrient[7]. However, there is a lack of scientific studies that examine the effect of blended fertilizer (s) in improving the yield and nutrient uptake efficiency of maize in the Assosa district. The amounts of nutrients exploited in the harvested portion of the crop will depend on the yield and the concentration of the nutrients in time and space, variety, soil and environmental factors[8]. To use fertilizer sustainably, management practices must aim at maximizing the number of nutrients that are taken up by the crop and minimizing the number of nutrients that are lost from the soil[9]. Therefore, this experiment was designed to assess the role of blended and conventional fertilizers on yield, nutrient uptake and nutrient use efficiency of maize at Assosa district.

MATERIALS AND METHODS

Description of the study sites: The experiment was conducted at Assosa Agricultural Research Center (AsARC) in Benishangul Gumuz Regional State, in the 2016-2017 main cropping season under rainfed field condition. The region is located between 9°30' to 11°39'' N latitude and 34°20' to 36°30''E longitude covering a total land area of 50,000 square kilometers. The study site is located at 10°02' 05'' N latitude and 34°34' 09'' E longitudes. The study area is situated east of Assosa town and west of Addis Ababa about 4 and 660 km distance, respectively. Assosa has a unimodal rainfall pattern, which starts at the end of April and extends to mid-November, with maximum rainfall amount received in June to October. The total annual average rainfall of Assosa is 1275 mm. The minimum and maximum temperatures are 16.75 and 27.92°C, respectively. The dominant soil type of the Assosa area is Nitisols with the soil pH ranges from 5.0-6.0.

Table 1: Fertilizer treatments based on recommended N and P and blended fertilizer types and rates applied

Treatment no.	Rate (kg ha^{-1})	Blended fertilizers' mineral contents (%)
1	Control (no fertilizer)	0
2	200 kg urea+100 kg TSP	92 N and 46 P_2O_5
3	250 kg urea+125 kg TSP	115 N and 57.5 P_2O_5
4	300 kg urea+150 kg TSP	138 N and 69 P_2O_5
5	100 kg NPSB+73.9 N	18.1 N-36.1 P_2O_5-0.0 K_2O+6.7 S+0.0 Zn+0.71 B
6	150 kg NPSB+110.8 N	27.15 N-54.15 P_2O_5-0.0 K_2O+10.05 S+0 Zn+1.07B
7	200 kg NPSB+147.8 N	36.2 N-72.2 P_2O_5-0.0 K_2O+13.4 S+Zn+1.42B
8	100 kg NPSZnB+75.1 N	16.9 N-33.8 P_2O_5-0.0 K_2O+7.3 S+2.23 Zn+0.67B
9	150 kg NPSZnB+112.6 N	25.35 N-50.7 P_2O_5-0.0 K_2O+10.95 S+3.35 Zn+1.01B
10	200 kg NPSZnB+150.2 N	33.8 N-67.6 P_2O_5-0.0 K_2O+14.6 S+4.46 Zn+1.34B

Experimental design and treatments: The experiment was laid out in randomized complete block design with three replications. Hybrid maize variety (BH546) was used as a test crop. The treatments included control, three rates of nitrogen and phosphorus (92 N+46 P_2O_5, 115N+57.5 P_2O_5, 138 N+69 P_2O_5 kg ha^{-1}) and two different formula of blended fertilizers each with three rates, 100 kg NPSB+73.9 N, 150 kg NPSB+110.8N and 200 kg NPSB+147.8 N kg ha^{-1} and 100 kg NPSZnB+75.1 N, 150 kg NPSZnB+112.6 N and 200 kg NPSZnB+150.2 N kg ha^{-1}) based on soil fertility map of the region in Table 1. Blended fertilizers and TSP were basally applied at planting and Urea was top-dressed twice (at knee height and tasseling). The plot size of 4.5$\times$5.1 m (22.95 m^2) was used. The crop was planted in rows with recommended spacing (75$\times$30 cm). Other field management practices were applied uniformly for all plots as per the recommendation for the crop.

Plant tissue sampling and analysis: Representative grain and straw samples were taken from each plot at crop physiological maturity. The samples were oven-dried and ground for laboratory analysis of total N, P, S and K. The measurement of N was carried out according to the Kjeldahl procedure by transforming organic N into ammonium N by digesting with H_2SO_4 and a catalyst[10]. Potassium was measured using dry ashing, by flame Photometer[10]. Phosphorus was determined by spectrophotometer using the dry ash of maize samples. Total S was analyzed using Calorimeter. The grain and straw concentrations of N, P, S and K were used to estimate the uptake of representative elements which was calculated by multiplying grain and straw yields on a hectare basis with the respective N, P, S and K concentration. Agronomic use efficiencies were calculated by using procedures[11] as:

$$\text{Agronomic efficiency} = \frac{\text{A-B}}{\text{C}}$$

where, A is the grain yield of fertilized (kg ha^{-1}). B is the grain yield unfertilized (kg ha^{-1}). C is the Amount of fertilizer applied (kg ha^{-1}).

Partial budget analysis: Economic analysis was performed to investigate the feasibility of fertilizer application for maize production in Assosa district[12]. The mean grain yield of maize was used for the study. A partial budget, dominance and marginal analysis were used. The average open market price (Birr kg^{-1}) for maize and the official prices of blended, Urea and TSP fertilizers were used for economic analysis. The dominance analysis procedure[12] was used to select potentially profitable treatments from the ranges that were tested. The selected and discarded treatments using this technique are referred to as undominated and dominated' treatments, respectively. The undominated treatments were ranked from the lowest (the farmers' practice) to the highest cost treatment. For each pair of ranked treatments, the percentage Marginal Rate of Return (MRR) was calculated. The MRR between any pair of undominated treatments denotes the return per unit of investment in fertilizer and expressed as a percentage.

Statistical analysis: Analyses of variances for the recorded data were conducted using the SAS GLM procedure. The least significant difference (LSD) test at 5% probability was used for mean separation when the analyses of variance indicate the presence of significant differences.

RESULTS AND DISCUSSION

Effects of blended fertilizer rates and types on maize grain and stover yields: The analysis of variance for grain and straw yields revealed a highly significant ($p\leq 0.01$) difference among the treatments. However, the two blended fertilizer types was not significantly different n affecting most parameters in Table 2. The two types of blended fertilizer had significantly improved grain yield, which might be attributed to the contribution of relatively more types of nutrients (N, P, S, B and Zn) supply in the blended fertilizer as compared to the recommended N and P and control. The low yield of maize under application of recommended N and P might be due to

Table 2: Above ground biomass yield, grain yield, stover yield and harvest index of maize as influenced by blended fertilizer types and rates in Assosa district

Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index
Control	2996.0^{e}	4400.9^{e}	0.41^{bcd}
100 kg TSP+200 kg urea	3342.5^{de}	5119.8^{de}	0.40^{cd}
125 kg TSP+250 kg urea	3569.3^{de}	5337.7^{de}	0.40^{cd}
150 kg TSP+300 kg urea	3958.9^{d}	5882.4^{cd}	0.40^{cd}
100 kg NPSB+73.9 kg N	5789.8^{bc}	6971.7^{ab}	0.46^{ab}
150 kg NPSB 110.+8 kg N	6863.4^{a}	7886.7^{a}	0.47^{a}
200 kg NPSB+147.8 kg N	6563.8^{a}	6971.7^{ab}	0.48^{a}
100 kg NPSZnB+75.1 kg N	5473.3^{c}	6644.9^{bc}	0.45^{abc}
150 kg NPSZnB+112.6 kg N	6538.7^{ab}	7124.2^{ab}	0.48^{a}
200 kg NPSZnB+150.2 kg N	7056.2^{a}	7559.9^{ab}	0.49^{a}
LSD (0.05)	758.71**	1065.4**	0.05**
CV (%)	8.48	9.72	6.95

Mean followed by different letters within column showed significant differences at 5% while means followed by the same letter(s) within a column are not significantly different at 5%. LSD: Least significant difference at 5%, CV: Coefficient variation

the absence of other macro and micro nutrients (S, Zn and B). a similar trend has been reported in another study[13].

Application of 200 kg NPSZnB+150.2 kg N ha^{-1} increased grain yield by 135.5 and 111.1% over control and 100% recommended NP, respectively. A similar trend has been observed[14] in the rice crop. Grain yield increment with the application of blended fertilizers which contained S, B and Zn indicated that there is a need to supplement these elements for maize production. The increase in grain yield could be attributed to the beneficial influence of yield contributing characters and positive interaction of nutrients in the blended fertilizer[15]. Strong relationships were found between grain yield and ear length, grain yield and 100 kernels weight and the number of kernels per row.

The low yield in unfertilized plots might have been due to reduced leaf area development resulting in lesser radiation interception and, consequently, low efficiency in the conversion of solar radiation[16]. The highest maize stover yield (7886.7 kg ha^{-1}) was recorded with 150 kg NPSB+110.8 N kg ha^{-1} application, while the lowest value (4400.9 kg ha^{-1}) was recorded with control treatment. Application of 150 kg NPSB+110.8 N kg ha^{-1} resulted in 79.21 and 54.0% more stover yield as compared to the control and recommended N and P.

Harvest index: The physiological ability of maize to convert total dry matter into grain yield is determined by its Harvest Index (HI). The analysis of variance revealed that fertilizer rates and types had highly significantly ($p \leq 0.01$) influenced harvest index of maize. However, there were no significant differences between the two blended fertilizer types effect on HI of maize in Table 2. Both blended fertilizer types (NPSZnB and NPSZnB) gave more response to harvest index than recommended N and P and the control. Nevertheless, a non-significant difference between recommended N and P and control was observed concerning harvest index. The highest harvest index (0.49) was obtained at the application of 200 kg NPSZnB+150.2 kg N ha^{-1} while the lowest harvest index (0.40) was recorded under the recommended N and P.

The increase in the harvest index due to the application of micronutrients may be attributed to their role in enhancing the photosynthesis process and translocation of photosynthetic products to the economic part. Generally, application of blended fertilizers had significant effects on the harvest index of maize crop than recommended N and P. This result agrees with the findings of previous study[17] who reported that harvest index of teff was found to be highest in blended fertilizer treatments. This report was also slightly similar with[18] those reported the harvest index of maize was found to be significantly higher in plots that received blended fertilizers at a rate of 150 kg NPSZnB ha^{-1} as contrasted to the control treatment but, it was signed in par with 300 kg NPSZnB ha^{-1} and recommended NP fertilizers.

N, P, K and S concentration and uptake in grain and straw of maize: Application of blended fertilizer and recommended N and P had influenced the grain and stover N concentration and uptake. Grain and total nitrogen uptake were linearly increased with the increase of N fertilizer rates in Table 3. The maximum grain N uptake (56.10 kg ha^{-1}) was recorded with the application of 200 kg NPSZnB+150.2 kg N ha^{-1}. This rate NPSZNB application improved grain N uptake by 250.4 and 150.2% over control and the recommended N and P rate. Similarly, stover total N uptake was increased by 145.62 and 238.19% over recommended N and P and control, respectively. The maximum N concentration of grain and stover was 0.80 and 0.08%, respectively with T10 and T8, whereas the least was for control plots in Table 4. The grain N concentration increased from the minimum of 0.54% obtained with control to a maximum of 0.8% recorded for the 200 kg

Table 3: N, P, K and S uptake in grain and straw of maize in response to blended and conventional fertilizer application at Assosa district, Western Ethiopia

	Grain nutrient uptake (kg ha^{-1})				Straw nutrient up take (kg ha^{-1})				Total nutrient up take (kg ha^{-1})			
Fertilizers	N	P	K	S	N	P	K	S	N	P	K	S
Control	16.01	3.75	2.08	1.20	1.74	1.28	15.78	2.64	17.75	5.02	17.86	3.84
100 kg TSP+200 kg urea	22.29	4.01	3.08	1.67	2.15	1.43	38.96	3.07	24.44	5.44	42.04	4.74
125 kg TSP+250 kg urea	24.50	4.85	4.34	1.43	2.48	1.23	28.18	3.20	26.99	6.08	32.52	4.63
150 kg TSP+300 kg urea	27.57	5.78	7.82	1.19	3.47	1.47	32.15	4.12	31.04	7.25	39.97	5.31
100 kg NPSB+73.9 kg N	40.38	6.72	3.94	2.32	3.17	1.60	38.90	3.49	43.56	8.32	42.84	5.80
150 kg NPSB 110.+8 kg N	48.18	9.20	3.40	2.75	3.43	1.66	44.17	3.94	51.61	10.85	47.56	6.69
200 kg NPSB+147.8 kg N	45.13	8.93	6.14	2.63	3.94	1.67	42.49	4.18	49.07	10.60	48.63	6.81
100 kg NPSZnB+75.1 kg N	35.80	7.66	10.10	2.19	5.35	2.33	38.67	3.99	41.14	9.99	48.77	6.18
150 kg NPSZnB+112.6 kg N	44.30	9.28	9.61	2.22	4.70	1.92	38.01	4.27	49.00	11.21	47.62	6.50
200 kg NPSZnB+150.2 kg N	56.10	11.15	12.28	2.82	3.93	2.12	71.03	4.54	60.03	13.27	83.30	7.36

Table 4: N, P, K and S concentration in grain and straw of maize in response to blended and conventional fertilizer application at Assosa district, Western Ethiopia

	Grain nutrient concentration (%)				Straw nutrient concentration (%)			
Fertilizers	N	P	K	S	N	P	K	S
Control	0.54	0.12	0.069	0.04	0.04	0.03	0.359	0.06
100 kg TSP+200 kg urea	0.67	0.12	0.092	0.05	0.04	0.03	0.761	0.06
125 kg TSP+250 kg urea	0.69	0.14	0.122	0.04	0.05	0.02	0.528	0.06
150 kg TSP+300 kg urea	0.70	0.15	0.198	0.03	0.06	0.03	0.547	0.07
100 kg NPSB+73.9 kg N	0.70	0.12	0.068	0.04	0.05	0.02	0.558	0.05
150 kg NPSB 110.+8 kg N	0.70	0.13	0.049	0.04	0.04	0.02	0.560	0.05
200 kg NPSB+147.8 kg N	0.69	0.14	0.094	0.04	0.06	0.02	0.609	0.06
100 kg NPSZnB+75.1 kg N	0.65	0.14	0.185	0.04	0.08	0.04	0.582	0.06
150 kg NPSZnB+112.6 kg N	0.678	0.14	0.147	0.034	0.07	0.03	0.534	0.06
200 kg NPSZnB+150.2 kg N	0.80	0.16	0.174	0.04	0.05	0.03	0.939	0.06

NPSZnB+kg ha^{-1}+150 N kg ha^{-1}. Compared to recommended N and P, blended fertilizer had improved grain and stover N concentration by 19.4 and 100%, respectively. This increment in N uptake and concentration over recommended N and P could be due to improved efficiency of N attributed to macro and micronutrient present in blended fertilizer applied.

It is essential to note that the average N concentration of grain (0.7%) and stover (0.05%) of the present study were relatively low as compared to earlier reports of 1.0% and 0.8%, respectively for grain and strover[19]. This is perhaps due to the differences in laboratory analysis efficiency. In addition, the grain and stover nutrient concentration of nitrogen was lower than recoded in several other studies[15,20,21]. This might be due to the small amount of sulfur in blended fertilizer which limited the efficiency of added and indigenous soil N. This was in line with the findings of other study[22] who reported that a low rate of S limits the efficiency of added nitrogen. Omission of S in fertilizer experiment (100% NPK-S) decreased the nutrients uptake over balanced NPK with sulphur[23]. Several studies indicated the synergistic effect of the combined application of S and N on the uptake of these nutrients by maize and rapeseed[22]. The N, P and S uptake by maize plant was influenced significantly with the application of S and N fertilizer, furthermore, the highest N uptake was recorded with the application of S[24].

The highest removal of P (11.15 kg ha^{-1}), by grain, was obtained with the application of 200 kg NPSZnB+150.2 kg N ha^{-1}. The mean values of P uptake of grain, stover and total biomass of maize supplied with blended fertilizer were higher than that of the recommended N and P rate and the control plants. Application of 200 kg NPSZnB+150.2 N ha^{-1} and 100 kg NPSZnB+75.1 kg N ha^{-1} increase the grain (11.15 kg ha^{-1}) and stover (2.33 kg ha^{-1}) P uptake of maize, respectively. Application of blended fertilizer improved grain P uptake by 178.1% as compared to the recommended N and P fertilizer rate and by 197.3% as compared to the control plot. This increment might be due to the synergic effect of Zn and another nutrient in the blended fertilizer which improved uptake of phosphorus and potassium as the highly significant and strong association was observed between the grain of P uptake and K grain uptake, N grain uptake, P recovery and S grain uptake.

Increased blended fertilizer rates also increased grain P content in Table 4. This result was in line with the previous study findings[15] who reported that application of blended fertilizer with Cu and Zn resulted in the highest grain P uptake and contents. Application of blended fertilizer improved grain and stover P contents by 33.3% as compared to the control plants. Similarly, the application of blended fertilizer

Table 5: Mean of agronomic use efficiency of maize in response to blended and conventional fertilizer application at Assosa district, Western Ethiopia

Treatment (nutrients ha^{-1})	AUE (kg kg^{-1})
Control	-
100 kg TSP+200 kg urea	2.51
125 kg TSP+250 kg urea	3.30
150 kg TSP+300 kg urea	4.70
100 kg NPSB+73.9 kg N	19.64
150 kg NPSB+110.8 kg N	18.13
200 kg NPSB kg+147.8 kg N	12.54
100 kg NPSZnB+75.1 kg N	16.94
150 kg NPSZnB+112.6 kg N	16.15
200 kg NPSZnB+150.2 kg N	13.71

AUE: Agronomic fertilizer use efficiency

also improved grain and stover P contents by 33.3% over the plot that received recommended N and P fertilizer. This indicates that there was no difference between recommended N and P rate and the control treatment for grain and stover P contents. The highest P contents of grain (0.16%) and stover (0.04) were observed at blended fertilizer rate of 200 kg NPSZnB+150.2 N kg ha^{-1} and 100 kg NPSZnB+75.1 N kg ha^{-1}, respectively. Generally, the highest removal of P was observed more toward the grain as compared to the stover. These results were in line with the funding[25] that the quantity of P in grain at harvest ranged from 78-90% of the total P content. The low P uptake and concentrations in plant materials might be attributed to low soil fertility, low available P and high soil P fixation to Al and Fe oxides and clays[26].

Unlike nitrogen and phosphorous, K content and uptake in stover were higher as compared to its removal by the grain in Table 5. The highest K uptake in grain, stover and total biomass with respective values of 12.28, 71.03 and 83.30 kg ha^{-1} were recorded for application of 200 kg NPSZnB+150.2 kg N ha^{-1}, respectively. These increments might be due to the optimum supply of nitrogen via blended fertilizer that ensures optimum uptake of potassium as well as phosphorus. Similarly, optimal levels of zinc in the blended fertilizer might have improved the uptake of potassium. Generally, application of 200 kg NPSZnB+150.2 kg N had improved K uptake in grain, stover and total biomass of maize plants by 298.7, 82.3 and 98.1%, respectively as compared to the recommended N and P rate. Similarly, its blended fertilizer (T10) had increased K uptake in grain, stover and total biomass maize plant by 490.4, 350 and 366.4% as compared to control plants.

On other hand, a treatment that accumulated the maximum total biomass K gave the highest yield. The highest stover (0.939 c moil(+) kg^{-1}) and total biomass 1.114 (+) kg^{-1}) K content were recorded for 200 kg NPSZnB+150.2. kg N ha^{-1}, whereas the least value (0.359 and 0.428 (+) kg^{-1}) were recorded for control plants, respectively (Table 5). On the other hand the highest content (0.198 (+) kg^{-1}) of K in maize grain was recorded for 150 kg TSP and 300 kg Urea, whereas the least value (0.049 (+) kg^{-1})) was recorded for 150 kg NPSB kg+110.8 N ha^{-1}. The grain and stover low nutrient content (K, N, P and S) of the studied area were low, which is probably caused by laboratory quality and interactions between chemical and physical soil quality.

Blended fertilizer had improved K content in stover and total biomass of maize plants by 23.4 and 30.6%, respectively as compared to the recommended N and P rate. The same blended fertilizer application (200 kg NPSZnB+150.2 kg N) had increased K content in stover and total biomass by 161.5 and 160.1%, respectively as compared to the control plants. This result is in line with other study[27] who reported fertilizer use efficiency for different crops increased by the application of suitable micronutrients.

The grain and strover[28] potassium concentration range from 0.2-0.53 and 0.57-1.61 for maize, respectively. However, the grain potassium concentration is below the range. On the other hand, potassium removal is more by stover than grain and the potassium concentration of stover is within the range for maize crops. The nutrient contents of the plant tissues reflect the availability of the respective elements from the soil[29] and hence the amendments of soil with different fertilizer types and rates might be having improved the indigenous K availability.

Sulfur uptake was affected by different levels of blended fertilizer and recommended N and P application. Maximum grain, stover and total biomass uptake (2.82, 4.54 and 7.36 kg ha^{-1}) of sulfur were noted for application of 200 kg NPSZnB+150.2 kg N ha^{-1} and minimum removal of sulfur was recorded for the control plot (Table 3). On the other hand, the maximum concentration of sulfur (0.05%) was recorded for 100 kg TSP+200 kg Urea. Less concentration of sulfur in grain and stover in responsive to blended fertilizer might be due to low amount of sulfur below the recommended rate for cereal crops. Sulfur uptake of grain and stover increased with levels of blended fertilizer and their maximum uptakes were obtained at 200 kg NPSZnB+150.2 kg N ha^{-1}, hence grain and stover uptake increased by 135% and 71.9% over control, respectively. Similarly 200 kg NPSZnB+150.2 kg N ha^{-1} increased grain and stover uptake by 68.6% and 47.8% over recommended N and P, respectively. N application increased the grain S[23] concentration at high but not at low S and increased grain N concentration in all S treatments. The S nutrient content and uptake were the contribution of macro and micronutrients present in blended fertilizer. This result was also in line with other study[30] that matching

Table 6: Dominance analysis of blended fertilizer and recommended N and P application for production of maize in Assosa district during 2016/17

Treatments (nutrient ha^{-1})	TGR (ETB ha^{-1})	VC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)	B:C ratio
Control	16080	0	16080	0	0
100 kg NPSB+73.9 kg N	30667	2721.3	27945.7	436.0	10.3
100 kg NPSZnB+75.1 kg N	28996	2825.6	26170.4	D	9.3
100 kg TSP and 200 kg urea	17964	3,073	14891.0	D	4.8
125 kg TSP and 250 kg urea	19151	3622.5	15528.5	D	4.3
150 kg NPSB+110.8 kg N	21235	3937.6	32321.4	5329.4	8.2
150 kg NPSZnB+112.6 kg N	36259	3971.9	30478.1	D	7.7
150 Kg TSP and 300 kg urea	34450	4639.5	16595.5	D	3.6
200 kg NPSB+147.8 kg N	34537	5106.5	29430.5	D	5.8
200 kg NPSZnB+150.2 kg N	37139	5293.4	31845.6	D	6.0

TC: Total cost, Gross return (Return from Grain and straw yield): Price kg^{-1}* yield in kg, Net return: Ggross return-total cost, VC: Variable cost, GR: Growth return, TGR: Total growth return from straw and grain, NB: Net benefit, D: Dominated, B:C ratio: Benefit-cost ratio, N. B: Prices, Urea: 8.24 birr kg^{-1}, NPSB: 11.02, NPSZnB: 11.7, TSP: 12.75 birr kg^{-1}, Price of maize: 5 birr kg^{-1}, Price of straw: 0.25 birr kg^{-1}, Seed: 10 birr kg^{-1} and Labor cost: 30 birr/person/day for 8 hrs

appropriate essential macronutrients and micronutrients with crop nutrient uptake could optimize nutrient use efficiency and crop yield.

The amount of S in a cereal crop at harvest can range between 7 and 30 kg ha^{-1}, depending on both S supply and yield level, although most crops contain nearer to 15 kg ha^{-1} [31]. Therefore the S uptake and concentration in the present study were below the optimum level for cereals. The low uptake and concentration of S might be due to poor soil fertility of the studied area and below-recommended rate of sulfur fertilizer present in blended fertilizer. Application of S[32] increased the grain S concentration at high but not at low S. According to previous study[33], an optimal N: S ratio should range from 10:1-15:1, depending on a maize variety and, thus N: S ratio of the studied area was above the range that indicated the deficiency of sulfur in plant tissue and soil. However at maximum N and S uptake 200 Kg NPSZnB+150.2 N the N: S was 20: 1 and this indicated that the deficiency of S can be observed in grain. Adequate N: S ratio is 7.5:1 in grains, above which deficiency of S can be observed[34]. N: S ratio of 15.5:1 in plant tissue of mustard to be critical, above which the inadequacy of S may cause a drastic reduction in grain yield[35].

Agronomic fertilizer use efficiency of maize grain: Agronomic fertilizer use efficiencies of maize were influenced by fertilizer rates and varied from 2.5-19.64 kg ha^{-1} at the harvest stage. The highest agronomic fertilizer use efficiency (19.64 kg kg^{-1}) was recorded for application of 100 kg NPSB+73.9 N, while the minimum value (2.5 kg kg^{-1}) was recorded for 100% recommended N and P rate. Therefore, it seems that recommended N and P could not be an adequate application level for nourishing the hybrid maize variety, perhaps due to limitation in the numbers of essential nutrients applied. Agronomic fertilizer use efficiency of any nutrient can be increased by increasing plant uptake and use of nutrient and by decreasing nutrient losses from the soil-plant system. In the present study, the application of blended fertilizer improved agronomic fertilizer use efficiency by 682.47% over recommended N and P fertilizer rate. This is because the nutrient use efficiency (NUE = kg yield per kg nutrient) is very low for Ethiopian farmers using fertilizers compared to other East-African countries, which is probably caused by interactions between chemical and physical soil quality, improper management and limited supply of fertilizers. For instance, the AE of maize in Ethiopia is 9-17 kg of grain kg^{-1} of N, while in Kenya and Tanzania the AE of maize is 7-36 and 18-43 kg grain kg^{-1} of N, respectively[33].

It was suggested[30] that agronomic fertilizer use efficiency value for a nutrient should not be less than 5. The current result, therefore, showed that the values for recommended N and P rate ranged from 2.51-4.7 kg kg^{-1} which was less than the minimum standard for AE probably due to nutrient imbalance in the recommended N and P rate. On the other hand, the agronomic efficiency for blended fertilizer types and rates of the studied area were within the optimum range (12.54-19.64 kg kg^{-1}). This result is similar to the previous study[7] who reported that agronomic fertilizer use efficiency should be within the ranges of 10-30 kg kg^{-1}.

Partial budget analysis: Partial budget analysis was employed to verify which treatments are more profitable for maize production on acidic soils of the Assosa area. With this regard, treatments with MRR greater than 100% were considered as the best with higher net benefits. Application of 150 kg NPSB+110.8 kg N ha^{-1} had the highest net-benefit (32321.4 ETB) followed by 200 kg NPSZnB+150.2kg N, 150 kg NPSZnB+112.6 kg N, 200 kg NPSB+147.8 kg N and 100 kg NPSB+73.9 kg N kg ha^{-1} with the respective net benefit of 31,845.6, 30,478.1, 29,430.5 and 27,945.7 ETB net benefit, respectively. The lower net benefits were obtained from the control and application of 100% recommended N and P in Table 6.

Furthermore, 150% recommended N and P also had the lower net benefit (16,595.5ETB). Increased production of a crop due to the application of inputs might or might not be beneficial to farmers(CIMMYT, 1988). Therefore application of 150 kg NPSB+110.8N kg ha^{-1} and 150 kg NPSZnB+112.6 kg N ha^{-1} provided relatively high net benefit (32,321.4 and 30,478.1 ETB) respectively are recommended for maize production in Assosa area of western Ethiopia.

CONCLUSION

The application of blended fertilizer on acidic soils of Assosa significantly ($p<0.05$) improved grain and straw yield of maize as their rates increased, however, there were no significant differences between the two blended fertilizer types. The highest grain yield (7056.2 kg ha^{-1}) was recorded with the application of 200 kg NPSZnB+150.2 kg N, while the highest net benefit (32321.4 ET Birr) and highest MRR were recorded with the application of 150 kg NPSB+110.8 kg N ha^{-1} with grain yield of 6863.4 kg ha^{-1}. Similarly, maize straw yield was improved with increased NPSB application. Blended fertilizer had improved nutrient concentration, uptake and agronomic efficiency. The improvements of uptake and nutrient use efficiency of maize by blended fertilizer might be due to the contribution of macro and micro nutrients present in blended fertilizer. Therefore the application of 150 kg NPSB+110.8 kg N ha^{-1} which result in a high marginal rate of return, high net benefit and relatively lower total cost of production could be recommended for maize production in the Assosa area of western Ethiopia.

SIGNIFICANCE STATEMENT

The data or results from this study will be integral in providing more knowledge, verify and update blended fertilizer recommendations for maize crop to farmers and relevant authorities who influence policy implementation such as the Ministry of Agriculture. The results of this work will assist in strategies to increase food production and food security in the country. This study indicated that the blended or balanced fertilizer applied to the soil improves the nutrient use efficiency of the maize than the most farmers is mainly done to maize in many places, particularly in the Assosa district, which is a blanket recommendation i.e. application of 46 kg ha^{-1} N and 46 kg ha^{-1} P_2O_5 ha^{-1} in the form of Urea and DAP, which are commonly applied at once (during planting time). Additionally, the blended fertilizer had more affordable or economic importance than the blanket recommendation i.e., application of 46 kg ha^{-1} N and 46 kg ha^{-1} P_2O_5 ha^{-1} in the form of Urea and DAP. A study area must be more work to explore on different location with different test crops.

ACKNOWLEDGMENT

The authors dully acknowledge the financial support of the Ethiopian Institute of Agricultural Research for funding the first author to pursue his MSc study and for the undertaking of this piece of field research to fulfil his MSc requirement.

REFERENCES

1. Rasheed, M., H. Ali and T. Mahmood, 2004. Impact of nitrogen and sulfur application on growth and yield of maize (*Zea mays* L.) crop. J. Res. Sci., 15: 153-157.
2. Kidane, H., H. Yirga, Y. Teklay, Z. Teklay and J. Juhar, 2016. Pre-extension popularization of improved maize varieties: In Raya-Azeboworeda South of Tigray, Ethiopia. J. Econ. Sustainable Dev., 7: 5-11.
3. Getache, A., A. Dejene, E. Zewdu and I. Fisseha, 2013. The State of Science and Technology in Soil Fertility and Plant Nutrient Management Research In Ethiopia. Proceedings of the State of Agricultural Science and Technology in Ethiopia. November 28-30, 2011, Ethiopian Academy of Sciences, pp: 373-412.
4. Ryan, J., 2008. A perspective on balanced fertilization in the Mediterranean region. Turky J. Agric., 32: 79-89.
5. Barker, A.V. and D.J. Pilbeam, 2007. Handbook of Plant Nutrition. CRC Press/Taylor and Francis, USA, ISBN-13: 9780824759049, Pages: 632.
6. Hati, K.M., K.G. Mandal, A.K. Misra, P.K. Ghosh and K.K. Bandyopadhyay, 2006. Effect of inorganic fertilizer and farmyard manure on soil physical properties, root distribution and water-use efficiency of soybean in Vertisols of Central India. Bioresour. Technol., 97: 2182-2188.
7. Dobermann, A., 2007. Nutrient Use Efficiency-Measurement and Management. In: Fertilizer Best Management Practices-General Principles, Strategy for their Adoption and Voluntary Initiatives vs. Regulations, Krauss, A., K. Isherwood and P. Heffer (Eds.)., First edition, IFA, Paris, France.
8. Fageria, N.K., V.C. Baligar and C.A. Jones, 2011. Growth and Mineral Nutrition of Field Crops. 3rd Edn., CRC Press, Boca Raton, FL., USA.
9. Bationo, A., T. Fairhurst, K. Giller, V. Kelly, R. Lunduka, A. Mando and Z. Shamie, 2012. Africa Soil Health Consortium: Handbook for Integrated Soil Fertility Management. CAB International, United Kingdom, ISBN-13: 9781780642918.
10. Estefan, G., R. Sommer and J. Ryan, 2013. Methods of Soil, Plant and Water Analysis: A Manual for the West Asia and North Africa Region. 3rd Edn., ICARDA, Beirut, Lebanon, pp: 65-119.

11. Habtegebrial, K., S. Mersha and S. Habtu, 2013. Nitrogen and sulphur fertilizers effects on yield, nitrogen uptake and nitrogen use efficiency of upland rice variety on irrigated fulvisols of the Afar Region, Ethiopia. J. Soil Sci. Environ. Manage., 4: 62-70.
12. Kevin, O., J.L. Joyce and M.M. Samuel, 2021. Soil properties and maize (*Zea mays* L.) growth and yield response to water hyacinth (*Eichhornia crassipes*) compost application in Lake Victoria Basin, Kenya. J. Soil Sci. Environ. Manage., 12: 17-28.
13. Bhuiyan, M.K.A., L. Nahar, M.M. Mahbub, R. Shultana, M.A.J. Mridha, M.A. Rahman and M. Kamruzzaman, 2016. Yield response and nitrogen use efficiency of boro rice varieties as affected by different methods of USG and prilled urea application. Bangladesh Agron. J., 19: 1-10.
14. Dagne, C., 2016. Blended fertilizers effects on maize yield and yield components of Western Oromia, Ethiopia. Agric. For. Fish., 5: 151-162.
15. Adhikari, K., S. Bhandari, K. Aryal, M. Mahato and J. Shrestha, 2021. Effect of different levels of nitrogen on growth and yield of hybrid maize (*Zea mays* L.) varieties. J. Agric. Nat. Resour., 4: 48-62.
16. Ekero, D., W. Haile, A. Lelago and M. Bibiso, 2021. Response of tef (*Eragrostis tef* (Zucc.) Trotter) to balanced fertilizer in Wolaita Zone, Southern Ethiopia. J. Agric. Chem. Environ., 10: 124-142.
17. Kinfe, T., T. Tsadik, B. Tewolde, G. Weldegebreal, K. Gebresemaeti, M. Solomon and A. Goitom, 2019. Evaluation of NPSZnB fertilizer levels on yield and yield component of maize (*Zea mays* L.) at Laelay Adiyabo and Medebay Zana Districts, Western Tigray, Ethiopia. J. Cereals Oilseeds, 10: 54-63.
18. Cui, Z.L., F.S. Zhang, G.H. MI, F.J. Chen and F. Li *et al*. 2009. Interaction between genotypic difference and nitrogen management strategy in determining nitrogen use efficiency of summer maize. Plant Soil, 317: 267-276.
19. Brady, N.C. and R.R. Weil, 2002. Nature and Properties of Soils. 13th Edn., Pearson, New York.
20. Iżewska, A. and C. Wołoszyk, 2015. Yields of grain and straw, their content and ionic proportions of macroelements in maize fertilized with ash from municipal sewage sludge combustion. J. Elem., 20: 319-329.
21. Fazili, I.S., A. Jamal, S. Ahmad, M. Masoodi, J.S. Khan and M.Z. Abdin, 2008. Interactive effect of sulfur and nitrogen on nitrogen accumulation and harvest in oilseed crops differing in nitrogen assimilation potential. J. Plant Nutr., 31: 1203-1220.
22. Suman, J., B.S. Dwivedi, A.K. Dwivedi and S.K. Pandey, 2018. Effect of long term application of nitrogen and sulphur nutrition onnitrogen assimilation in soybean. J. Pharmacogn. Phytochem., 7: 2000-2004.
23. Rahman, M.M., A.S. Abdou, H. Fareed and G. Faruq, 2011. Growth and nutrient uptake of maize plants as affected by elemental sulfur and nitrogen fertilizer in sandy calcareous soil. Afr. J. Biotechnol., 10: 12882-12889.
24. Wilhelm, W.W., G.S. McMaster and D.M. Harrell, 2002. Nitrogen and dry matter distribution by culm and leaf position at two stages of vegetative growth in winter wheat. Agron. J., 94: 1078-1086.
25. Fayisa, B.A., G.D. Welbira and D.A. Bekele, 2016. Determination of optimum rates of nitrogen and phosphorus fertilization for finger millet (*Eleusine coracana* L. Gaertn) production at Assosa Zone. Benishangul-Gumuz Region of Ethiopia. Adv. Sci. Hum., 2: 1-6.
26. Malakouti, M.J., 2008. The effect of micronutrients in ensuring efficient use of macronutrients: Soil Science Department; TarbiatModares University. Turk. J. Agric. For., 32: 215-220.
27. Gaj, R. and D. Gorski, 2014. Effects of different phosphorus and potassium fertilization on contents and uptake of macronutrients (N, P, K, Ca, Mg) in winter wheat I. Content of macronutrients. J. Cent. Eur. Agric., 15: 169-187.
28. Shehu, H.E., 2014. Uptake and agronomic efficiencies of nitrogen, phosphorus and potassium in sesame (*Sesamum indicum* L.). Am. J. Plant Nutr. Fertil. Technol., 4: 41-56.
29. Jones, C., K. Olson-Rutz and C.P. Dinkins, 2011. Nutrient uptake timing by crops: To assist with fertilizing decisions. Montana State University Extension, USA, pp: 2-8.
30. Blake-Kalff, M.M.A., F.J. Zhao, M.J. Hawkesford and S.P. McGrath, 2000. Diagnosis of sulphur deficiency in oilseed rape and wheat (HGCA project report no. 217). Home grown cereals authority (HGCA) London.
31. Jamal, A., Y.S. Moon and M.Z. Abdin, 2010. Sulphur-a general overview and interaction with nitrogen. Aust. J. Crop Sci., 4: 523-529.
32. Blake-Kalff, M., F.J. Zhao and S.P. Mc-Grath, 2002. Sulphur deficiency diagnosis using plant tissue analysis. Fertilizers Fertilization 5: 5-25.
33. Aulakh, M.S., N.S. Pasricha and N.S. Sahota, 1980. Yield, nutrient concentration and quality of mustard crops as influenced by nitrogen and sulphur fertilizers. J. Agric. Sci., 94: 545-549.