

Research Article

Maize Fertilizer Requirement Estimates Through Nutrient Use Efficiency and Economic Analysis from Assosa, Western Ethiopia

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Abstract

Scientific information with regards to the response of maize (*Zea mays* L.) to different blended fertilizer rates for its optimum production in Nitisols of Assosa area is limited. Therefore, a field experiment was conducted on Nitisols of Assosa Agricultural Research Centre during 2016/17 cropping season to investigate the response of growth, yield and nutrient use efficiency of maize (*Zea mays* L.) to different blended fertilizer rates and types. The treatments consists of: control, three rates of N and P combined (92/46, 115/57 and 138/69 N/P₂O₅ kg ha⁻¹ and two formula of blended fertilizers with different rates, formula 2 consists of 100 kg NPSB + 73.9 N, 150 kg NPSB + 110.8 N and 200 kg NPSB + 147.8 N kg ha⁻¹ and formula 4 consists of 100 kg NPSZnB + 75.1 N, 150 kg NPSZnB + 112.6 N¹ and 200 kg NPSZnB + 150.2 N kg ha⁻¹. The treatments were laid out as a Randomized Complete Block Design with three replications. Application of blended fertilizers (NPSB, NPSZnB) hastened days to tasseling silking and maturity by 10, 7 and 15 days, respectively as compared to combined N and P rates. Application of blended fertilizer increases significantly ($p < 0.01$) the plant height, cob weight, ear length, 100 kernels weight, number of kernels per row and ear height as compared to combined N and P and the control. The analysis of variance revealed that fertilizer types and rates significantly ($P < 0.01$) affected on grain yield, straw yield and harvest index. However there was no significant difference between the two blended fertilizer types. Maximum grain yield (7056.2 kg ha⁻¹) was recorded with 200 Kg NPSZnB + 150.2 N kg ha⁻¹ application, while minimum grain yield 2996.0 kg ha⁻¹ was recorded from control treatment. The application of 150 kg NPSB + 110.8 N kg ha⁻¹ had highest Marginal rate of return (MRR%) and net benefit. Therefore, we recommended the treatment (150 Kg NPSB + 110.8N kg ha⁻¹) since it produced high marginal rate of return, high net benefit and relatively small total cost of production, for maize production in Asossa area. Furthermore, based on yield, net benefit and relatively low total cost of production the farmer of Asossa area also can use 150 kg NPSZnB + 112.6 N in case of absence of NPSB in market.

Keywords

Blende Fertilizer, Rate, Yield, Yield Components, Net Benefit, Marginal Rate Return

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1. Introduction

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 human diet in large parts of the world, besides served as important feed component for livestock. In terms of total world production, maize out ranked paddy rice and wheat [1]. Cereals are the primary food crops in Ethiopia covering 79.88% (9,974,316 hectares) of total crop lands, while maize covered 16.91% (about 2, 111,518 hectares) of land allocated for cereal and gave 7,150,835.4 tons of grain yield [2]. 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 center based yields (8 t ha⁻¹) in Ethiopia [3]. 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 [4]. Thus, maize is one of the heaviest feeder of nutrients to produce high and quality yields among cereals. This is because of the fact that it produces higher grain and straw yields than other cereals. Hence 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 [5]. 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 micro-nutrients. 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.

Nutrient use efficiency is the ability of a plant to utilize soil available nutrients to result in measurable yield or yield parameters such as plant height, leaf development, dry matter and fruit grain production [6]. Partial factor productivity (PFP), agronomic efficiency (AE), uptake efficiency (RE), physiological efficiency (PE) and internal utilization efficiency (IE) constitute 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 crop to a nutrient [7]. The 'difference method' (calculation of nutrient use efficiencies using differences in crop yield and/or nutrient uptake between fertilized plots and an unfertilized control) is cost-efficient and simple making it particularly

suitable for on-farm research [7]. However, there is a lack of scientific studies to examine the effect of blended fertilizer in improving the yield and nutrient uptake efficiency of maize in Asossa 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 in a sustainable manner, management practices must aim at maximizing the amount of nutrients that are taken up by the crop and minimizing the amount of nutrients that are lost from the soil [9]. Therefore this experiment was designed to assess the role of blended and conventional fertilizer effects on yield, economic importance and nutrient use efficiency of maize at Asossa district.

2. Materials and Methods

2.1. Description of the Study Sites

The experiment was conducted at Assosa Agricultural Research Center (AsARC) in Benishangul Gumuz Regional State, in 2016/17 main cropping season under rain fed 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 kilometer. 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 km and 660 km distance, respectively. Assosa has 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 °C and 27.92 °C, respectively. The dominant soil type of Assosa area is Nitosols with the soil pH ranges from 5.0 to 6.0.

2.2. Experimental Design and Treatments

The experiment was laid out in randomized complete block design with three replications. Hybrid maize variety (BH546) was used as test crop. The treatments included control, three rates of nitrogen and phosphorus (92N + 46 P₂O₅, 115N + 57.5 P₂O₅, 138 N + 69 P₂O₅ kg ha⁻¹) and two different formula of blended fertilizers each with three rates, 100 kg NPSB + 73.9N, 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 N¹ and 200 kg NPSZnB + 150.2 N kg ha⁻¹) based on soil fertility map of the region. Blended fertilizers and TSP were basal applied at planting and Urea was top dressed twice (at knee height and tasseling). The plot size of 4.5 m x 5.1 m (22.95 m²) was used. The crop was planted in rows with recommended spacing (75 x 30 cm). Other field management practices were applied uniformly for all plots as per the recommendation for

the crop.

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

Trt. No	Rate (kg/ha ⁻¹)	Blended fertilizers' mineral contents (%)
T1	Control (no fertilizer)	0
T2	200kg Urea + 100 kg TSP	92N & 46 P ₂ O ₅
T3	250 kg Urea + 125 kg TSP	115N & 57.5 P ₂ O ₅
T4	300 kg Urea + 150 kg TSP	138 N & 69 P ₂ O ₅
T5	100 kg NPSB +73.9 N	18.1 N - 36.1 P ₂ O ₅ - 0.0 K ₂ O + 6.7 S + 0.0 Zn + 0.71 B
T6	150 kg NPSB + 110.8 N	27.15 N - 54.15 P ₂ O ₅ - 0.0 k ₂ O + 10.05 S + 0 Zn + 1.07B
T7	200 kg NPSB + 147.8 N	36.2 N - 72.2 P ₂ O ₅ - 0.0 k ₂ O + 13.4 S + Zn + 1.42B
T8	100 kg NPSZnB +75.1 N	16.9 N - 33.8 P ₂ O ₅ - 0.0 k ₂ O + 7.3 S + 2.23 Zn + 0.67B
T9	150 kg NPSZnB + 112.6 N	25.35 N - 50.7 P ₂ O ₅ - 0.0 k ₂ O + 10.95 S + 3.35 Zn + 1.01B
T10	200 kg NPSZnB +150.2 N	33.8 N - 67.6 P ₂ O ₅ - 0.0 k ₂ O + 14.6 S + 4.46 Zn + 1.34B

2.3. 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 H₂SO₄ and a catalyst [10]. Potassium was measured using dry ashing, by flame Photometer as described by [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 hectare basis with the respective N, P, S and K concentration.

Apparent fertilizer N and P recovery were calculated following the formula as:

$$AP = \frac{TU \text{ fertilized treatment} - TU \text{ control}}{\text{Amount of nutrient applied kg/ha}} \times 100$$

Where AP = Apparent recovery, TU stands for total nutrient uptake at 'n' rate of fertilizer nutrient.

A Physiological efficiency is the yield obtained per unit of nutrient uptake [11].

$$\text{Physiological efficiency} = \frac{\text{grain yield of fertilized kg/ha} - \text{grain yield unfertilized kg/ha}}{\text{Nutrient uptake of fertilized in kg} - \text{Nutrient uptake of control in kg}}$$

$$\text{Agronomic efficiency} = \frac{\text{grain yield of fertilized kg/ha} - \text{grain yield unfertilized kg/ha}}{\text{Amount of fertilizer applied (kg/ha)}}$$

2.4. Partial Budget Analysis

Economic analysis was performed to investigate feasibility of fertilizer application for maize production in Assosa district [12]. 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 as detailed in [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, 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.

2.5. Statistical Analysis

Analyses of variances for the recorded data were conducted using SAS GLM procedure [13]. Least significant difference (LSD) test at 5% probability was used for mean separation when the analyses of variance indicate the presence of significant difference.

3. Result and Discussion

3.1. Effects of Blended Fertilizer Rates and Types on Phonological, Growth and Yield Components of Maize

Days to 50% silking, tasseling, maturity, Ear height, Plant height, Ear length, 100 kernels weight and Number of kernels per row except Number of kernel row per cob were highly significantly ($P < 0.01$) affected by application of fertilizer types and rates (Table 2). Early silking, tasseling and maturity were recorded from plots which received blended fertilizers followed by recommended N and P. On the other hand the longest days to 50% silking, tasseling and maturity were recorded from the control (without fertilizer applied). This result is in agreement with the finding of [14], who indicated early tasseling, silking and maturity days were recorded with the application of blended fertilizer and the longest days to 50% tasseling, silking and maturity were recorded for control (without fertilizers). This result indicated that the fertilizer blend in different proportion of N, P, S Zn and B might have

encouraged early establishment, rapid growth and development of crop thus shorten the day to tasseling silking and heading. Application of blended fertilizers hastened days to tasseling silking and maturity by 10, 7 and 15 days, respectively as compared to recommended nitrogen and phosphorous. This could be attributed to the positive interaction of S, B and Zn in the blended fertilizers, which agreed with the finding of [15] who reported positive relations between B, K and N fertilizers for improving crop yields and maturity.

Application of treatments had increased the plant height and ear height as compared to recommended N and P and the control. This plant height increment might be the cell elongation and vegetative growth that attributed to different nutrient (N, P, S, B and Zn) contents in blended fertilizers. The highest plant height (245.67 cm) and ear height (113.67cm) were recorded under the applications of 200 kg of F4 (T10), while the least plant height (186.13 cm) and ear height (72.33cm) were recorded from plot that received the control plants. In conformity with the results obtained from this study, Plant growth and development may be retarded significantly if any of nutrient elements is less than its threshold value in the soil or not adequately balanced with other nutrient elements [16].

Table 2. Mean of days to 50% silking, tasseling and maturity of maize as influenced by blended fertilizer types and rates at Asossa district.

Treatments (Nutrients ha ⁻¹)	Days to 50% tas- seling	Days to 50% Silking	Days to 50% maturity	Ear height (cm)	Plant height (cm)	Ear length (cm)	100 kernels weight (g)	Number of kernels per row	Number of kernel row per cob
T1	78.66 ^a	88.66 ^a	146.66 ^a	72.33 ^c	186.13 ^c	11.57 ^e	40.69 ^d	24.23 ^d	14.6
T2	72.00 ^b	82.00 ^b	140.00 ^b	80.33 ^c	201.50 ^{bcde}	14.13 ^{abcd}	42.42 ^{cd}	30.70 ^{bc}	14.6
T3	72.00 ^b	82.00 ^b	140.00 ^b	80.17 ^c	188.00 ^{de}	13.07 ^{cde}	40.83 ^d	30.50 ^{bc}	14.5
T4	72.00 ^b	82.00 ^b	140.00 ^b	76.33 ^c	199.83 ^{cde}	12.100 ^{de}	42.92 ^{cd}	29.10 ^{cd}	14.9
T5	62.00 ^c	72.00 ^c	125.00 ^c	100.67 ^{ab}	235.17 ^a	14.47 ^{abc}	46.60 ^{abc}	34.63 ^{ab}	15.1
T6	62.00 ^c	72.00 ^c	125.00 ^c	101.83 ^{ab}	232.67 ^{ab}	15.53 ^{ab}	46.61 ^{abc}	35.67 ^{ab}	15.2
T7	62.00 ^c	72.00 ^c	125.00 ^c	99.00 ^{ab}	238.33 ^a	14.20 ^{abc}	46.59 ^{abc}	32.70 ^{abc}	14.9
T8	62.00 ^c	72.00 ^c	125.00 ^c	87.00 ^{bc}	221.67 ^{abc}	13.933 ^{bcd}	43.32 ^{bcd}	31.43 ^{bc}	15.4
T9	62.00 ^c	72.00 ^c	125.00 ^c	88.33 ^{bc}	219.00 ^{abcd}	13.36 ^{cde}	48.85 ^a	33.17 ^{abc}	15.1
T10	62.00 ^c	72.00 ^c	125.00 ^c	113.67 ^a	245.67 ^a	16.10 ^a	47.30 ^{ab}	37.10 ^a	15.1
LSD (0.01)	3.13**	3.13**	3.13**	16.869**	32.667**	2.04**	4.26**	5.42**	-
CV	1.39	2.38	2.74	10.93	8.78	8.61	5.66	9.90	2.95

Key: T1=Control, T2=100 kg TSP & 200 kg Urea, T3= 125 kg TSP & 250 kg Urea, T4 =150 kg TSP & 300 kg Urea, T5= 100 kg NPSB kg +73.9 kg N, T6= 150 kg NPSB kg + 110.8 kg N, T7 = 200 kg NPSB+ 147.8 kg N, T8 = 100 kg NPSZnB + 75.1 kg N, T9 = 150 kg NPSZnB + 112.6 kg N and T10 = 200 kg NPSZnB + 150.2 kg N. Mean value of followed the same letter(s) are non-significant difference at 1%; probability level: CV = coefficient variation

Similarly application of treatments had increased the ear length, 100 kernels weight, number of kernels per row as compared to recommended N and P and the control. Blended

fertilizer rates and types had highly significant ($P < 0.01$) effects on ear length of maize (Table 2). However, there were no significant differences between the two formula types.

Blended fertilizer which contains B improved cob weight. This results agree with the finding of Mozafar (1989), who reported that application of B fertilizer to maize production encourage good cob development. The largest ear length (16.10cm) was obtained under the application of 200 kg NPSZnB + 150.2 N (T10), while the shortest ear length of maize (11.57cm) was recorded under the control. The two types of blended fertilizer formulas (NPSZnB and NPSB) gave similar response to these parameters. Comparing the 100 kernels weight showed that 150 kg NPSZnB + 112.6 N kg ha⁻¹ application resulted in 20.05% and 15.15% more 100 kernels weight as compared to the control treatment and recommended N and P respectively (Table 2). Both blended fertilizer types (NPSZnB and NPSZnB) gave more response to number of kernels per row than recommended N and P, and the control. The maximum number of kernels per row (37.10) was obtained under application of (T10), while minimum number of kernels per row (24.23) was recorded under the control plants.

The analyzed data of number of kernel row per cob indicated that non-significant difference was observed among fertilizer rates tasted. Application of blended fertilizer T10 increases the number of kernels per row by 53.11% over the control plot. As compared to the recommended N and P, the mean value of number of kernels per row increased by 20.84% for T10. The highest ear length, 100 kernels weight and number of kernels per row observed under blended fertilizer could be due to the combined effect of nutrients like N, P, S, Zn and B in blended fertilizer which might have enhanced growth and development of crop as compared to the recommended N and P and control or without fertilizer. Data regarding to the number of kernel row per cob for various treatments are indicated (Table 2). The mean value and analysis of variance of treatment on number of kernels per row

revealed non-significant ($P>0.05$) difference among fertilizer rates and types. The maximum number of kernel row per cob (15.43) was obtained under application T8 (100 kg NPSZnB + 75.1 N), while this treatment was at par with all other treatments.

3.2. Effects of Blended Fertilizer Rates and Types on Maize Grain and Straw Yields

The analysis of variance for grain and straw yields revealed highly significant ($P<0.01$) difference among the treatments. However the two blended fertilizer types was not significantly different in affecting most parameters (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 the absence of other macro and micro nutrients (S, Zn and B). Similar trend has been reported by [17].

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. Similar trend has been observed by [18] in wheat crop. Grain yield increment with 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 beneficial influence of yield contributing characters and positive interaction of nutrients in the blended fertilizer [14]. The strong relationships were found between grain yield and ear length, grain yield and 100 kernels weight, and number of kernels per row.

Table 3. Above ground biomass yield, grain yield, straw yield and harvest index of maize as influenced by blended fertilizer types and rates in Assosa district.

Treatments	Grain yield (kg ha ⁻¹)	Straw 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 ^{**}

Treatments	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Harvest index
CV (%)	8.48	9.72	6.95

Means followed by different letters within column showed significant differences at 5% while means followed by the same letter(s) with in a column are not significantly different at 5%. LSD= least significant difference at 5%. CV = coefficient variation.

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 [19].

The highest maize straw yield (7886.7 kg ha⁻¹) was recorded with 150 kg NPSB + 110.8Nkg ha⁻¹ application, while the lowest value (4400.9 kg ha⁻¹) was recorded with control treatment. Application of 150 kg NPSB + 110.8N kg ha⁻¹ resulted in 79.21% and 54.0% more straw yield as compared to the control and recommended N and P.

3.3. Effects of Blended Fertilizer Rates and Types on Maize Harvest Index

The physiological ability of maize to convert total dry matter in to grain yield is determined by its harvest index (HI). The analysis of variance revealed that fertilizer rates and types had highly significantly ($P < 0.01$) influenced harvest index of maize. However there were no significant differences between the two blended fertilizer types effect on HI of maize (Table 2). Both blended fertilizer types (NPSZnB and NPSZnB) gave more response to harvest index than recommended N and P and the control. Nevertheless, non-significant difference between recommended N and P and control was observed with regard to harvest index. The highest harvest index (0.49) was obtained at 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 application of micronutrients may be attributed to their role in enhancing the photosynthesis process and translocation of photosynthetic products to economic part. Generally application of blended fertilizers had significant effects on harvest index of maize crop than recommended N and P. This result agrees with the findings of [19] who reported that harvest index of tef was found to be highest in blended fertilizer treatments. This report was also slightly similar with [20] those reported the

harvest index of maize was found to be significantly higher in plots that received blended fertilizers at rate of 150 kg NPSZnB ha⁻¹ as contrasted to the control treatment but, it was significantly in par with 300 kg NPSZnB ha⁻¹ and recommended NP fertilizers.

3.4. Physiological Efficiency Grain and Apparent Recovery of Biological Yield of Maize

The highest mean of apparent recoveries of N and P recorded were 28.05% and 14.70%, respectively. The apparent N recovery decreased with increasing rate of blended fertilizer application (Table 4), however P recovery decreased with increasing rate of blended fertilizers were inconsistency. The maximum (28.05%) and minimum (7.27%) apparent recoveries of N were obtained at 100 kg NPSB + 73.9 N kg ha⁻¹ and 100 kg TSP & 200 kg Urea ha⁻¹, respectively. There was a decrease in the apparent recovery of fertilizer N at each successive increment of fertilizer so that the highest recovery always occurred at lowest increment of fertilizer [21]. Similarly the maximum (14.70%) and minimum (0.92%) apparent recoveries of P were obtained at 100 kg NPSZnB + 75.1 N kg ha⁻¹ and 100 kg TSP & 200 kg Urea ha⁻¹, respectively (Table 4). The blended fertilizer had improved the N and P recovery over recommended N and P might be the contribution of macronutrient (S) and micronutrient (B and Zn) present in blended fertilizer increased the availability of macro nutrients. The N and P apparent recovery is in line with the findings of [22] which indicate that the level and types of nutrient fertilization affects the nutrient availability in soil and at high contents of soil nutrients and their availability more nutrients might be taken up by plants. In general, fertilizer N recovery by rice is never too high due to various types of losses including denitrification, volatilization and leaching losses [23].

Table 4. Mean of apparent recovery, physiological efficiency and agronomic use efficiency of maize.

Treatment (Nutrients ha ⁻¹)	AR %		PE Kg kg ⁻¹		AUE kg kg ⁻¹
	P	N	P	N	
Control	-	-	-	-	-
100 Kg TSP&200 Kg Urea	0.92	7.27	818.60	51.77	2.51

Treatment (Nutrients ha ⁻¹)	AR %		PE Kg kg ⁻¹		AUE kg kg ⁻¹
	P	N	P	N	
125 Kg TSP & 250 Kg Urea	1.84	8.03	540.51	62.09	3.30
150 Kg TSP & 300 Kg Urea	3.23	9.63	431.92	72.44	4.70
100 Kg NPSB Kg +73.9 N	9.14	28.05	847.02	108.27	19.64
150 Kg NPSB Kg + 110.8 N	10.77	24.54	663.15	114.22	18.13
200 Kg NPSB Kg + 147.8 N	7.73	17.02	639.54	113.94	12.54
100 Kg NPSZnB + 75.1 N	14.70	25.43	498.74	105.90	16.94
150 Kg NPSZnB + 112.6 N	12.20	22.98	572.58	113.37	16.15
200 Kg NPSZnB + 150.2 N	12.20	22.64	492.49	96.04	13.71

Where, AR = Apparent recovery; PE = physiological efficiency; AUE = Agronomic fertilizer use efficiency

The small number of grain and straw nutrient concentration and up take of P might be due to the P fixation by acidity, and Al toxicity of the experimental site. Low available P of these soils could be one of the major soil fertility limiting factors in the study area, which limit the nutrient use efficiency of experimental site as was also confirmed by soil characterization of the studied area. This result is line with [24], who found phosphorus availability to plants is determined by the chemical characteristics of the soil and the P fertilizer source.

The physiological efficiency of N and P were influenced by the application of blended fertilizer rates, types and recommended N and P (Table 4). The highest (114.22 kg kg⁻¹) and lowest (51.77 kg kg⁻¹) values of physiological efficiency of N were recorded at application rate of 150 kg NPSB + 110.8N kg ha⁻¹ and 100 kg TSP & 200 kg Urea ha⁻¹, respectively. [25] explained physiological efficiency of crop and they found high physiological efficiency on N usage cereal achieved when high portion of N taken up is used for grain formation. Physiological N use efficiency [26] or N use efficiency for grain production [27] refers to the additional yield produced for each additional kg of fertilizer N uptake and is determined as the ratio of net grain yield produced due to the applied fertilizer to the net uptake from applied fertilizer N.

The highest (847.02 kg kg⁻¹) physiological efficiency of P at a blended fertilizer rate of 100 kg NPSB kg +73.9 N kg ha⁻¹, mean while the lowest value of (431.92 kg kg⁻¹) was obtained at 150 kg TSP & 300 kg Urea ha⁻¹ (Table 4). According to [28] the physiological efficiency values should commonly range between 30 to 60 kg kg⁻¹. If the obtained results are above these common values, it could be concluded that the farm was under well managed system and the reverse is true, if the results obtained are below the common values. The physiological efficiency of the experimental site was above the common values for both N and P physiological efficiency. Generally the physiological efficiency of P was high as compared to N this might be due to relatively higher yield produced with low uptake of P as compared with N of uptake.

3.5. Agronomic Fertilizer Use Efficiency of Maize Grain

Agronomic fertilizer use efficiencies of maize were influenced by blended fertilizer rates and recommended N and P (Table 4). The agronomic fertilizer use efficiency of maize was varied from 2.5 to 19.64 kg ha⁻¹ at harvest stage of maize. The highest agronomic fertilizer use efficiency (19.64 kg kg⁻¹) was obtained under application of 100 kg NPSB + 73.9 N, while minimum value of agronomic fertilizer use efficiency (2.5 kg kg⁻¹) was recorded from 100% recommended N and P. Therefore, it seems that recommended N and P could not be an adequate application level regarding nourishing of this hybrid maize, perhaps due to limitation in the numbers of essential nutrients applied.

[29] Suggested that higher fertilizer use efficiency which is always associated with low fertilizer rate, cultural practices meant for promoting integrated nutrient management will help to effect saving in the amount of fertilizer applied to the crops and there to improve fertilizer use efficiency. 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. The blended fertilizer applied improved agronomic fertilizer use efficiency by 682.47% as compared to recommended N and P fertilizers.

Agronomic fertilizer use efficiency value for a nutrient should not be less than 5. [30] This result therefore shows that the rates of recommended N and P of studied ranged from 2.51 to 4.7 kg kg⁻¹ which is less than the minimum standard AE according to [30]. Values of AE were lower than 5 for recommended N and P that may be due to nutrient imbalance of recommended N and P and this indicates that higher rate of N and P were not well utilized though a limiting nutrient. On the other hand, the agronomic efficiency for blended fertilizer

types and rates of studied area were within the optimum range (12.54 to 19.64 kg kg⁻¹). This result is similar with [28] who reported that agronomic fertilizer use efficiency should be within the ranges of 10 to 30 kg kg⁻¹.

3.6. Partial Budget Analysis

The net benefit curve is allows to mark out an efficient set of technologies for recommendation. The application of 150 kg NPSB + 110.8N kg ha⁻¹ had the highest net-benefit of 32321.4 ETB, followed by 200 kg NPSZnB + 150.2 N, 150 kg NPSZnB + 112.6 N, 200 kg NPSB + 147.8 N and 100 kg NPSB + 73.9 N kg ha⁻¹ which also had a total of 31,845.6, 30,478.1, 29,430.5 and 27,945.7 ETB net benefit respectively. The lowest net benefit was obtained by the application of the 100% recommended N and P with total of 14,891 ETB followed by 125% recommended nitrogen and phosphorous and

control with net benefit of 15,528.5 and 16,080 ETB the respectively. Furthermore 150% recommended nitrogen and phosphorous also had lower net benefit of 16,595.5ETB. The increased production of the crop due to the application of inputs might or might not be beneficiary to farmers [12]. Therefore, partial budget analysis [12] was employed to estimate the net benefit, dominance analysis and marginal rate of return that could be obtained from various alternative treatments [12]. The profitability of the study showed that application of 150 kg NPSB + 110.8N kg ha⁻¹ and 150 kg NPSZnB + 112.6 N kg ha⁻¹ which provided the relatively high net benefit (32,321.4 and 30,478.1ETB) respectively, was the peak to apply fertilizers. The total costs that vary increased over the optimum level, the net benefit obtained reduced as the result of higher variable costs associated with lower earnings.

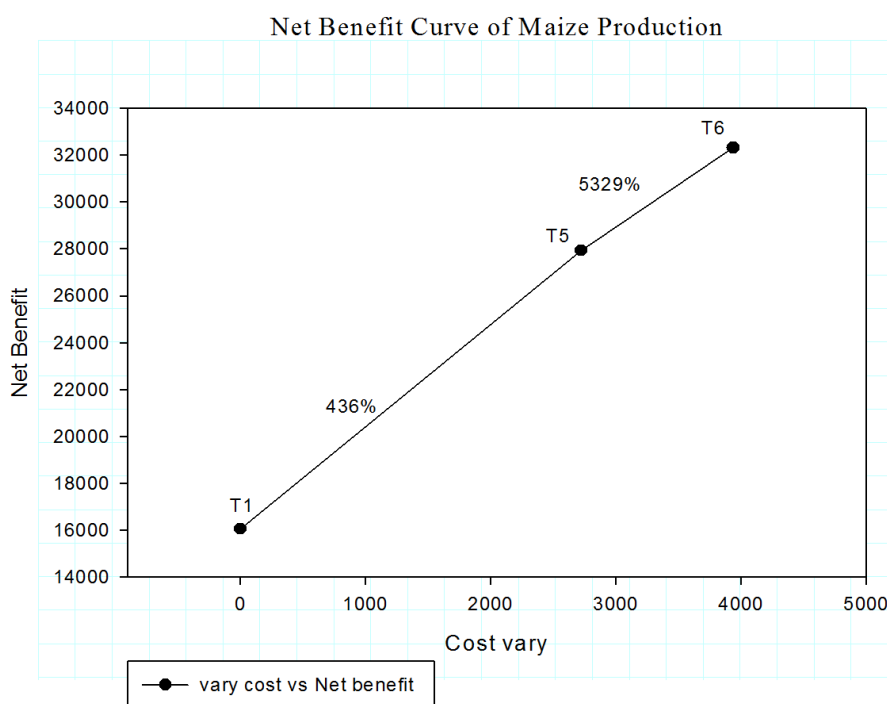


Figure 1. Net benefit curve of maize as influenced by blended fertilizer types and rates in Asossa district.

Table 5. Partial Budget Analysis of blended fertilizer application rates and types on maize at Asossa Zone.

Treatments	VC (ETB ha ⁻¹)	Yield kg ha ⁻¹		GR (ETB ha ⁻¹) from		TGR (ETBha ⁻¹)	NB (ETBha ⁻¹)
		Straw	Grain	Straw	Grain		
T1	0	4400	2996	1100	14980	16080	16080
T2	3,073	5019	3342	1254	16710	17964	14891
T3	3622.5	5227	3569	1306	17845	19151	15528.5
T4	4639.5	5762	3959	1440	19795	21235	16595.5
T5	2721.3	6870	5790	1717	28950	30667	27945.7

Treatments	VC (ETB ha ⁻¹)	Yield kg ha ⁻¹		GR (ETB ha ⁻¹) from		TGR (ETBha ⁻¹)	NB (ETBha ⁻¹)
		Straw	Grain	Straw	Grain		
T6	3937.6	7776	6863	1944	34315	36259	32321.4
T7	5106.5	6871	6564	17178	32820	34537	29430.5
T8	2825.6	6524	5473	1631	27365	28996	26170.4
T9	3971.9	7020	6539	1755	32695	34450	30478.1
T10	5293.4	7439	7056	1859	35280	37139	31845.6

N. B: Prices - Urea= 8.24 birr/kg, NPSB = 11.02, NPSZnB = 11.7, TSP=12.75 birr/kg, Price of Maize=5 birr/kg, Price of straw= 0.25 birr/kg, Seed=10 birr/kg & Labor cost =30 birr/ person/day for 8 hours, TC=Total cost, Gross return (Return from Grain & straw yield) =price /kg* yield in kg and Net return = gross return – Total cost, VC = variable cost, GR= growth return, TGR = total growth return from straw and grain, NB = net benefit.

3.7. Dominance Analysis

The highest net benefits from the application of inputs for the production of the crop might not be sufficient for the farmers to accept as good practices. In most cases, farmers prefer the highest profit (with low cost and high income). For

this purpose it is necessary to conduct dominated treatment analysis [12]. The % MRR between any pair of undominated treatments denotes the return per unit of investment in fertilizer expressed as a percentage. A dominated treatment is any treatment that has net benefits that are less than those of a treatment with lower costs that vary [31].

Table 6. Dominance analysis of blended fertilizer and recommended N and P application in Asossa district during 2016/17.

Treatments (Nutrient ha ⁻¹)	VC (ETB ha ⁻¹)	NB (ETB ha ⁻¹)	MRR%	B:C ratio
Control	0	16080	0	0
100 Kg NPSB +73.9 N	2721.3	27945.7	436.0	10.3
100 Kg NPSZnB + 75.1 N	2825.6	26170.4	D	9.3
100 Kg TSP & 200 Kg Urea	3,073	14891.0	D	4.8
125 Kg TSP & 250 Kg Urea	3622.5	15528.5	D	4.3
150 Kg NPSB + 110.8N	3937.6	32321.4	5329.4	8.2
150 Kg NPSZnB + 112.6 N	3971.9	30478.1	D	7.7
150 Kg TSP & 300 Kg Urea	4639.5	16595.5	D	3.6
200 Kg NPSB + 147.8 N	5106.5	29430.5	D	5.8
200 Kg NPSZnB + 150.2 N	5293.4	31845.6	D	6.0

Where VC = variable cost, NB = net benefit, MRR% = marginal rate of return, D = dominated, B:C ratio = benefit cost ratio.

The dominance analysis showed that the net benefit of all treatments were dominated except application of 100 kg NPSB + 73.9 N kg ha⁻¹ and 150 kg NPSB + 110.8N kg ha⁻¹ (Table 6). This result indicated that the net benefit was decreased as the total cost that varies increased beyond undominated fertilizer treatments application. Therefore, no farmer may choose other dominated treatments in comparison with the undominated treatments. This also helps to avoid the

dominated treatment in further estimate of marginal rates of return.

3.8. Marginal Rate of Return

Economic analysis revealed that maximum marginal rate of return was recorded with application of 150 kg NPSB + 110.8 N kg ha⁻¹ (5329.4%), followed by 100 kg NPSB +73.9

N kg ha⁻¹ (436.0%). The marginal rates of those treatments were well above the 100% minimum [12]. According to [12] experience and empirical evidence, for the majority of situations indicated that the minimum rate of return acceptable to farmers would be between 50 and 100%. In the present study the treatments that had above 100% marginal rate return was recommended for the farmers, with treatments that had small number of variable cost. This treatment was 150 kg NPSB + 110.8 N kg ha⁻¹.

The % MRR between any pair of undominated treatments denotes the return per unit of investment in fertilizer ex-

pressed as a percentage. The results of undominated treatments indicated that for each one birr invested in purchase or production of fertilizers that was possible to recover one birr plus an extra of 4.36 birr ha⁻¹ and 53.29 birr ha⁻¹ as the fertilizer application changed from unfertilized plot to 100 kg NPSB + 73.9 N kg ha⁻¹ and 150 kg NPSB + 110.8N kg ha⁻¹ respectively. Passing from the first treatment that had the lowest costs that vary to the end treatment which had the highest cost that vary, the marginal rate of return obtained was above the minimum acceptable marginal rate of return.

Table 7. Marginal rate of return analysis of blended fertilizer and recommended N and P application for maize in Asossa district during 2016/17.

Treatments (Nutrient ha ⁻¹)	VC (ETB ha ⁻¹)	NB (ETB ha ⁻¹)	MRR%
Control	0	16080	0
100 Kg NPSB + 73.9 N	2721.3	27945.7	436.0
150 Kg NPSB + 110.8N	3937.6	32321.4	5329.4

Where VC = variable cost, NB = net benefit, MRR% = marginal rate of return, D = dominated, B:C ratio = benefit cost ratio.

In this study, 100% was considered as minimum acceptable rate of return for farmers' recommendation. Accordingly, the study revealed that application of 150 kg NPSB + 110.8N kg ha⁻¹ was considered as the best for recommendation. The best recommendation for treatments subjected to marginal rate of return is not necessarily based on the highest marginal rate of return, rather based on the minimum acceptable marginal rate of return and the treatment with the highest net benefit, relatively low variable cost together with an acceptable MRR becomes the tentative recommendation [12].

4. Conclusion

The fertilizer rates and types on grain yield and straw yield highly significant difference ($P < 0.01$), however there was no significant differences between the two blended fertilizer types. Maximum grain yield 7056.2 kg ha⁻¹ was recorded with T10 (200 kg NPSZnB + 150.2 N), while minimum grain yield 2996.0 kg ha⁻¹ was recorded from control treatment. This maximum grain yield was followed by T6, T7 and T9 with corresponding grain yield of 6863.4, 6563.8 and 6538.7 kg ha⁻¹ respectively, where these treatments were statistically at par with each other. The maximum maize straw was recorded with T6 (7886.7 kg ha⁻¹), while minimum value (4400.9 kg ha⁻¹) was recorded with control treatment. Accordingly, the study revealed that application of 150 kg NPSB + 110.8N kg ha⁻¹ and 150 kg NPSZnB + 112.6 N kg ha⁻¹ as the best rates recommended for maize production at Assosa area.

Blended fertilizer had improved nutrient concentration, uptake, agronomic efficiency, physiological efficiency and

apparent recovery of maize as compared to recommended N and P. 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. Improving nutrient efficiency is an appropriate goal for all involved in agriculture, and the fertilizer industry, with the help of agronomic studies at different agro-ecologies. However, effectiveness cannot be sacrificed for the sake of efficiency. Much higher nutrient efficiencies could be achieved simply by sacrificing yield, but that would not be economically effective or viable for the farmer, or the environment. The profitability of the study showed that application of 150 kg NPSB kg + 110.8N and 150 kg NPSZnB + 112.6 N kg which provided relatively high net benefit (32321.4 and 30,478.1ETB) was the best rates to apply. Marginal rate of analysis from undominated treatments indicated that for each one birr invested in purchase or production of fertilizers that was possible to recover one birr plus an extra of 4.36 birr ha⁻¹ and 53.29 birr ha⁻¹ as the fertilizer application changed from unfertilized plot to 100 kg NPSB + 73.9 N kg ha⁻¹ and 150 kg NPSB + 110.8N kg ha⁻¹ respectively.

The best recommendation for treatments subjected to marginal rate of return is not necessarily based on the highest marginal rate of return, rather based on the minimum acceptable marginal rate of return and the treatment with the high net benefit, relatively low variable cost together with an acceptable MRR becomes the tentative recommendation. Therefore we recommend the treatments (150 kg NPSB + 110.8N kg ha⁻¹) that have high marginal rate of return, high net benefit and relatively small total cost of production for maize production

in Asossa zone. But based on yield data, net benefit and relatively small total cost of production the farmer of Asossa district can also use 150 kg NPSZnB + 112.6 N when NPSB formula were not available on the market.

Abbreviations

AsARC	Assosa Agricultural Research Center
CIMMYT	International Maize and Wheat Improvement Centre
AP	Apparent Recovery
TU	Total Nutrient Uptake

Author Contributions

Bakala Anbessa: Conceptualization, Data curation, Formal Analysis, Project administration, Software, Supervision, Writing – original draft

Girma Abera: Conceptualization, Funding acquisition, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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