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Research Article

Determination of Most Limiting Nutrient for Maize Yield through Nutrient Omission Experiment for Site-Specific Nutrient Recommendation on *Typic ustipssament* of Maiduguri, Northeast Nigeria By

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Abstract

Effect of omitting one essential nutrient on the yield and yield parameters of maize (2000 Synthetic TZEEY, yellow) on a sandy loam soil was investigated in a field experiment conducted in 2018 and 2019 seasons in Maiduguri, Nigeria. The treatments involved no fertilizer (control), and recommended rates of PK, NK, NP, NPK, NPK + S + Ca + Zn + B, and NPK + S + Ca + Zn + B + Manure (cow dung) arranged in a randomized complete block design. Maize yield (per net plot), number of cobs, weight (kg) of the total maize stalks of each plot without cobs, weight (kg) of the cobs per plot, bulked weight of five cobs taken at random from each net plot were determined. Five cobs were shelled and grains and the cobs weighed. While the mean number and weight of cobs per plot declined significantly ($P < 0.05$) from 134 to 52 and 3.47 to 0.45 kg, respectively when phosphorus and potassium were applied alone without nitrogen, the means increased significantly from 134 to 189 and 7.70 to 11.18 kg when nitrogen was involved. The mean shelled and unshelled cobs per plot followed similar pattern. The effectiveness of the nitrogen application together with micronutrients and organic materials in terms of increasing maize stalk and grain yields was observed. Yields were lower when nitrogen was omitted. The most limiting nutrient was observed to be nitrogen, followed by phosphorus, but potassium not limiting nutrient for maize production in this area. For site specific nutrient recommendations, the rates involving nitrogen in combinations with organic materials and micronutrients should be encouraged and not potassium.

Keywords: Nutrient Omission; Most Limiting Nutrient; Maize; SSNM; Northeast Nigeria

Introduction

Maize is a staple cereal crop grown in almost all parts of the world. It is a high yielding cereal grown successfully under rainfed environment and requires less capital. According to a study a yield of up to 7.5 t/ha is attainable under good management [1], but yield in Nigeria is below 5.0 t/ha due to low nutrient status of the soils, especially N, P and K. Much of the nutrients required by maize plants come from the soil, but the supply of nutrients is not able to meet the nutrient requirements for realizing higher yields. The use of fertilizers is therefore essential to fill the above gap between the crop needs for nutrients and the supply of nutrients from soil and available organic inputs ensuring the right rate and right time of fertilizer application.

Several researches conducted on nutrient omission have indicated different responses of maize to nutrient uptake and crop yield. A long-term permanent plot experiment conducted at the Regional Agricultural Research Station, Parwanipur, Nepal reported that application of phosphorus, potassium or both phosphorus and potassium along with nitrogen did not improve the yield of rice, indicating that phosphorus and potassium were not limiting yields [2]. Omission of phosphorus, potassium or both for wheat led to yield similar to those of nitrogen, phosphorus and potassium, indicating that the wheat did not respond to phosphorus and potassium. In a similar nutrient omission study, mean grain yields of rice had been reported to be 2.6, 6.1, and 6.3 t/ha in the nitrogen, phosphorus and potassium omitted plots, respectively during dry season [3]. The same treatments yielded 2.5, 3.2, and 4.0 t/ha in the nitrogen, phosphorus, and potassium omitted plots, respectively during the wet season. They stated that nitrogen and phosphorus were yield limiting nutrients, while the indigenous potassium supply was considerable to sustain crop production.

A comparison was made with seven soils using nutrient omission trials in Vanuatu with maize as test crop [4]. The findings indicated that relative top dry weight of maize was significantly affected by different treatments. The study revealed deficiencies of phosphorus in all soils tested, of nitrogen in four soils, of potassium in two soils and of sulphur in two soils. No other nutrient deficiencies had been detected. Optimization of major nutrients for lowland rice production in eastern Uganda was carried out [5] using nutrient omission trial for estimating indigenous nutrient supply of the major nutrients and response function. Application of nitrogen significantly increased yield components and consequently the grain yield of rice. The major limiting nutrient for lowland rice production is nitrogen and the soil nitrogen supplying potential can support yield target of 2.8 t/ha. Whereas the indigenous phosphorus and potassium supply can support yield target of up to 9.0 t/ha and therefore, not limiting at achievable yield targets of 6.0 t/ha.

There are several studies that examine the impact of site-specific nutrient management (SSNM) approach on fertilizer use primarily using field experiment. On-farm experiments to develop and test a new SSNM approach for eight key irrigated maize production domains of Asia located in six countries from 1997-1999 was carried out [6]. They hypothesized that maize yields, profit, plant nutrient uptake, and nitrogen use efficiencies can be significantly increased by applying fertilizer on a field-specific and cropping season-specific basis, i.e., through SSNM. They found that average grain yield increased by 0.36 Mg per hectare with SSNM as compared to current farmers' fertilizer practice in their study in cropping systems in Asia. Their results show that SSNM led to significant increases in nitrogen use efficiency. Average agronomic efficiency of applied nitrogen (kg grain yield increase per kg nitrogen applied) under SSNM was 15 kg kg^{-1}, apparent recovery efficiency of applied nitrogen (kg nitrogen taken up per kg nitrogen applied) 0.40 kg kg^{-1}, and partial factor productivity of applied nitrogen (kg grain yield per kg nitrogen applied) 52 kg kg^{-1}. Compared to the farmers' practice, average agronomic efficiency of applied nitrogen and recovery efficiency of applied nitrogen increased by almost 30 percent, partial factor productivity of applied nitrogen by six percent.

Analysis of the SSNM in irrigated maize systems of the Red River Delta was carried out on 24 farm fields as a comparison with farmers' fertilizer practice and found that SSNM results in a small yield increase of 0.19 tonnes per hectare on winter-spring season over farmers' fertilizer practice [7]. The authors also looked at the effect of SSNM on fertilizer use and profit and found that SSNM decreased the total fertilizer cost by about $2 per hectare in 1998 and by $22 per hectare in 1999. The average profit increase over farmers' fertilizer practice was $41 per hectare in 1998 and $74 per hectare in 1999. In a similar study, similarly, [8] explored the environmental impact and economic benefits of SSNM in irrigated maize systems in Asia, particularly in the Philippines, southern India, and southern Vietnam using on-farm trials, research data showed that SSNM led to higher efficiency of nitrogen use. While the annual nitrogen use was the same for SSNM and farmers' fertilizer practice in India, the reduction in fertilizer uses with SSNM averaged 10 percent in the Philippines, and 14 percent in Vietnam. In all the three locations, the estimated grain yields were significantly higher in SSNM than in farmers' fertilizer practice fields. In addition, the partial factor productivity of nitrogen increased significantly with SSNM in the Philippines and Vietnam. This increase had been associated with increased plant use of nitrogen and reduced loss of nitrogen. Economic performance of SSNM had also been assessed using economic data. Gross revenue and gross return above fertilizer costs were higher for SSNM than non-SSNM farmers across the three countries. Although, their results showed that the practice of SSNM did not reduce the total input costs, it raised the net benefits of farmers by $169, $106, and $34 per hectare per year in India, the Philippines, and Vietnam, respectively. Studies of [9] in north-western India and [10] in China found similar results.

In a related study of a site-specific approach to nutrient management evaluation in 56 on-farm experiments with irrigated wheat and transplanted maize crops in north-west India, the result revealed that field-specific management of macronutrients increased yields of maize and wheat crops by 12% and 17% and profitability increased by 14% and 13%, respectively as compared to farmers' fertilizer practice [11]. Overall average yields with SSNM increased by 7% and profitability by 12%. Report of [12] indicated that the results of trials conducted on irrigated maize in different countries of south Asia revealed the benefit of SSNM, where fertilizer nitrogen rates significantly reduced by 10% to 20% at the experimental sites in China, Vietnam and Indonesia. Reduction in phosphorus requirement amounted to 20%, while reduction in potassium requirement of 15% has been found in Hanoi in the Red River Delta of north Vietnam.

An evaluation on the impact of SSNM in irrigated rice farms in the Red River Delta, northern Vietnam indicated that the impact analysis identified several directions that can be pursued to improve further the adoption of SSNM [13]. A pot experiment using SSNM for management of maize and rubber growing soil was carried out by [14]. The pot trial using maize and rubber showed that nitrogen, phosphorus and lime were limiting factors. However, order of limiting for maize has been found to be P > N > Lime, whereas for the rubber it was N > P > Lime. Rubber in the experimental field was reported to have been responded to nitrogen and phosphorus fertilization, corresponded to the pot trial. Furthermore, [15] also found that SSNM provided an increase in grain yield of about 0.5 t/ha and gave higher benefit than farmers' fertilizer practice. Fertilizer rates as estimated by SSNM has almost been met the requirement of crop, therefore it could save nutrients, especially nitrogen which was applied too high by farmers.

Considering the low fertilizer use by farmers in the northeastern Nigeria and the correspondingly lower yield compared to the other regions of the country, this experiment was designed to determine the most limiting nutrient for maize production on sandy soils of Maiduguri, Nigeria.

Materials and Methods

Site description

A field experiment was conducted during rainy seasons of 2018 and 2019 at the University of Maiduguri Commercial Farm, Maiduguri (11°48' N; 13º 13' E; 322 m above sea level), in Sudan savanna, Nigeria. The site has an average minimum and maximum monthly temperature of 28.5 and 32.8° C, respectively, with highest temperatures between March to July and the lowest temperatures between November to February. Average annual rainfall is between 500 to 600 mm. Rain distribution is unimodal, which starts on average from mid-June and lasts towards the end of September [16] The soil of the study area is sandy loam with poor physical properties [17] and inherently low in fertility.

Soil sample collection and preparation

Prior to the experiment four samples per replicate were bulked together to form a composite sample. After the experiment three samples from each plot were also bulked. The bulk samples from the field were prepared by air-drying and sieving through 2 mm. A 400 g sub-sample of the processed samples was carefully weighed and used for determination of soil properties such as particle size distribution, soil bulk density (the core method was used to determine bulk density), soil pH (water) and EC, soil organic C (combustion), total N, available P, exchangeable bases (K, Na, Ca, Mg), and CEC.

Treatments and experimental design

The experiment consisted of NPK omission plots and additional control and NPK + secondary and micronutrient treatments, making seven treatments. The treatment structure in the field were control (no fertilizer), PK, NK, NP, NPK, NPK + S + Ca + Zn + B, and NPK + S + Ca + Zn + B + Manure (cow dung). These were replicated three times in a randomized complete block design (RCBD) in plots sizes of 8 m by 8 m. Maize variety used was 2000 Synthetic TZEEY (yellow). Nutrients (NPK) were applied at rates requirements to achieve the expected attainable yield without nutrient limitation in the location. Application rate of 120:60:30 NPK kg/ha was used due to low rainfall and low potential maize production of the area, with attainable yield of 5-6 t/ha. Nitrogen was applied in three splits as follows: 1st application as basal, 2nd topdressing i.e., V6 (approx. 21 Days after emergence, DAE) and at 3rd topdressing i.e., V10 (approximately 42 DAE) using urea (46%). All other nutrients (P and K from SSP and MOP) were applied as basal at the time of planting. The amount of fertilizer applied per plot was calculated as follows

Fertilizer (g/plot) = Nutrient application rate (kg/ha) x (100/% nutrient content) x (plot area/10,000) x 1000

Cattle manure was applied at 10 tonnes per hectare. The manure was well composted, dried and with low sand/soil content. The manure was sourced locally from one farm to ensure that the manure used in the area is of homogenous quality. Three samples of 500 g were taken after mixing thoroughly and taken to the laboratory for moisture content determination. After drying, 200 g subsamples were stored in clearly labelled sample bags for nutrient content analysis. Considerable amounts of manure (500 kg on dry weight basis) were procured and packed in large bags and stored to avoid wetting in the event of rain occurrence before application. At planting time, the manure heap was thoroughly mixed, weighed in bags, broadcasted and incorporated into the soil during land preparation. A spacing of 75 x 25 cm was followed for planting hybrid maize varieties in order to maintain a plant population of at least 53,000 plants/ha.

Field management practices

Land preparation was carried out using conventional tillage. The plots were cleared and the residues from previous seasons' crops removed before ploughing and harrowing at a depth of 20 cm using tractor harrow in the first year and hand hoe in the second year. The plots of the first season were maintained in the second season to take advantage of the residual nutrient effects. The plots were weeded manually twice during the cropping season. First at 2 weeks after planting and the second at 4 weeks after planting.

Agronomic data collection

Timing parameters such as date of sowing, date of emergence, dates of fertilizer application and dates of weeding were recorded. Maize was harvested at the right time after physiological maturity when moisture content is less than 18%. Harvesting was done from a net plot of 4 m x 4 m. All the plants from a net plot were cut above the ground and measurements taken as described under data collection section.

Parameters measured at harvest were maize grain (kg)**,** number of cobs, weight (kg) of the total maize stalks of each plot without cobs, weight (kg) of the cobs per plot, five cobs taken at random from each net plot, bulked and their weight immediately taken**.** The five cobs were shelled and grains and the cobs weighed. The data collected were subjected to Analysis of Variance (ANOVA) using statistical software *STATISTIX* (Version 10.0) and significant means were compared using Duncan Multiple Range Test at 5% level of probability.

Results and Discussion

Selected soil physico-chemical properties of the experimental field

Soil physical and chemical properties of the experimental site are presented in Table 1. The sand fractions were higher in soils in both years than the silt and clay fractions and this translated into sandy loam texture. The slow rate of weathering and relatively young age of the soils was attributed to the low silt and clay fractions in soils [18]. The lower clay content in soil was also due to continues cultivation [19] which promotes further weathering and erosion processes as it shears and pulverizes the soil and changes the moisture and temperature regimes, which encourages the finer fraction to be carried away by erosion. The sandy loam textural class of the area indicates the homogeneity of soil forming processes and similarity of parent materials as reported by [20].

The soil pH measured in water varied from slightly alkaline to neutral in 2018 and 2019, respectively [1]. This may be due to low amount of rainfall leading to lower leaching of soil cations [18,21]. It is indicative that the pH range was optimum for cultivation of most crops. The organic carbon content (Table 1) was low in both years. Soil organic carbon plays an important role in nutrient availability and soil aggregate formation [22]. The generally low levels of soil organic matter in the study area might be due to the effect of sparse vegetation cover and persistent cultivation [21], coupled with high temperature which resulted to soils rapid mineralization. For example, studies conducted by [18], [21], and [23], opined that intensive cropping and tillage practices destroy soil structure through compaction, loss of soil moisture, increased bulk density and make such soils susceptible to soil wash and loss of basic cations. The total nitrogen of the area was rated low, below 1.5 gkg^{-1} critical level recommended [24]. However, the lower total nitrogen across the years may be attributed to loss of total nitrogen through leaching and rapid mineralization due to exposure to solar radiation and to high temperatures which characterize the study area [25]. Available phosphorus was found to be low in both years as also observed by [24], indicating serious deficiency problem of phosphorus. Despite the addition of phosphorus bearing fertilizers in the first year, the available phosphorus level of the second year is still low, indicating inherently low level of phosphorus in the soils of the study area. The mean value of exchangeable K was rated high in both years as per [24] ratings. The higher exchangeable K obtained in the soil could be due to the inherently higher amount in the soil during soil formation [25].

Effect of nutrient omission on yield parameters of maize

Properties	Values	
	2018	2019
Particle size distribution ($g\ kg^{-1}$):		
Sand	716	815
Silt	146	72
Clay	138	113
Texture	Sandy loam	Sandy loam
Bulk density ($g\ cm^{-3}$)	1.74	1.68
$pH_{1:2.5}$ (water)	7.8	7.4
Electrical conductivity ($dS\ m^{-1}$)	0.03	0.08
Organic matter ($g\ kg^{-1}$)	2.57	2.84
Total nitrogen ($g\ kg^{-1}$)	0.85	0.90
C:N ratio	1.75	1.85
Available Phosphorus ($mg\ kg^{-1}$)	5.25	6.83
Exchangeable cations ($cmol\ kg^{-1}$):		
Potassium (K)	0.99	1.08
Sodium (Na)	0.31	0.29
Calcium (Ca)	0.80	1.90
Magnesium (Mg)	1.90	3.30
Exchangeable acidity (H + Al)	0.35	0.35
Cation Exchange Capacity (CEC)	5.44	5.82
Base saturation (%)	93.58	94.02

Table 1: Selected physical and chemical properties of the soil before commencement of the experiment.

Effect of nutrient omission on number of cobs per plot and weight of cobs per plot

The effect of nutrient omission on number of cobs per plot and weight of cobs per plot are presented in table 2. Significant different responses of maize yield parameters and yield to nutrient omission were observed among the treatment means in both years and their combined means. Significantly higher number of cobs and weight of cobs per plot were observed with application of NPK + micronutrients + manure in both years and their combined means. Number of cobs per plot obtained with this treatment was at par with that obtained with NP, NPK and NPK + micronutrient in 2019, while in the combined means similar number of cobs per plot obtained only with application of NPK.

Weight of cobs per plot in 2019 were similar for both NPK + micronutrient and NPK + micronutrient + manure, although slightly higher in treatments with manure. There was an improvement over the 2018 due to residual nutrient effect. In the combined means application of phosphorus or both phosphorus and potassium along with nitrogen or nitrogen, micronutrients and manure significantly (P < 0.05) improved the weight of cobs per plot, indicating that potassium was not limiting yields.

Application of nitrogen together with phosphorus proved to be the most required nutrient for maize yield in the experimental site, while potassium is shown not to be most limiting nutrient. Omission of potassium for maize production led to yield parameters similar to those of nitrogen, phosphorus and potassium with micronutrients and manure, indicating that the maize did not respond to potassium. It was evident from the result that application of phosphorus or both phosphorus and nitrogen with micronutrients and manure resulted to improved maize yield. The inclusion of manure has benefit of improving the physical conditions as well as reserviour of nutrients necessary for maize production. Similar study by [2] indicated that phosphorus and potassium did not limit crop yield as nitrogen did, meaning that phosphorus and potassium were not limiting yield.

Effect of nutrient omission on weight of unshelled and shelled cobs per plot

The effect of nutrient omission on weight of five unshelled and shelled cobs per plot chosen at random is shown on table 3. The treatments had significant effects in 2018 and combined means only. In 2018, the weight of five unshelled cobs were significantly (P ≤ 0.05) higher with application of NPK + micronutrients + manure compared to all other treatments, while in the combined means the treatment means obtained with application of phosphorus and nitrogen or both nitrogen with micronutrients and manure significantly outweighed the other treatment means. In 2019, the residual effects of the nutrients applied in the previous year cancelled the treatment effects, thereby showing no significant (P ≥ 0.05) differences among the means.

Treatment	Number of cobs/plot			Weight of cobs/plot (kg)		
	2018	2019	Mean	2018	2019	Mean
Control	43[e*]	61[c]	52[d]	0.53[g]	0.37[e]	0.45[b]
PK	79[d]	102[bc]	91[c]	1.50[f]	0.77[e]	1.13[b]
NK	85[d]	92[bc]	89[c]	3.27[e]	3.67[d]	3.47[b]
NP	109[c]	159[ab]	134[b]	4.30[d]	11.10[c]	7.70[a]
NPK	144[b]	159[ab]	152[ab]	4.85[c]	12.37[bc]	8.61[a]
NPK + Micro.	147[b]	150[ab]	148[b]	6.03[b]	13.70[ab]	9.87[a]
NPK + Micro + M	196[a]	173[a]	185[a]	7.73[a]	14.63[a]	11.18[a]
SE±	4.993	22.96	11.61	0.177	0.532	1.284

Table 2: Effect of nutrient omission on number and weight of cobs per plot of maize at harvest.

*Means followed by the same letter(s) within a column are statistically not significantly different at 5% level of probability according to the Duncan's Multiple Range Test.

In a similar vein, the weight of five shelled cobs per plot were significantly higher with application of NPK + micronutrients + manure than any other treatment, except NPK. In 2019, no significant differences among the treatment means were observed, while in the combined means application of phosphorus, potassium or both phosphorus and potassium along with nitrogen or nitrogen, micronutrients and manure improved the weight of shelled cobs of maize.

Effect of nutrient omission on stalk and grain yields of maize

The result of the effect of nutrient omission on stalk and grain yields of maize is presented on Table 4. Application of NPK alone or in combination with micronutrients and manure significantly (P ≤ 0.05) affected the stalk and grain yields. Application of phosphorus, potassium or both phosphorus and potassium along with nitrogen did not improve the stalk and grain yields, indicating that phosphorus and potassium were not limiting while nitrogen was. Similarly, when compared with NPK fertilizers alone, the treatments involving micronutrients with manure did not significantly increase both

Treatment	Weight of five unshelled cobs/plot (g)			Weight of five shelled cobs/plot (g)		
	2018	2019	Mean	2018	2019	Mean
Control	135.5^{e}	167.9^{a}	151.7^{c}	113.3^{c}	119.0^{a}	116.1^{b}
PK	182.6^{d}	170.5^{a}	176.5^{bc}	148.1^{bc}	113.7^{a}	130.9^{b}
NK	182.8^{d}	180.5^{a}	181.7^{bc}	160.9^{b}	118.3^{a}	139.6^{ab}
NP	230.9^{c}	160.8^{a}	195.9^{abc}	169.9^{b}	115.9^{a}	142.9^{ab}
NPK	261.6^{bc}	201.2^{a}	231.4^{ab}	189.3^{ab}	136.1^{a}	162.7^{ab}
NPK + Micro.	271.6^{b}	195.5^{a}	233.5^{ab}	174.8^{b}	144.5^{a}	159.7^{ab}
NPK + Micro + M	318.5^{a}	187.5^{a}	253.0^{a}	228.2^{a}	135.9^{a}	182.1^{a}
SE±	10.55	23.11	20.01	14.44	18.50	17.27

Table 3: Effect of nutrient omission on weight of unshelled and shelled cobs per plot.

*Means followed by the same letter (s) within a column are statistically not significantly different at 5% level of probability according to the Duncan's Multiple Range Test.

stalk and grain yield. This means omitting phosphorus, potassium, micronutrients and manure or all led to yields similar to those of nitrogen, indicating that the maize stalk and grain yields did not respond to either phosphorus, potassium, micronutrients, manure or all of these as did for nitrogen. The indigenous potassium supply was considerable to sustain crop production.

In a similar nutrient omission trial to develop site specific nutrient management it was reported that mean grain yields of rice to be less when nitrogen was omitted than when phosphorus and potassium were omitted [3]. They stated that nitrogen and phosphorus were the two limiting nutrients during the wet season. Relative top dry weight of maize was reported to be significantly affected by different treatments [4] their findings indicated that nitrogen and phosphorus were not yield limiting nutrients as compared to nitrogen. The report of the study [5] on the optimization of major nutrients for lowland rice production also found that application of nitrogen significantly increased yield and yield components. Results of on-farm experiments to develop and test SSNM by [11] found that maize yields can be significantly increased by applying fertilizer on a field-specific and crop specific basis. The analysis of the SSNM by [7] in irrigated maize systems also showed that SSNM use decreased the total fertilizer cost and increased the average profit over farmers' practice.

Conclusion

Treatment	Stalk yield (kg ha^{-1})			Grain yield (kg ha^{-1})		
	2018	2019	Mean	2018	2019	Mean
Control	1948^{e}	4042^{d}	4125^{c}	334^{g}	229^{e}	646.0^{c}
PK	3609^{d}	4636^{d}	9782^{bc}	938^{f}	479^{e}	1229.5^{bc}
NK	4859^{c}	8719^{c}	11709^{abc}	2042^{e}	2292^{d}	4448.0^{abc}
NP	6740^{b}	12010^{b}	16667^{ab}	2688^{d}	6938^{c}	7625.2^{ab}
NPK	6677^{b}	14563^{a}	20094^{a}	3031^{c}	7729^{bc}	8625.3^{a}
NPK + Micro.	7063^{a}	14229^{a}	15667^{ab}	3771^{b}	8563^{ab}	8250.2^{a}
NPK + Micro + M	7188^{a}	11029^{b}	17083^{ab}	4834^{a}	9146^{a}	8739.8^{a}
SE±	85.066	717.05	3129.4	110.69	332.59	2293.1

Table 3: Effect of nutrient omission on stalk and grain yields of maize.

*Means followed by the same letter(s) within a column are statistically not significantly different at 5% level of probability according to the Duncan's Multiple Range Test.

The physico-chemical properties of the soil indicated that the soil was poor in fertility, sandy loam in texture with neutral reaction, low N, P, but moderate K. Organic matter was found to be low due to low vegetation cover and high temperature that resulted to higher mineralization rates. Effect of nutrient omission on yield parameters indicated higher number of cobs and weight of cobs with treatment combination involving nitrogen and phosphorus only. Similarly, the weight of shelled and unshelled cobs was improved with nitrogen and phosphorus application. This means nitrogen and phosphorus are the most limiting nutrients for yield parameters in the area. For stalk and grain yields omitting both phosphorus and potassium did not affected the yields as that of omitting nitrogen. The treatments involving micronutrients and manure, together with nitrogen gave higher yields which showed that nitrogen was the limiting nutrient in the short-run, but manure and micronutrients will prove to be beneficial in the long-run.

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