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Determination of the limiting Nutrient for Maize (*Zea Mays L.*) Production in Yeki District, Southwest Ethiopia

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***Abstract*—The site specific fertilizer type for crop production in Ethiopia does not show crop yield variability when compared with the previously recommended NP fertilizer. Identifying the most yield-limiting nutrient is very important. Hence, the objective of this study was to identify the yield-limiting nutrient and quantify the level of yield penalty in maize under three locations in the Yeki district during the 2023 cropping season. Ten treatments constitute of control, recommended nitrogen and phosphorus (RNP), RNP +sulfur (S2), six nutrients (NPKSBZn), nitrogen omitted (PKSBZn), phosphorus omitted (NKSBZn), potassium omitted (NPSBZn), sulfur omitted (NPKBZn), boron omitted (NPKSZn) and zinc omitted (NPKSB) were arranged by randomized complete block design under three replication. Agronomic data were taken and analyzed by using R software 4.2.2. The mean difference of treatments was compared by LSD at a probability level of 5%. The pool means analysis of variance indicated that maize grain yield and yield components were significantly ($p \leqslant 0.05$) influenced by different nutrient omissions. The highest maize grain yield penalty 42.19% and 34.26% were recorded under the control plot followed by nitrogen omitted plots respectively and the lowest 0.65% from the previously recommended NP fertilizer applied plots. In the study area, the most yield reduction that showed more than 10% yield penalty of maize 34.26%, 23.20%, 19.92%, and 10.66% was due to N, S, P, and K omitted respectively. Since the study was conducted for one season further validation and demonstration for specific nutrients across multi-location and soil tests will be better to see more variability.**

***Keywords*—Above-ground biomass, grain yield, harvest index, nutrient omission, yield penalty**

I. INTRODUCTION

The projected global population, projected to reach 9.9 billion by 2025 according to the UN [1], necessitates a significant increase in food production to meet the expanding demand. ForAfrica, improving crop yield and food self-sufficiency under increasing population pressure is a primary goal to attaining food security [2]. This goal, however, is significant challenged by increasing climate variability, and a widespread declining soil fertility, major constraint that impede improved agricultural productivity across the continent [3; 4; 5 and 6]. Inorganic fertilizers play a crucial role in modern agricultural production system, providing essential nutrients in readily available forms for immediate plant uptake. The global trend reflects a growing reliance on synthetic fertilizers to boost crop production, emphasizing their importance in sustaining agricultural output. However, the effectiveness and sustainable application of these input require careful consideration, particularly in regions with unique soil status and economic constraints [7].

Decline in soil fertility is considered the major constraint to increased food production in most soils of Ethiopian high lands [8]. Most of the soils are characterized by their highly weathered, deep and nutrient depleted because of leaching of nutrients via runoff and expansion of soil acidity [9].

Different report showed Ethiopian soil are deficient of major and micro nutrients [10; 11] and their symptom also observed on crop [12; 13]. Currently, based on specific location nutrient deficiencies new fertilizer types are nationally developed. Deficiencies or unavailability of nutrient in appropriate amount and form can limit crop productivity. For Ethiopian agriculture fertilizer is the most important input to increase crop productivity and food security status of farmer [14].

For more than four decades, Ethiopian farmers used urea and DAP fertilizer types for their crop production as blanket recommendations across wide agroecology. However, the new specific location developed fertilizer that significantly improved yield but, it does not when compared with the previous N from urea and P from DAP fertilizer application. The study by Esubalew et al. [150] revealed a negative balance of N, P, and K in all farmlands growing barley, tef, and wheat, with the exception of P in tef. Optimizing fertilizer recommendations that are economically affordable for Ethiopian smallholder farmers and developing a strategically improved crop nutrient management to a specific Location; knowing the soil nutrient status and crop response to fertilizer application is very important. Therefore, the objectives of this study were to identify the most yield-limiting nutrient and quantify the level of yield penalty in maize crop due to omission of individual nutrients (N, P, K, S, B and/or Zn) in Yeki district.

II. Materials And Methods

A. *Description of the study area*

The study was conducted in Yeki District on three farmers' field at Fide, Shosha and Kubito during 2023 cropping season. Yeki District is Located in Southwest Ethiopia People Regional State (Fig 1) at an elevation 1280 m.a.s and latitude of 7.2◦ and Longitude of 35.35◦ East of Ethiopia and away approximately 611 km from the capital city of Addis Ababa. A mean annual rainfall is 1559 mm which extends from April to December, the area is known as hot to warm humid lowland agroecology. The Maximum and minimum annual temperatures of the area is 29.7°C and 15.5°C respectively. The soil type of the area is dominated by Nitisols [15].

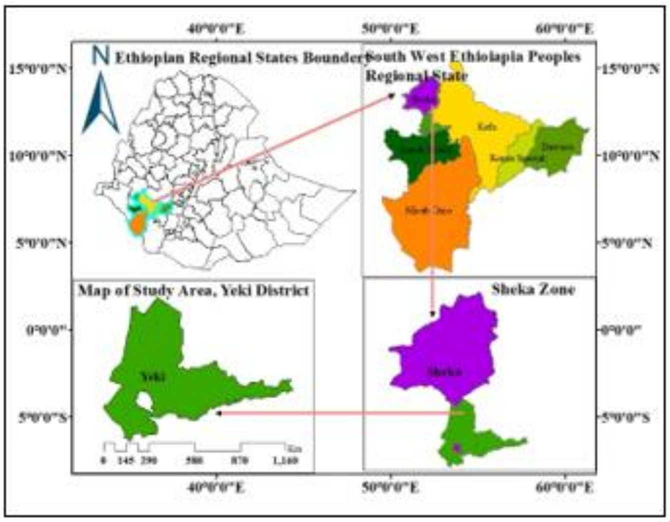

Fig. 1. Yeki district map of study area

B. *Maintaining the Integrity of the Specifications*

A hybrid maize variety (BH140) was used for the experiment. The source of each nutrients were urea, triple super phosphate, murate of potash, magnesium sulfate, borax, Zn-EDTA for N, P, K, S, B and Zn source respectively used.

C. *Experimental Design*

On-farm experiment was laid in randomized complete block design with three replication of each of consists ten treatment sets. Which was consisted; Control plot (without fertilizer), recommended NP, recommended NP +S2, NPKSBZn, PKSBZn (-N), NKSBZn (-P), NPSBZn (-K), NPKBZn (-S), NPKSZn (-B), NPKSB (-Zn) (Table1). The plot size of each was 4m x 3m (width and length respectively) and a total experimental area (14x34.5) m^2 was used. The spacing between rows and plants 75cm x 25cm respectively was used. All nutrients from each fertilizer were applied at planting time except N, where split in three equal amount 1/3 at planting, 1/3 knee height and 1/3 at flag leaf emergence.

TABLE I. Treatment Details

Treatments	Detail description of treatments (kg/ha)					
	N	***P_2O_5***	***MOP***	***$MgSO_4$***	***Borax***	***Zn-EDTA***
Control	0	0	0	0	0	0
RNP (recommended)	92	69	0	0	0	0
RNP + S2	92	69	0	30	0	0
NPKSBZn	92	69	100	10.5	1	5
PKSBZn (-N)	0	69	100	10.5	1	5
NKSBZn (-P)	92	0	100	10.5	1	5
NPSBZn (-K)	92	69	0	10.5	1	5
NPKBZn (-S)	92	69	100	0	1	5
NPKSZn (-B)	92	69	100	10.5	0	5
NPKSB (-Zn)	92	69	100	10.5	1	0

Negative sign (-) indicate omitted nutrient

D. *Data collection and analysis*

Before the experimentation composite surface soil samples was collected from the plough layer (0-20 cm) depth across the experimental plot. The composite soil sample was analyzed in laboratory and used for analysis of soil chemical properties like soil reaction (pH) in a 1:2.5 soil water suspension by a glass electrode pH meter [17], total nitrogen by modified Kjeldahl method [18], available phosphorus by Olsen method [19], available potassium by ammonium acetate extracts flame photometer [20], available sulfur and boron by Mehlich-3 method [21], cation exchangeable capacity (CEC) [22], organic carbon by Walkley and Black method [23], organic matter was estimated as organic carbon multiplied by 1.74 assuming the average carbon concentration of organic matter is 58%.

Eight plants from each net plot were randomly taken to measure plant height, ear length, thousand seed weight, grain yield, straw yield, above-ground dry biomass and harvest index of maize.

Plant height: was measured from the soil surface to the base of the tassel of eight randomly take maize plants from the net plot at maize physiological maturity.

Ear length: was measured from the point where the ear attached to the stem to the tip of ear after the husk removed.

Thousand seed grain weight: was measured from 1000 seed randomly taken and weighed by sensitive balance.

Grain yield: eight maize randomly taken at physiological maturity from the net plot and the ear where shelled manually by hand and then the grain was sun dried and seed adjusted to 12.5 % moisture content and finally converted to hector bases.

Straw yield: the eight maize harvested for straw was sun dried until it had uniform weight and converted to hector bases.

$$Harvest\ Index = \frac{Grain\ yeild}{above-dry\ biomass}\ x\ 100 \quad (1)$$

$$Yl = \frac{\sum_{t=1}^{n}(yt-ya)}{ya}\ x\ 10 \quad (2)$$

Where; YL=yield limiting (%), n=number of treatments, yt =yield obtained from each treatment, ya=yield obtained from all nutrient supplied plot.

All data were analyzed using analysis of variance (ANOVA) statically procedure using by R software 4.2.2. For the ANOVA showed significant level the treatment effects, mean separation was carried out using least significant difference (LSD) at alpha 95% probability level of significance.

III. RESULTS AND DISCUSSION

A. Pre-plant top soil properties

Pre-plant topsoil samples were collected from the experimental field in Fide, Shosha and Kubito. The chemical properties of these soil samples were analyzed in the laboratory and the results were presented in (Table 2).

Soil pH levels at the experimental site were ranged from 5.9 to 6.3. This range is within the optimal range for maize crop production. According to Landon [24], a soil pH range of 5.5 to 7 is considered medium. Therefore, the experimental sites fell within this ranges.

The total soil nitrogen (N) content in the experimental sites ranged from 0.05 to 0.18 %. According to Tekalign [25] total soil N availability is classified as: extremely low (0.1%), low (0.1-0.2%), moderate (0.2-0.5%), high (0.5-1%), and very high (>1%). Based on this classification, the soil at the Fide site was extremely low (0.05%), while the Shosha and Kubito sites were low in N (0.17% and 0.18%) respectively. Therefore, these areas needs nitrogen application, as maize has a high N demand and its productivity is significantly limited by N nutrient deficiency soil.

The available soil phosphorus (AP) content ranged from 4.3 to 21.7 mg/kg of soil. According to Landon [24], available (Olsen extractable) soil P level (<5 mg/ha as low, 6-15 mg/ha as medium and >15 mg/ha as high), the experimental site ranged from low to high in AP, indicating a need for phosphorus source fertilizer. Therefore, the av. P of the experimental location were ranged from low to high ranges and need nutrient supply for crop production.

The available soil potassium (AK) content ranged from 37.21 to 46.9 mg/kg of soil. According to Horneck et al. [26], soils having potassium level as low (<150 mg/kg, medium (150-250 mg/kg) and excessive (>800mg/kg). Consequently, the experimental location's soil were low in AK.

The available soil sulfur (S) level ranged from 6.59 to 11.9 gm/kg of soil. Horneck et al. [26] classify soil as extremely low (< 2 gm/kg), low (2–5 gm/kg, medium (5–20 gm/kg), and high (>20 gm/kg). As a result, based on this classification, the experimental site was considered medium in sulfur availability.

The available soil boron (B) level at the experimental location ranged from 0.79 to 2.12 gm/kg of soil. According to Horneck et al. [26] rated soil B availability ratings (very low: <0.2 gm/kg, low: 0.2-0.5 gm/kg, medium: 0.5- 1 gm/kg, high: 1-2 gm/kg and excessive :> 2 gm/kg). Thus, the soil of the experimental sites ranged from medium to excessive in available boron.

The available soil Zink (Zn) level at the experimental site ranged from 11.52 to 18.04 gm/kg of soil. Singh and Saha, [27] classified the soils Zn levels as: adequate (>15 gm/kg), marginal (10-15 gm/kg), low (5-10 mg/kg) and very low (<5mg/kg). Based on this classification, the soil at the experimental sites ranged from marginal to adequate in available Zn.

The cation exchangeable capacity (CEC) at the experimental site ranged from 43.44 to 52.12 meq/100gm of soil. Landon [23] classified the CEC as: very high (>40 meq/100gm), high (25–40 meq/100gm), medium (15–25 meq/100gm), and low (5–15 meq/100 gm), and very low (<5 meq/100gm). Consequently, the experimental sites were classified as very high in CEC, like high CEC might due to the comparatively high amount of organic matter in the experimental region, which suggests suitability for agricultural use.

The organic carbon (OC) level at the experimental sites ranged from 3.08 to 7.48 %. Landon, [23], classified soil OC as low (< 4%), medium (4-10%) and high (>10%). Accordingly, the experimental sites ranged from low to high in OC content. This relatively high OC content might be attributed to the incorporation of agricultural residues and litter fall into the surface soil. The high organic carbon level may be linked to its organic matter content. The value of organic matter (OM) content at the experimental sites ranged from 5.30 to 12.80%.

TABLE II. PRE-PLANT SOME SOIL CHEMICAL PROPERTIES OF THE EXPERIMENTAL LOCATION

Site	Ph	TN %	av. P mg/kg soil	av. K mg/kg soil	S mg/kg	B mg/kg	Zn mg/kg	CECmeq/100 gm	OC %	OM %
Fide	5.9	0.05	6.5	41.54	11.9	0.79	18.04	43.44	4.42	7.62
Shosha	5.9	0.17	4.3	37.21	10.5	0.88	11.52	51.47	7.48	12.89
Kubito	6.3	0.18	21.7	46.9	6.59	2.12	11.56	52.12	3.08	5.3

B. Effects of different nutrients on maize growth parameters

At each site, maize plant height was significantly ($p \leqslant 0.05$) affected by different nutrient applications compared to the control and nitrogen omitted treatments. However, no significant differences ($p>0.05$) in plant height were observed among the other nutrient application (Table 3).

At each sites, ear length was significantly ($p \leqslant 0.05$) affected by different nutrient application compared to the control and nitrogen omitted treatments. While, ear length did not differ significantly among the other nutrient applications, except for the nitrogen omitted at Fide. Poor maize ear growth performance was observed under nitrogen omitted plot (Fig.2. a).

a) Poor kernel set due to nutrient omitted

b) Poor kernel set due to N omitted

c) Fully kernel set under all nutrients (NPKSBZn)

Fig. 2. Maize ear performance to different nutrient

TABLE III. EFFECTS OF DIFFERENT NUTRIENT ON MAIZE PLANT HEIGHT AND EAR LENGTH IN YEKI DISTRICT DURING 2023 CROP SEASON

Treatments	Locations					
	Fide	Shosha	Kubito	Fide	Shosha	Kubito
	Plant height (cm)			Ear length (cm)		
Control	215.83^{b}	250.87^{b}	236.74^{c}	11.83^{b}	15.70^{c}	12.61^{c}
RNP	255.63^{a}	274.70^{a}	270.09^{a}	16.73^{a}	17.70^{b}	15.75^{ab}
RNP +S2	256.27^{a}	269.40^{a}	263.75^{a}	16.07^{a}	17.10^{b}	15.67^{ab}
NPKSBZn	255.57^{a}	277.77^{a}	261.67^{a}	15.17^{a}	20.07^{a}	16.29^{a}
PKSBZn (-N)	223.23^{b}	253.57^{b}	247.17^{bc}	14.60^{a}	17.33^{b}	13.54^{bc}
NKSBZn (-P)	251.4^{a}	256.13^{b}	261.05^{a}	16.00^{a}	17.43^{b}	15.81^{ab}
NPSBZn (-K)	253.47^{a}	269.97^{a}	262.71^{a}	15.77^{a}	18.17^{b}	15.48^{ab}
NPKBZn (-S)	237.7^{ab}	275.57^{a}	266.67^{a}	15.73^{a}	17.67^{b}	15.79^{ab}
NPKSZn (-B)	250.07^{a}	274.47^{a}	260.50^{ab}	14.80^{a}	17.63^{b}	14.51^{abc}
NPKSB (-Zn)	258.03^{a}	273.20^{a}	266.34^{a}	16.27^{a}	18.00^{b}	14.58^{abc}
LSD	26.12	11.62	13.54	2.31	1.2	2.53
CV %	6.19	2.53	3.04	8.82	3.96	9.85

CV%=Coefficient of variation in percent, LSD=least significant difference, Mean with similar letter(s) within the column were none significantly different at alpha 5% probability level

C. *Effects of different nutrients on maize yield and yield components*

Thousand grain weight was not significantly ($p>0.05$) influenced by the treatments at Fide. However, at Shosha and Kubito, thousand grain weight as significantly ($p<0.05$) lower in the control plots compared to the nutrient received treatments, with the exception of the nitrogen omitted plot at Shosha (Table 4).

Maize yield was significantly ($p<0.05$) influenced by nutrient applications at each sites. At Fide, the highest grain yield (11183.09 kg/ha) was recorded with RNP + S2, while the control yielded the lowest (5743.09 kg/ha). Similarly, RNP resulted in the highest yield at Shosha (13001.77 kg/ha) compared to the control (5650.47 kg/ha). At Kubito, RNP + S2 again produced the highest grain yield (9173 kg/ha) and the control the lowest (5413.65 kg/ha) Table 4).

TABLE IV. EFFECTS OF DIFFERENT NUTRIENT ON MAIZE THOUSAND SEED WEIGHT AND GRAIN YIELD IN YEKI DISTRICT DURING 2023 CROP SEASON

Treatments	Location					
	Fide	Shosha	Kubito	Fide	Shosha	Kubito
	Thousand grain weight (gm)			*Grain Yield kg/ha*		
Control	386.37	354.4 b	253.82b	5743.09e	5650.47g	5413.65 d
RNP	418.63	460.4 a	379.08a	10821.09ab	13001.77 a	9036.35 a
RNP +S2	441.07	445.9 a	391.32a	11183.09a	12340.20 abc	9173.87 a
NPKSBZn	443.6	462.7 a	395.51a	11168.79a	12880.73 ab	9052.94 a
PKSBZn (-N)	389.6	353.6 b	356.57a	7978.79 d	6296.67g	6681.64 cd
NKSBZn (-P)	436.7	438.0 a	383.25a	9221.09c	11311.70 ef	8007.21 abc
NPSBZn (-K)	432.47	445.0 a	350.47a	10266.79b	10815.07f	8286.83 ab
NPKBZn (-S)	427.57	440.3 a	380.31a	7935.69 d	12167.43 bcd	8424.27 ab
NPKSZn (-B)	411.93	445.8 a	378.41a	10399.09ab	11474.87 def	8133.80 ab
NPKSB (-Zn)	445.07	440.7 a	347.38a	10785.29ab	11952.87 cde	7385.36 bc
LSD	ns	37.18	50.27	784.69	789.85	855.74
CV%	10.66	5	8.1	4.79	4.26	9.92

CV%=Coefficient of variation in percent, LSD=least significant difference, ns=none significant, Mean with similar letter(s) within the column were none significantly different at alpha 5% probability level

The highest maize above-ground biomass yield were recorded with NPKSBZn at Fide 27. 27 t/ha, RNP at Shosha (22.56 t/ha), Kubito (19.32t/ha). The control treatment resulted in the lowest grain yields at each site: 14.08 t/ha Fide, 14.80 t/ha at Shosha, and 12.76 t/ha at Kubito (Table 5).

TABLE V. EFFECTS OF DIFFERENT NUTRIENT ON MAIZE STRAW, BIOMASS AND HARVEST INDEX ON-FARM IN YEKI DISTRICT DURING 2023 CROP SEASON

Treatments	Fide	Shosha	Kubito	Fide	Shosha	Kubito
	Above-ground dry Biomass t/ha			***Harvest Index***		
Control	14.08d	14.80f	12.7b	0.41b	0.38d	0.42bc
RNP	20.60ab	27.27a	19.23a	0.53a	0.48a	0.47ab
RNP +S2	22.52a	25.20bc	19.32a	0.5a	0.49a	0.47a
NPKSBZn	22.56a	26.09ab	19.16a	0.49a	0.49a	0.47a
PKSBZn (-N)	16.65cd	16.23e	16.9a	0.48a	0.39d	0.39c
NKSBZn (-P)	18.41bc	24.05c	17.67a	0.50a	0.43c	0.45ab
NPSBZn (-K)	20.38ab	22.48d	18.62a	0.50a	0.48a	0.44ab
NPKBZn (-S)	17.27c	25.17bc	19.09a	0.46ab	0.44bc	0.44abc
NPKSZn (-B)	20.48ab	24.59c	17.69a	0.51a	0.47ab	0.46ab
NPKSB (-Zn)	20.90ab	24.62c	16.94a	0.52a	0.49a	0.43abc
LSD	2.85	1.36	3.08	0.06	0.03	0.05
CV %	8.56	3.44	10.12	7.61	3.61	6.41

CV%=Coefficient of variation in percent, LSD=least significant difference, Mean with similar letter(s) within the column were none significantly different at alpha 5% probability level

Overall sites, plant height was significantly ($p \leqslant 0.5$) affected by nutrient omissions compared to control and N omitted treatments (Table 6 and Table 7). The highest plant height (266.6 cm) was recorded in the RNP fertilized treatments, while the control plots had the lowest height (235.46cm).

The lowest maize plant height recored in the nitrogen omitted treaments likely resulted from compromised photosynthesis and vegetative growth, resulted to stunsted growth and leaf yellowing. In accordance with these findings, previously students have shown that nitrogen nutrient deficiency decreases the rate of photosynthesis (carbon assimilation per unit leaf area), ultimately which decreases plant height of maize [28; 29].

Ear length and thousand seed weight were only significantly ($p<0.05$) influenced by the treatments. But only in comparison to the control plots. The NPKSBZn treatment showed in the longest ears (17.18 cm) and heaviest (433.94gm) thousand seed weight, while the control treatments resulted the shortest (13.52 cm) and lightest thousand seed weight (344.88 gm).

Nitrogen (N) is primary an essential plant nutrient critical for growth and development, and its deficiency can lead to stunted growth, including reducing ear length of maize. Consistent with these findings both N and P source fertilizer application improved ear length cereal crop [30; 31].

The grain production was significantly influenced by the plant's ability to efficiently produce and distribute assimilated nitrogen during silk [30]. N plays a crucial in photosynthesis and seed formation, contributing to increase grain of weight of maize [32; 33].

Maize grain yield was significantly ($p<0.05$) influenced in the control and N omitted plots. The highest grain yield (10212.63 kg/ha) was recorded with the all nutrient content plot (NPKSBZn), while the control plots yielded the lowest (6379.31 kg/ha). Insufficient N source fertilize resulted in decreased grain yields of maize due to poor performing kernel set (Fig. 2a and B). Applying optimal N is critically imports for maize growth as it improves photosynthesis, protein synthesis and cell multiplication. Compared to N, omission of other nutrients did not significantly impact yield relative to previously recommended NP fertilizer application. Given that farmers in the study area often rotate maize with sorghum, as a cropping system that can reduce soil fertility through nutrient removal, these results underscore the importance of nitrogen management for sustaining maize yields.

Cereal crops known for their nutrient-exhaustive crops, primary extract from the upper soil layer [33]. Among essential plant nutrients, N is widely observed as primary limiting factor for maize production [35; 36; 37; 38). N role's wider role, including its involvement in plant photosynthesis, protein development, a constituent of chlorophyll and various biological processes like water and mineral absorption, storage of vacuole and xylem transport contribute to maize yield improvements. Additionally, N is crucial for carbohydrate formation during grain filling, leading to increased both gain and biomass [39]. Conversely, deficient N available can severely restrict biomass and yield in crops

TABLE VI. OVERALL EFFECTS OF DIFFERENT NUTRIENT ON MAIZE PLANT HEIGHT, EAR LENGTH, THOUSAND GRAIN YIELD AND GRAIN YIELD ON-FARM IN YEKI DISTRICT DURING 2023 CROP SEASON

Treatments	**Plant height (cm)**	**Ear length (cm)**	**Thousand seed weight (gm)**	**Grain Yield kg/ha**
Control	235.46^{c}	13.52^{d}	344.88^{c}	6379.31^{d}
RNP	266.6 ^{a}	17.03^{ab}	420.08^{a}	10962.65^{a}
RNP +S2	262.38^{ab}	15.97^{abc}	413.02^{ab}	10212.63^{a}
NPKSBZn	265^{ab}	17.18^{a}	433.94^{a}	11034.13 ^{a}
PKSBZn (-N)	244.66^{c}	15.64^{c}	371.45^{bc}	7254.18^{d}
NKSBZn (-P)	257.37^{ab}	16.08^{abc}	414.02^{a}	8835.70^{bc}
NPSBZn (-K)	261.01^{ab}	16.72^{abc}	419.30^{a}	9857.85^{ab}
NPKBZn (-S)	256.65^{b}	15.78^{bc}	410.27^{ab}	8473.77^{c}
NPKSZn (-B)	261.61^{ab}	15.61^{c}	407.47^{ab}	9985.91^{ab}
NPKSB (-Zn)	265.79 ^{ab}	16.40^{abc}	410.96^{ab}	10111.5^{a}
LSD	9.88	1.35	42.41	1218.35
CV%	2.23	4.95	6.11	7.62

CV%=Coefficient of variation in percent, LSD=least significant difference, Mean with similar letter(s) within the column were none significantly different at alpha 5% probability level

Above-ground dry biomass differed significantly ($p<0.05$) between the control and N omitted plots. The heaviest biomass yield (22.6 t/ha) was recorded with the all nutrient content (NPKSBZn) treatment, while the control treatment had the lighter (16.93 t/ha). The highest harvest index (0.49%) was recorded in the NPR allied treatments, and the lowest (0.41%) in the control plots (Table 7).

Sufficient N source fertilizer application, it improves photosynthesis which leading to an increase in total crop biomass [40; 41; 42]. This positive effects of N on biomass in maize has been consistently observed on different precious studied [43].

The highest maize harvest index (0.49) was recorded with the RNP treatment, while the lowest harvest indices, were recorded in the control (0.41) and N omitted (0.42) plot (Table 6).

Under favorable environmental condition, couple with balanced nutrient application, enable maize crops to effective divide dry substance into grain yield, leading to increase harvest index [44].

TABLE VII. OVERALL EFFECTS OF DIFFERENT NUTRIENT ON MAIZE STRAW YIELD, BIOMASS, AND HARVEST INDEX ON-FARM IN YEKI DISTRICT DURING 2023 CROP SEASON

Treatments	Above-ground dry Biomass	Harvest Index
Control	16.93[de]	0.41[c]
RNP	22.49[a]	0.49[a]
RNP +S2	21.44[ab]	0.47[ab]
NPKSBZn	22.60[a]	0.48[a]
PKSBZn (-N)	16.97[de]	0.42[c]
NKSBZn (-P)	19.37[bc]	0.46[ab]
NPSBZn (-K)	20.56[abc]	0.48[a]
NPKBZn (-S)	19.10[cd]	0.44[bc]
NPKSZn (-B)	20.90[abc]	0.47 [ab]
NPKSB (-Zn)	22.49[a]	0.48[a]
LSD	2.32	0.03
CV%	6.79	3.89

CV%=Coefficient of variation in percent, LSD=least significant difference, Mean with similar letter(s) within the column were none significantly different at alpha 5% probability level

Across overall sites, the greatest maize yield penalty was recorded in the control (42.19%) in which all nutrient omitted plots, followed by N omitted plots (34.26). The smallest yield reduction (0.65%) recorded with the previously recommended NP (RNP) fertilizer (Table 8). The most yield limiting nutrient in the study area, resulting in yield reductions greater 10%, were N (34.26%, S (23.20%), P (19.92% and K (10.66%) (Table 8).

TABLE VIII. OVERALL MAIZE GRAIN YIELD PENALTY DUE TO SPECIFIC NUTRIENT OMISSION

Treatments	Grain yield kg/ha	Yield penalty (%)	Omitted nutrients
Control	6379.31	-42.19	N,P,K,S,B, Zn
RNP	10962.65	-0.65	K, S, B, Zn
RNP +S2	10212.63	-7.45	K, B, Zn
NPKSBZn	11034.13	0.00	
PKSBZn (-N)	7254.18	-34.26	N
NKSBZn (-P)	8835.7	-19.92	P
NPSBZn (-K)	9857.85	-10.66	K
NPKBZn (-S)	8473.77	-23.20	S
NPKSZn (-B)	9985.91	-9.50	B
NPKSB (-Zn)	10111.5	-8.36	Zn

Note: Negative sign (-) indicate that yield reduction due to nutrient omitted

IV. CONCLUSION

This study showed that maize grain yield was significantly influenced by nutrient omission, particularly in control plots, which showed the greatest yield reduction (42.19%) and 34.26%, respectively). The previously recommended NP fertilizer source recorded in minimal yield reduction (0.65%). Among, the individual omitted nutrients, sulfur omission, I addition to N, had a notable impact on yield reduction, while a significant impact was also created with P to other treatments like as K, S and B. Generally, the relative importance of different omitted nutrients was assessed with the finding that those resulting in more than 10% maize yield reduction as follow: N>S>P>K which suggests that N is the primary limiting nutrient for maize production in Yeki district, southwest Ethiopia. Given that this study was conducted for one single season, further multiple year validation and demonstration of trials are important across wide agro ecology and soil types to confirm the findings and refine nutrient management in crop production system.

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