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Nutrient Recovery Efficiency and Economics of Fertilizer Use of Maize (*Zea mays* L.) as Determined by Nutrient Combinations in Jimma Zone, Southwestern Ethiopia

Habetamu Getinet

Ethiopian Institute of Agricultural Research, Debre Markos Agricultural Research Center, Debre Markos, Ethiopia

Email address:
habtamugetinet12@gmail.com

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Abstract: Balanced fertilization based on indigenous soil nutrient status and crop demand is imperative for efficient nutrient management and enhancing crop yield. A field experiment was conducted at Kersa District, Southwestern Ethiopia during 2019/20 cropping season to determine the effects of nutrient combinations on nutrient recovery fraction, physiological efficiency and economic benefits of maize. The treatments includes T_1 [Control], T_2 [NP], T_3 [PKS (-N)], T_4 [NKS (-P)], T_5 [NPS (-K)], T_6 [NPK (-S)], T_7 [NPKS], T_8 [NPKSZn (-B)], T_9 [NPKSB (-Zn)] and T_{10} [NPKSZnB]. The treatments were arranged in randomized complete block design (RCBD) with four replications each. Maize grain yield, total (grain + straw) nutrient concentration and economic of fertilizer use were analyzed during experimentation. The data were analyzed using SAS 9.0 version software. The results indicated that grain yield, biomass yield and nutrient recovery fractions of maize responded significantly due to different mineral fertilizer combinations. Accordingly the maximum grain yield (8702.6kg ha^{-1}) and biomass yield (20.1tha^{-1}) were obtained from T_8 treated with (N_{120} P_{40} K_{40} S_{20} Zn_5 $kgha^{-1}$), while the lowest grain yield (2028.5 $kgha^{-1}$ and 2793.5 $kgha^{-1}$) and biomass yield (5.6 tha^{-1} and 7.2 tha^{-1}) were recorded from control and N-omitted plots, respectively. Compared with NP and control plots, application of NPKSZn produced 76.6% and 29.8% yield advantages, respectively. The maximum apparent recovery fraction of each nutrient was obtained from application of N_{120} P_{40} K_{40} S_{20} Zn_5 $kgha^{-1}$. Economic analysis showed, this treatment generate the highest net benefit of 80,364 ETB ha^{-1} (1$=42Birr) with acceptable marginal rate of return (MRR) (486.35%). Therefore, incorporating Zn with in major macronutrients (NPKS) is more important to increase maize production in the study area.

Keywords: Grain Yield, Economic Use, Nutrient Combination, Physiological Efficiency, Recovery Efficiency

1. Introduction

Declining soil productivity due to nutrient degradation is the major constraint against food insecurity in the country. This situation is manifested by reduction crop yield, decreasing vegetation cover, increasing soil erosion and finally low agricultural income. Due to this, the nation is directly victims from food shortage and hunger. Application of suitable nutrients is one of the most important notable measures that help to increase agricultural productivity and to achieve sustainable productivity of crops. So far, in Ethiopia fertilizer application was mainly focused only two major plant nutrients (N and P) in the form of DAP and urea and they haven't consider economic return, whereas very little attention has been given to other macro and micronutrients which causes unbalanced and poor nutrient management and crop quality [26].

Ethiopian population is growing from 47.88 million in 1990 to 114.89 million in 2020 [27] which implies that a huge food demand of the ever-rising population. Cultivated land is currently getting less and less and expanding farm plot size per household is not more possible to satisfying food demand of ever-increasing population. For instance, the average farm plot size in Tanzania declined from 1.43 ha in 1977 to 1.03ha in 2000 [18]. This implies that population growth and food insecurity are twin problems that must be addressed together for enhancing food security [8]. About 24.8% of the households faced chronic food shortages in 2016 and their continued existence depended on food assistance [3]. Therefore, food security for the increasing human population calls for sustainable intensification in the current agricultural land.

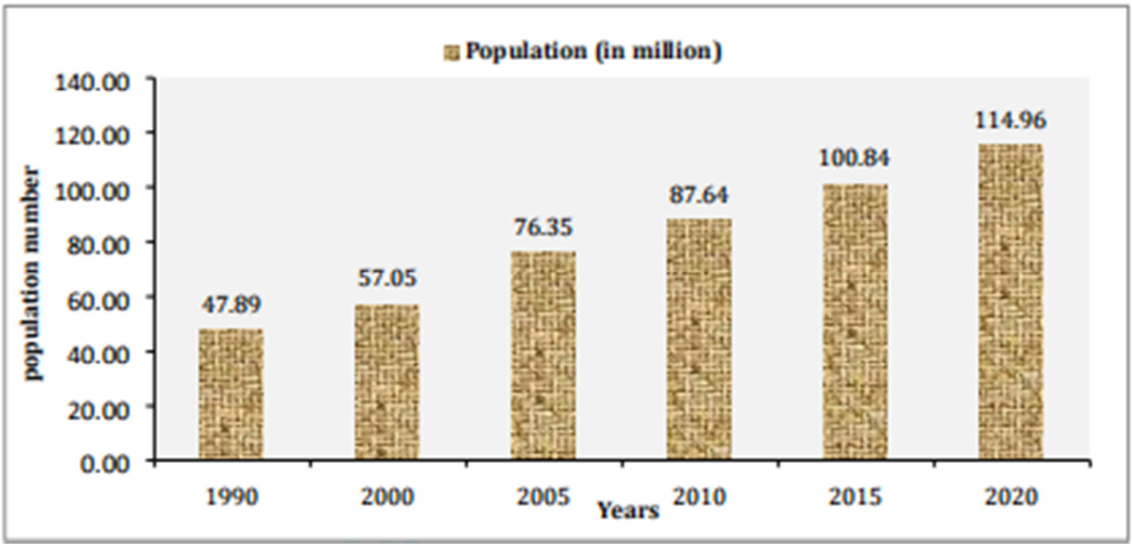

Figure 1. *Population growing trends from 1990 to 2020 in Ethiopia.*

Among cereal crops, maize (*Zea mays* L.) is one of the most important cereal crop cultivated in Ethiopia. It grows in many parts of the country where Oromia (55.4%), Amhara (21.78%) and SNNPR (14.95%) are leading producing regions. However, the yield is still limited because of several factors where continuous monocropping and inadequate fertilizer use, which in turn caused soil fertility degradation, are the most important problems. Unbalanced application of nutrients among other factors explains the poor annual value of crop production, which is below the average of Sub - Saharan Africa [5]. Declining soil fertility status is one of the biggest challenges, an obvious strategy to increase balanced fertilizer application and promote good agronomic practices to enhance the productivity of crops is of paramount importance.

In Ethiopia previous fertilizer research works was mainly focused on nitrogen (N) and phosphorus (P) in different soil types and various agro ecological conditions, while very limited works have been done with other essential macro and micronutrients which indirectly affects nutrient use efficiency thereby the overall productivity of crops. Previous research studies revealed that optimum N and P rates differed for different maize growing locations and with different cropping system, suggesting that the old tradition of using blanket fertilizer recommendation can no more be an appropriate practice to follow [20].

Moreover, the magnitude of N, P, K and other micronutrient effects on yield of maize vary with sites due to differences in crop management practices which produce variability in indigenous soil nutrient supplying capacity in each farm lands [23]. The wider variability in soil fertility, climatic condition and poor farmers' nutrient management practices further contribute to reduce the production. Eventually, the recovery efficiency of N is 20-40%, for P is 15-20% and 40-50% for K, while for secondary and micronutrients, it is very low ranging between 5-12% [17]. Thus, appropriate fertilization based on the relative importance of a given nutrient corresponding with their economic return is a prerequisite to minimize the presence of yield variability in small hold farming system. Therefore, the experiment was conducted (i) to identify best nutrient combinations for maximize nutrient recovery fraction, physiological efficiency and (ii) to determine optimum and economically feasible nutrient combinations in the study area.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Jimma Zone, Southwestern Ethiopia during 2019/20 main cropping season. The experimental field was geographically located at 7° 40' 09 3" N latitude, 37° 14' 41.5" E longitudes and an altitude of 1750 meter above sea level (Figure 2). The area is endowed with bimodal rainfall distribution. The average mean annual rainfall recorded was 1198 mm and the minimum and maximum temperature was about 11.8°C and 27.2°C.

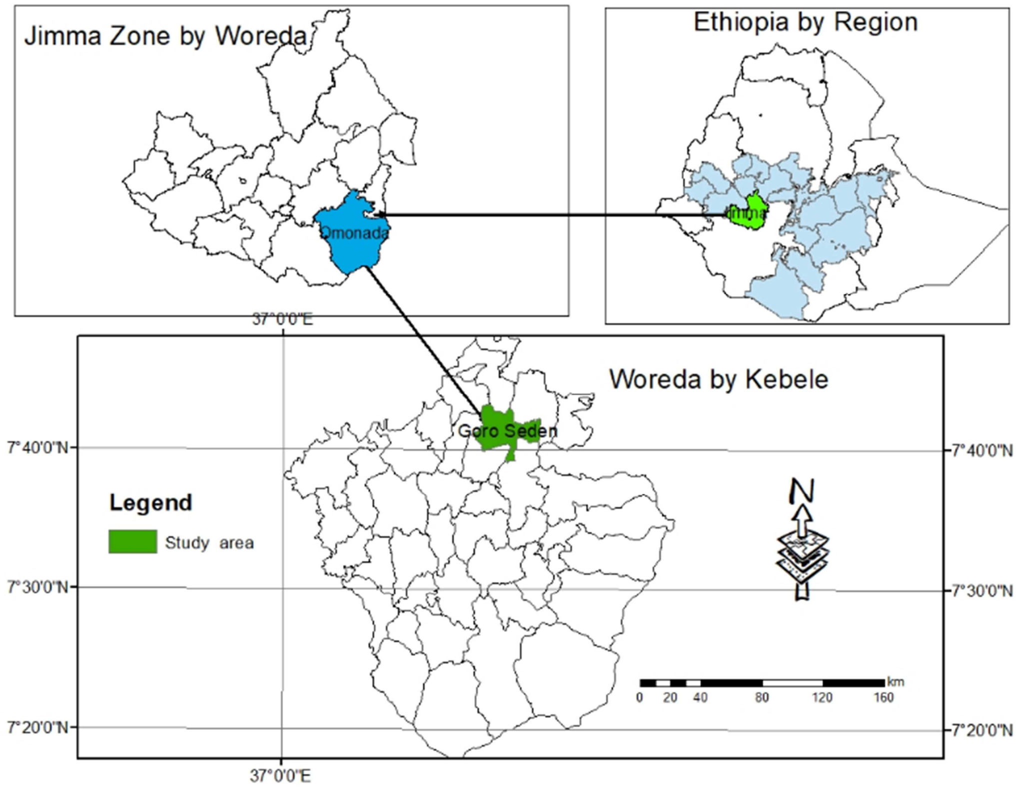

Figure 2. *Map of the study district.*

2.2. Treatment Arrangement and Experimental Procedure

Six nutrient combinations (N_{120} P_{40} K_{40} S_{20} Zn_5 $B_{2.5}$ kg ha^{-1}) were used. Each single fertilizer rate was set based on recommendation given by [23] for maize in Nitisols of Jimma area. Even though farmers are not growing maize without fertilizer, control plot was included for comparison among the rest of treatments. The treatments were arranged in a randomized complete block design (RCBD) with four replications each. The gross plot area was 18 m^2 (6 m x 3 m), which accommodated 8 rows and 10 plants per row while the net plot area was 10.8 m^2 (4.5 m x 2.4 m). High yielding maize variety (BH-661) that was popularly accepted and growing by farmers was used as a test crop with the spacing of 0.3m and 0.75m between plants and rows, respectively.

Planting was done based on local farmers planting calendar. Full doses of all nutrients with respective treatments except the nutrient to be omitted were applied once during planting. Nitrogen was applied in splits where half rate during planting and the remaining half rate were applied when the plant reaches at knee height stage. Urea, Triple Super Phosphate (TSP), Murate of Potash (KCl), Calcium Sulfate ($CaSO_4{\cdot}2H_2O$), Zinc Sulfate ($ZnSO_4{\cdot}7H_2O$) and Borax ($Na_2B_4O_7{\cdot}5H_2O$) were used as sources of fertilizer for supplying N, P, K, S, Zn and B, respectively. All agronomic practices such as weeding and hoeing were done uniformly for all plots.

Table 1. *Nutrient combinations used for the present study.*

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (kg ha^{-1})	Zn (kg ha^{-1})	B (kg ha^{-1})
T_1 = Control	0	0	0	0	0	0
T_2 = NP	120	40	0	0	0	0
T_3 = PKS (-N)	0	40	40	20	0	0
T_4 = NKS (-P)	120	0	40	20	0	0
T_5 = NPS (-K)	120	40	0	20	0	0
T_6 = NPK (-S)	120	40	40	0	0	0
T_7 = NPKS	120	40	40	20	0	0
T_8 = NPKSZn (-B)	120	40	40	17.6	5	0
T_9 = NPKSB (-Zn)	120	40	40	20	0	2.5
T_{10} = NPKSZnB	120	40	40	17.6	5	2.5

2.3. Data Collection

Grain yield from each net plot were collected and weighted and finally adjusted to standard moisture contents of maize (12.5%). Biomass yield of maize from each harvestable plot was harvested from the ground level from each plot were measured and reported on a hectare basis. Grain and straw samples were collected from each plot to determine each nutrient concentration thereby to quantify nutrient recovery efficiency of each nutrient.

2.4. Nutrient Use Efficiency Indices

Apparent nutrient recovery efficiency: The apparent nutrient recovery efficiency of nutrients was determined as the quantity of nutrient uptake per unit of nutrient applied then finally changed to percentage as follows:

$$ARE\ (\%) = \frac{(Nf-Nu)}{Na} x100$$

Where, Nf - total nutrient uptake of fertilized plot (kg ha^{-1}),
Nu - total nutrient uptake of unfertilized plot (kg^{-1}),
Na - the quantity of nutrient applied (kg ha^{-1}).

Physiological use efficiencies (PE): is the biological yield obtained per unit of nutrient uptake. The physiological use efficiencies of N, P, K, S and Zn fertilizers were calculated using the procedure described by [25] as:

$$PE = (\frac{BYf-BYu}{Nf-Nu})$$

Where, BYf - biological yield of fertilized plots at 'n' rate,
BYu - biological yield of unfertilized plots,
Nf - nutrient uptake at 'n' rate of fertilizer applied, and
Nu - indicates nutrient uptake unfertilized or control plot.

2.5. Data Analysis

The collected data was analyzed using analysis of variance (ANOVA) appropriate to completely randomized block design using statistical analysis system [19] 9.3 version software and the interpretations were made following the procedure described by [6]. Least Significant Difference (LSD) test at 5% probability level was used for treatment mean comparison when the ANOVA showed significant differences among treatments.

2.6. Economic Analysis

Economic analysis was done to investigate the economic feasibility of treatments that would give acceptable returns at low risk to farmers following procedures of [2]. The average grain yield obtained from each treatment was adjusted to 10% downward to reflect the difference between researchers experimental plot yield and the yield farmers will expect from the same treatment because researchers are using small plot sizes and applying better crop management practices during experimentation. The average open market price (Ethiopian Birr kg^{-1}) for maize and the official prices of fertilizers were used for analysis as a common denominator during the time of input use and maize grain yield at the time of harvest based on local market condition. The local market price of maize (11.5 birr kg^{-1}) and the official price of inputs were (Urea = 14.80, TSP = 18.50, KCl = 13.22, $CaSO_4 \cdot 2H_2O$ = 4.40, $ZnSO_4 \cdot 7H_2O$ = 28.08 and Borax=15.17birrkg^{-1}). Gross benefit (GB) was obtained by multiplying the adjusted grain yield with grain unit price as: GB = adjusted grain yield x grain unit price. Total variable cost (TVC) is the aggregate amount of all variable costs associated with the costs of inputs purchased during planting as: TVC = (amount of each nutrient x their unit price). Net benefit (NB) was obtained by subtracting all variable costs from the gross benefit as: NB = GB-TVC. The cost that varied for each treatment was ranked in order of ascending variable costs for dominance analysis. The marginal rate of return (MRR) was calculated for two non-dominated treatments using the formula: [change in net benefit (NB_2 - NB_1) /change in TVC (TVC_2 - TVC_1)] × 100 and a minimum acceptable MRR of 100% was assumed.

3. Results and Discussion

3.1. Nitrogen Concentration in Grain and Straw

The analysis result showed nitrogen concentration was significantly affected due to nutrient combinations both in grain and straw. The value of grain N concentration ranged from 0.45 to 0.83% where the minimum was recorded from control while the maximum value was obtained from application of NPKSZnB (Table 2). In case of straw N concentration, the highest value (0.24%) was obtained from application of NPKSZnB which was statistically at par with plots treated with NPKSB (0.21%) while the lowest straw N concentration (0.09%) was recorded from the control. The highest value obtained might be due to application of N which also improves N concentration in grain and straw. This might also be due to integrated use of N in combination with S nutrients since these two nutrients have synergistic interaction. The current result was in conformity with the finding of Potarzycki [16], who reported that application of mineral fertilizers containing sulfur positively influences accumulation of N in grain. Gondek and Gondek [7] also reported that spring wheat fertilization including S resulted in a significant increase in N content in the straw compared with control. This ensures that there is a positive interaction among (N and S) for metabolic processes which is reflected in growth and development of crops, which ultimately affects the level and quality of yield.

3.2. Phosphorus Concentration in Grain and Straw

The analysis result showed P concentration in both grain and straw significantly affected due to nutrient combination. Phosphorus grain content ranged from 0.23 to 0.31% where the highest value (0.31%) was obtained from application of NPKSZn while the lowest P content was recorded from unfertilized plots. In case of straw P concentration, the value ranged from 0.13 to 0.18% where the highest P concentration was obtained from plots treated with NPKSZn while the lowest P concentration was recorded from control. The highest value recorded might be due to combined use of P and N that can detrimental when a limited dose of S was applied. When the soil N content is high, there might be prohibited influence for P buildup in the plant and its absorption improved in soil. Similarly finding was obtained by [24] who reported that N can increase P concentration levels in plants by increasing root growth and by increasing the ability of roots to absorb and translocate phosphorus.

3.3. Potassium Concentration in Grain and Straw

The analysis result showed nutrient combinations significantly influenced K concentration in grain and straw. The value ranged from 0.41 to 0.65% where the highest K concentration (0.65%) in grain was recorded from plots treated with NPKSZn while the lowest K concentration (0.41%) in grain was observed from unfertilized (control). The results showed that K concentration in straw was higher than of grain in all treatments. The highest K concentration in straw (0.82%) was observed in plot treated with NPKSZn which was statistically similar with plots treated with NPKS while the lowest P concentration (0.49%) was recorded from the control.

3.4. Sulfur Concentration in Grain and Straw

Based on the results S concentration both in grain and straw were significantly influenced by nutrient combinations. The value ranged from 0.11 to 0.14% where the highest S concentration (0.14%) in grain was observed from application of NPKSZn while the lowest (0.11%) in grain was obtained from control (Table 2). In straw, S concentration also influenced significantly due to nutrient combinations. Accordingly the value ranged from 0.12 to 0.14% where the highest S concentration (0.12%) in straw was found from NPKSZn while the lowest S concentration (0.12%) was found from the control plots, which was statistically at par with T_2, T_3, T_4, T_5 and T_{10} having a value of (0.12%). This might be due to increasing sulfur content which improved the existing of SO_4^- in soil which is available form for plants. The current result was in line with the finding of [11] who reported that the higher values of sulfur concentration was recorded where a high level of sulfur was applied compared to control or where low levels were applied to maize crop. Howarth [9] also reported that N deficiency caused a slower accumulation of N and S in grain, which resulted in the lower final content of these elements.

3.5. Zinc Concentration in Grain and Straw

Zinc concentration in grain was significantly influenced due to nutrient combinations but in case of straw, there was no significant variations observed due to nutrient combinations. The value of Zn concentration in grain varied from 0.01 to 0.02% where the highest Zn concentration (0.02%) in grain was observed from application of NP which was statistically similar with PKS, NKS, NPK, NPKSZn and control.

Table 2. *Effect of nutrient combination on grain and straw. N, P, K, S and Zn concentration.*

Treatments	Nutrient Concentration (%)									
	Grain					Straw				
	N	P	K	S	Zn	N	P	K	S	Zn
T_1 = Control	0.45^{f}	0.23^{e}	0.41^{e}	0.11c	0.02^{a}	0.09^{e}	0.13^{c}	0.49^{d}	0.12^{b}	0.01
T_2 = NP	0.62^{d}	0.30^{abc}	0.45^{d}	0.14^{ab}	0.02^{a}	0.11^{de}	0.16^{ab}	0.64^{b}	0.12^{b}	0.02
T_3 = PKS (-N)	0.56^{e}	0.25^{de}	0.42^{de}	0.12^{bc}	0.01^{bc}	0.10^{de}	0.14^{bc}	0.55^{cd}	0.12^{b}	0.02
T_4 = NKS (-P)	0.61^{de}	0.25^{de}	0.58^{bc}	0.13^{ab}	0.02^{a}	0.11^{de}	0.16^{ab}	0.63^{bc}	0.12^{b}	0.02
T_5 = NPS (-K)	0.72^{bc}	0.26^{d}	0.57^{c}	0.12^{bc}	0.01^{c}	0.12^{cde}	0.14^{bc}	0.66^{b}	0.12^{b}	0.02
T_6 = NPK (-S)	0.70^{c}	0.28^{c}	0.56^{c}	0.13^{ab}	0.02^{a}	0.14^{bc}	0.15^{abc}	0.79^{a}	0.13^{ab}	0.01
T_7 = NPKS	0.73^{bc}	0.28^{c}	0.55^{c}	0.12^{bc}	0.01^{c}	0.16^{b}	0.16^{ab}	0.75^{a}	0.12^{b}	0.01
T_8 = NPKSZn (-B)	0.76^{b}	0.31^{a}	0.65^{a}	0.14^{a}	0.02^{a}	0.24^{a}	0.18^{a}	0.82^{a}	0.14^{a}	0.03
T_9 = NPKSB (-Zn)	0.83^{a}	0.29^{bc}	0.56^{c}	0.13^{ab}	0.01^{bc}	0.21^{a}	0.15^{abc}	0.64^{b}	0.13^{ab}	0.02
T_{10} = NPKSZnB	0.65^{d}	0.30^{ab}	0.61^{b}	0.14^{ab}	0.01^{c}	0.13^{cd}	0.17^{ab}	0.62^{bc}	0.12^{b}	0.02
LSD (0.05)	0.05	0.02	0.04	0.12	0.01	0.03	0.03	0.09	0.01	ns
CV (%)	5.50	4.81	4.96	7.98	31.89	12.98	11.83	9.04	7.36	46.1

3.6. Apparent Recovery of Fertilizers

The apparent recovery efficiency of each nutrient showed positive response due to nutrient combinations. The highest recovery fraction of N (0.64) was recorded from application of NPKSZn which was statistically at par with plots treated with NPKSB (0.60) while the lowest N recovery (0.27) was recorded from plots treated NKS (-P), that showed application of NPKSZn fertilizer, up to 64% of the applied N recovered by maize crop. Application of NPKSZn fertilizer improved N recovery efficiency by 49.3% and 56.8% as compared to recommended NP and P-omitted plots respectively. The increment of recovery fraction might be due to application of combined macronutrients with micronutrients in appropriate form of fertilizer. Similar to this finding, Jones [10] reported stated matching appropriate essential macronutrients and micronutrients with crop nutrient uptake could optimize nutrient use efficiency and crop yield and might be split application technique, which is in agreement with the finding of [22]. They showed that split application of N efficiently take up by maize and would not decrease N uptake from the soil. Kurwakumire [12] also reported that higher N recovery fraction of 0.79 and 0.83 kg N kg^{-1} of applied N was obtained, due to application of NPS and NPKS, respectively compared to application of NK alone, where AREN was only 0.44.

The apparent recovery efficiency of phosphorus (AREP) was significantly ($P < 0.01$) affected due to nutrient omitting, where the maximum value (80.82 kg P kg^{-1} of applied P) was obtained from plots treated with NPKSZn. Thus, in areas having appropriate moisture conditions maize crop could recover up to 80.82% of P applied under balanced combination of NPKSZn nutrients. Phosphorus recovery efficiency was too low in plots where N was missed. This indicates that combined application of N with other nutrients enhances P recovery efficiency, as was also supported by [23].

The apparent recovery efficiency of potassium (AREK) ranged from 18.11 to 236.32 kg K kg^{-1} of applied K where the maximum was recorded from application of NPKSZn while the minimum was obtained from PKS (-N) indicating integrated use of N with major macronutrients enhances the recovery of K nutrients. In agreement with the current result, [4] reported that highest K recovery efficiency in lowland rice genotypes was ranged from 51% to 81% due to balanced fertilization.

The apparent recovery efficiency of sulfur (ARES) was significantly ($P < 0.01$) affected due to nutrient combination, where the maximum value (87.40 kg S kg^{-1}) of applied S was obtained from plots treated with NPKSZn. Thus, in areas having appropriate moisture conditions maize crop could recover up to 87.40% of S applied under balanced combination of NPKSZn. Sulfur recovery efficiency was very low in plots where N was missed. This indicates that combined application of N with other nutrients enhances S recovery efficiency.

The value of Zinc recovery efficiency (ZnRE) varied from 36.55 to 40.10 Kg Zn per kg of Zn applied with an average of 38.33 which is relatively smaller as compared with macronutrients. The highest value (40.10) was obtained from plots treated with NPKSZn. This may be due to the effectiveness of Zn functions in plant physiology. In general, it has been shown the increment of fertilizer use efficiency for different crops by the application of suitable micronutrients [13]. But compared with macronutrients, apparent recovery efficiency of applied micronutrients was relatively low which is in line with [14]. Such low recover is due to their uneven distribution in a soil because of low application rates, reaction with soil to form unavailable products, and low mobility in soil.

Table 3. *Apparent recover fraction of N, P, K, S, Zn and B as affected by nutrient combinations.*

Treatments	Apparent Recovery Efficiency (kg nutrient uptake kg^{-1} nutrient applied)				
	AREN	AREP	AREK	ARES	AREZn
T_1 = Control	-	-	-	-	-
T_2 = NP	30.88^{d}	55.77^{cd}	130.30^{d}	61.96^{c}	-
T_3 = PKS (-N)	-	8.57^{e}	18.11^{e}	10.28^{e}	-
T_4 = NKS (-P)	26.85^{d}	-	133.77^{d}	52.28^{d}	-
T_5 = NPS (-K)	40.98^{c}	53.52^{d}	-	63.11^{c}	-
T_6 = NPK (-S)	43.28^{c}	60.81^{c}	206.79^{b}	-	-
T_7 = NPKS	52.35^{b}	71.24^{b}	205.69^{b}	75.34^{b}	-
T_8 = NPKSZn (-B)	63.23^{a}	80.82^{a}	236.32^{a}	87.40^{a}	40.10^{a}
T_9 = NPKSB (-Zn)	59.83^{a}	70.38^{b}	183.15^{c}	78.29^{b}	-
T_{10} = NPKSZnB	48.97^{b}	73.66^{b}	192.97^{bc}	79.05^{b}	36.55^{a}
LSD (0.05)	4.47	5.93	16.47	6.77	15.07
CV (%)	6.64	6.79	6.85	7.25	

Means followed by a common letter are not significantly different at P<0.05. AREN- Apparent recovery efficiency of nitrogen, AREP Apparent recovery efficiency of phosphorus, AREK Apparent recovery efficiency of potassium, ARES Apparent recovery efficiency of sulfur and AREZn Apparent recovery efficiency of zinc.

In general, apparent nutrient recovery efficiency is a measure of the ability of the crop to extract nutrients from the soil, or is portion of the applied nutrient that is taken up by the crop as reported by [15] which is the primary index to describe the characteristics of nutrient uptake and utilization in crops. Based on the current result, the highest apparent nutrient recovery efficiency of each nutrient N (63.23%), P (80.82%), K (236.32%) S (87.40%) and Zn (40.10%) were obtained from plot treated with NPKSZn (Table 3). The highest value obtained from this treatment might be due to application of macronutrients in combination with micronutrients in appropriate form of fertilizer. Similar to this finding, [10] reported that matching appropriate essential macronutrients and micronutrients with crop nutrient uptake could optimize nutrient use efficiency and crop yield. This might also be due to the effectiveness of Zn functions in plant physiology because zinc has an important value from very simple to very complex reactions in the plant system. It plays a very important role in plant metabolism by influencing the activities of hydrogenase and carbonic anhydrase and stabilization of ribosomal proteins.

3.7. Physiological Nutrient Use Efficiency (PUE)

Physiological efficiency represents the fraction of plant acquired nutrients to be converted in to grain yield. From the present study, the highest value was recorded from plots treated with NPKSZn. This indicates the synergic effect of the elemental combination in mineral intake. Most of the fertilizer treatments showed high physiological nutrient use efficiency with increasing combined nutrient application especially with Zn. The result showed that yield increased per kilogram nutrient accumulated in maize plant was increased with increasing combinations of nutrient application. The result is in line with the finding of [13] who reported that adding micronutrients to NPK fertilizer increase nutrient use efficiency and grain yield for different cereal crops. It also reported that the micronutrient deficiency specifically Zn resulting in severe losses in yield and nutritional quality particularly areas of cereal production in rain fed production in many parts of the world [1, 21].

3.8. Economic of Fertilizer Use

Among the nutrient combinations, NPKSZn was the most economically feasible for maize production which produced net benefit of 80,364.6ETBha^{-1} with MRR 486.4% thereby recommended for the study area. This recommendation was in conformity with [2], which reported that farmers should be willing to change from one treatment to another if the marginal rate of return of that change is greater than the minimum acceptable rate of return.

Table 4. *Partial budget analysis for fertilizer use in maize crop production.*

Treatments	GY (Kg ha^{-1})	Adj.GY (Kg ha^{-1})	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (Birr ha^{-1})	MRR (%)
T_1 = Control	2028.50	1825.70	20995.00	0.00	20995.00	-
T_2 = PKS (-N)	2793.50	2514.20	28912.70	5230.60	23682.10	51.40
T_3 = NKS (-P)	6162.20	5446.00	62628.80	5390.20	57238.60	21029.30
T_4 = NP	6705.30	6034.80	69399.90	7559.60	61840.30	212.10
T_5 = NPS (-K)	7231.80	6508.60	74849.10	8032.60	66816.60	1052.10
T_6 = NPK (-S)	7499.30	6749.40	77617.80	8617.20	69000.60	373.60
T_7 = NPKS	8353.00	7517.70	86453.60	9090.20	77363.40	1768.00
T_8 = NPKSB (-Zn)	8205.80	7385.20	84930.10	9345.00	75585.10	D
T_9 = NPKSZn (-B)	8702.60	7832.30	90071.90	9707.30	80364.60	486.40
T_{10} = NPKSZnB	8080.00	7272.00	83628.00	9962.10	73665.90	D

Where; Adj.GY = Adjusted Grain Yield down to 10%, GY = Grain Yield, GFB = Gross Field Benefit, TVC = Total Cost that Varies, NB = Net Benefit, MRR = Marginal Rate of Return and ETB = Ethiopian Birr.

4. Conclusions

From this study, it is possible to conclude that substantiated the importance of micronutrients most probably (Zn) in combination with macronutrients NPKS fertilizers based on the indigenous soil nutrient status and crop requirement is not only essential for producing high quality crops in high yields but also for environmental sustainability. The nutrient uptake and nutrient recovery efficiencies linearly increased in response to balanced combination of mineral fertilizers. Therefore, it can be concluded that application of macronutrients in combination with micronutrient increased maize yield and concomitantly improved N, P and K uptake thereby its nutrient use efficiency. Among the microelements the contribution of boron in yield increment was relatively low. Application of N_{120} P_{40} K_{40} S_{20} Zn_5 kgha^{-1} also produced maximum net benefit which was superior from other treatments hence economically suitable for user cultivation. Therefore, NPKSZn fertilizer application can be recommended to maximize maize productivity particularly in the study area. But since this finding is one year data further studies concerning on mineral fertilizer combination, fertilizer rate and time of application is needed to increase maize production.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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