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Effect of NPS Fertilizer Rates on Growth, Yield and Yield Components of Maize in Shashemene District, West Arsi Zone of Oromia, Ethiopia

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Abstract: Depilation of soil fertility from year to year due to natural and human made factors is a serious constraint for crop production in Ethiopia. Therefore, the application of actual balanced recommended fertilizer rates based on soil and crop type is one of the best agronomic practices to maximize production. A field experiment was conducted for two consecutive of cropping seasons to evaluate the effect of newly introduced NPS fertilizer rates on growth, yield and yield components of maize. The six treatments used for the field experiment were control (without fertilizer), 25%pc, 50%pc, 75%pc, 100%pc from NPS and 100%pc from TSP. Except for control recommended N ha^{-1} was used and the treatments were laid out in RCBD design with three replications. The results of the study revealed that application of 100%Pc from NPS fertilizer with 46 kg urea ha^{-1} gave a maximum mean of above ground biomass yield (35.32 ton/ha) and plant height (251.1cm). The highest mean of grain yield (8766 kg ha^{-1}) was obtained by application rate of 75%Pc from NPS with 46 kg urea ha^{-1} and the lowest mean of grain yield was obtained from control (without application of fertilizer). According to partial budget analysis, the highest net benefit (60,156 ETB) with marginal rate of return (649%) was obtained from the application of 75%Pc from NPS fertilizer with recommended 46 kg urea ha^{-1}. Therefore, this treatment produced maximum grain yields, together with the best economic benefit and could be recommended for the farmers in the study area to maximize maize production.

Keywords: NPS Fertilizer, Control, Grain Yield, Biomass, Net Benefit, Marginal Rate of Return

1. Introduction

Maize (*Zeamays*L.) is an important crop in many parts of the developing world. It occupies the third place after wheat and rice (Food and Agriculture Organization of the United Nations [2]. Supplying nutritious, safe, and affordable food to a growing population is one of the far most burning issues currently facing Africa to fulfill food security in the region [3]. However, there are a number of factors which are responsible for the low production and productivity of maize. Among these factors, in appropriate crop nutrition management and poor soil fertility are the most important factors responsible for low yield of maize [9]. One of the major problems constraining the development of an economically successful agriculture is nutrient deficiency [4].

Maize is the most important staple food crop in terms of calorie intake in rural Ethiopia [18]. In Ethiopia, maize grows from moisture stress areas to high rain fall areas and from low lands to the highlands. According to [7] among cereals, maize is the first and second crop in terms of area coverage and production followed by and next to teff with area coverage of 2,111,518.23 ha and production of 71,508,354.11 quintals. Therefore, considering its importance in terms of wide adaptation, total production and productivity, maize is one of the high priority crops to feed the increasing population of the country [10 & 11].

In many parts of Africa including Ethiopia, repeated cultivation of land within appropriate farming methods is causing severe depletion of nutrients and soil organic matter, posing a serious threat to agricultural productivity and sustainability [6]. Declining soil fertility from time to time due to natural and human made factors are serious bottle necks for crop production in Ethiopia. Besides, lack of appropriate fertilizer blends and lack of micronutrients in fertilizer blends are the national problem which is major constraints to crop productivity [1]. Nutrient deficiencies are the most important problems influencing maize production in the mid and low altitude sub-humid agro-ecologies of Ethiopia due to limited use of commercial inputs and lack of soil fertility enriching rotations or fallows [14].

Reduction of soil fertility from year to year due to natural and human made factors is a serious constraint for crop production in Ethiopia [15]. An over view of Ethiopia's fertilizer sub-sectors how that fertilizer was introduced in the 1960s by higher learning institutions through limited laboratory and research activities [12]. In the early 1970s nationwide on-farm demonstration trials were conducted and as a result of these works a blanket rate of 100 kg ha^{-1} DAP or 50 kg ha^{-1} Urea + 100 kg DAP ha^{-1} were recommended irrespective of crop and soil types). However, according to the soil fertility map made over 150 districts, most of the Ethiopian soils lack many nutrients N, P, K, S, Ca, Ma, Cu, Zn and B [8 & 13].

Application of essential plant nutrients in optimum quantity and right proportion, through correct method and time of application, is the key to increased and sustained crop production. Therefore, application of actual balanced recommended fertilizer rates based on soil and crop type is one of the best agronomic practices to maximize production [1]. Even though new fertilizers such as NPS (19%N, 38%P_2O_5 and 7%S) are currently being used by the farmers in Ethiopia however its effect on yield components and yield of maize are unknown [16]. Therefore, this research activity was designed with the following objectives:

2. Objectives

a. To assess the effect of NPS fertilizer rates on growth, yield and yield components of maize production in the study District.
b. To determine economically appropriate NPS fertilizer rate for maize crop production.

3. Materials and Methods

3.1. Description of the Study Area

An experiment was executed under rain fed conditions for two consecutive seasons (2017/18 and 2018/19) under main cropping season on farmers' fields at Shashamane District, West Arsi Zone of Oromia, Ethiopia. Shashamane District is located at 70°04'50"to70°22'45" Nlatitudeand380°23'00" to 380°48'00"E longitude with about 150 miles above sea level and 240 km far from Addis Ababa.

3.2. Experimental Materials

Planting material: Maize variety BH-660, NPS fertilizer (19% N: 38% P_2O_5: 7% S), TSP and urea (46% N) were used for the study purpose.

3.3. Soil Sampling and Analysis

Before sowing, soil samples were taken randomly to a depth of 0-20 cm in a zigzag pattern to make one composite soil sample of the experimental field. The collected composite soil sample was air dried, grounded, and sieved using 2 mm sieve except for total nitrogen and organic matter. Small quantity of this 2 mm sieved soil material allowed passing through 0.2 mm sieve for soil organic carbon (OC) and total nitrogen. Then the composite soil sample was analyzed for its soil texture, soil pH, organic carbon, total nitrogen, available phosphorus, and cation exchange capacity (CEC) using standard laboratory procedures at Batu Soil Research Center.

Organic carbon was determined by Walkley and Black oxidation method. Total nitrogen was analyzed by Micro-Kjeldhal digestion method with sulfuric acid. Cation exchange capacity (CEC) was determined by leaching the soil with neutral 1N ammonium acetate [2]. Available phosphorus was determined by the Olsen's method using spectrophotometer. Soil pH was measured in water at soil to water ratio of 1:2.5 and Soil texture was analyzed by hydrometer method.

3.4. Treatments and Experimental Design

The treatments were based on already determined phosphorous critical and requirement factor and consisting of 100% Pc from TPS fertilizer, 100%, 75%, 50%, 25% Pc from NPS fertilizer and control (no fertilizer application).

*Applied P= (Critical P - P_o) * Pf.*

Whereas Pc = 35 ppm and Pf = 1.14 ppm [18].

The experiment was laid out in randomized complete block design (RCBD) with three replications. Inter and intra row spacing was 0.75 x 0.3 m respectively. The gross plot size was 6 x 3 m (18 m^2) accommodating 8 rows and 10 plants per row. The spacing between blocks and plots was 1.0 and 0.5 m, respectively. Nitrogen fertilizer in the form of urea (46% N) was used according to the recommended optimum rate of 46 kg N ha^{-1} [18]. However the amount of nitrogen found in NPS fertilizer was subtracted.

3.5. Management of the Experiment

The experimental field was prepared following the conventional tillage practice which includes four times plowing before sowing of the crop. As per the specification of the design, a field layout was prepared; the land was leveled and made suitable for crop establishment. Sowing was done during the main cropping season (May). All the required amount of NPS fertilizer as per the treatment and half of N alone were applied at sowing time. Full dose of NPS and the remaining half of N alone were top dressed at the mid-tillering crop stage. While conducting the experiment others necessary agronomic management practices were carried out uniformly for all treatments.

3.6. Data Collection and Measurements

Plant height (m): it was determined by measuring the height of 10 randomly sampled plants from ground level to the base of the tassel at physiological maturity.

Ear height (cm): it was recorded from 10 randomly taken plants by measuring the height of the stem from ground level to the point of attachment of upper most ears at physiological maturity.

Number of rows per ear: about 10 ears were taken randomly from the net plot area, and then their rows were counted at harvest and the average was recorded.

Thousand kernels weight (g): about 1,000 kernels were randomly taken and counted from the bulk of threshed kernels in each net plot area, and then weighed using sensitive balance.

Above ground dry biomass yield (t ha^{-1}): plants were harvested from the net plot area, weighed using field balance and recorded biomass yield at harvest.

Grain yield (t ha^{-1}): grain yield from the net plot area was weighed and finally, it was converted in to hectare basis.

Harvest index: it was calculated as the ratio of grain yield to the total above ground dry biomass yield per plot × 100.

3.7. Statistical Data Analysis

Growth parameters, yield components, and yield of maize data were analyzed by using GenStat, (15^{th} edition) statistical soft ware. For significant treatment effects, mean separation was done using the least significance difference (LSD) test at 5% level of significance.

3.8. Partial Budget Analysis

The partial budget analysis were carried out by using the methodology described in Centro Internacional de Mejor amientode Maizy Trigo/International Maize and Wheat Improvement Center in which prevailing market prices for inputs at sowing and out puts at harvesting were used.

4. Result and Discussion

4.1. Plant Height (cm)

The mean of plant height and the analysis of variance were showed in table 1. The mean of plant height of maize was significantly different ($p \leq 0.001$) among treatments. However, the mean values of plant height for application of 100% Pc, 75% Pc and 50% Pc from NPS ha^{-1} of NPS fertilizer rates, was not significant statistically.

Application of 100% Pc, 75% Pc and 50% Pc from NPS ha^{-1} NPS fertilizer increased the plant height as compared to the application of 100% Pc from TSP ha^{-1}, 25% Pc from NPS $ha^{-1}$and control. Similarly, application of 100% Pcfrom TSP ha^{-1} and 25% Pc from NPS ha^{-1} fertilizers also significantly increased plant height as compared to the control. In general, application of 100% Pc, 75% Pc and 50% Pc from NPS ha^{-1} NPS fertilizer increases the mean values of plant height linearly, but statistically did not bring about a significant difference in plant height. Similar result was reported by [1] that plant height of maize increased with fertilizer.

Table 1. *Main Effect of NPS on Yield and Yield Components of Maize in Shashemenne District.*

Treatments	NPS/TSP (kg/ha)	PH (cm)	EH (cm)	NRPE	BM (ton/ha)	GY (kg/ha)	HKW (gm)	HI (%)
Control	0	213.7^{c}	17.48^{d}	11.19^{c}	21.49^{c}	2932^{e}	30.49^{d}	18.53^{c}
25% Pc (NPS)	37	234.7^{b}	18.19^{c}	12.33^{b}	24.55^{c}	6712^{d}	30.92^{d}	27.39^{a}
50% Pc (NPS)	73	246.9^{a}	20.45^{a}	13.55^{a}	31.35^{b}	8206^{ab}	33.75^{ab}	26.41^{a}
75% Pc (NPS)	110	248.9^{a}	19.85^{b}	13.56^{a}	30.51^{b}	8766^{a}	34.46^{a}	28.73^{a}
100% Pc (NPS)	146	251.1^{a}	19.47^{b}	13.51^{a}	35.32^{a}	7849^{bc}	33.69^{b}	22.24^{b}
100% Pc (TSP)	121	226.2^{b}	18.21^{c}	13.43^{a}	28.35^{b}	7454^{c}	31.54^{c}	26.30^{a}
LSD (0.05)	-	9.45	0.4644	0.5	3.147	592.039	0.73	3.540
CV (%)	-	2.2	1.3	2.2	6.1	4.7	1.2	7.8

Means followed by the same letter within the same column of the respective treatment are not significantly different ($P \leq 0.05$) according to fishier Test, PH = plant height, EH = ear height, NRPE = number of row per ear, BM = biomass, GY = grain yield, TKW = thousand kernel weight, HI = harvest index, CV = Coefficient of variation, LSD = Least Significant differences, NS = not significant, Pc = phosphorus critical, Pf = phosphorous requirement factor, Po = initial soil phosphorus.

On the other hand the least plant height in unfertilized plots might have been due to low soil fertility level in the study area. 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. Thus, the results indicate that blended fertilizers application has enhanced the maize vegetative growth.

4.2. Ear Height and Number of Rows Per Ear

The mean values and analysis of variance of treatments of ear height and number of rows per ear revealed significant difference ($p \leq 0.05$) among the treatments (table 1). The maximum ear height was recorded from application of 50% Pc from NPS ha^{-1} fertilizer and followed by applications of 75% Pc and 100% Pc from NPS ha^{-1} respectively. Similarly, application of 100% Pc from TSP ha^{-1} and 25% Pc from NPS ha^{-1} increased ear height over the control. The ear length increment with the NPS fertilizer application might be attributed to good photo assimilates supply. The maximum assimilate supply should be available during maize grain filling. The highest mean number of rows per ear recorded for application of 100% Pc from TSP, 100% Pc, 75% Pc and 50% Pc from NPS ha^{-1}, and the lowest number of rows per ear was recorded for control and followed by application of 25% Pc from NPS ha^{-1}.

4.3. Above Ground Biomass Yield (ton/ha)

Based on the mean values and analysis of variances, above ground biomass yield was significantly influenced among the treatments. But, above ground biomass yield was not affected significantly by application of 100% Pc from TSP, 75% Pc and 50% Pc from NPS fertilizer ha^{-1}. Higher above ground biomass yield (35.32 t ha^{-1}) was obtained by applying 100% Pc from NPS while lowest above ground biomass yield (24.55 t ha^{-1} and 21.49 t ha^{-1}) was obtained by applying 25% Pc from NPS ha^{-1} and control respectively. This result is in agreement with [1].

4.4. Grain Yield (kg ha^{-1})

According to the mean values and analyses of variances showed in table1, the grain yield was significantly influenced by application of different rate of NPS fertilizer. Therefore, the highest grain yield (8766 kg ha^{-1}) was obtained by applying 75% Pc from NPS ha^{-1} with recommended urea (46 kg ha^{-1}) and followed by application of 50% Pc from NPS (8206 kg ha^{-1}). While the lowest grains yield (2932 kg ha^{-1}) was recorded for control (without fertilizers). 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 [5]. This result was in line with [1] who found that grain yield was affected by interaction of phosphorus with urea and application of different rates of NPS and urea fertilizer.

4.5. Hundreds Kernels Weight (gm)

The results of analysis of variance (table 1) showed that there were significant differences ($P \leq 0.05$) among treatments for hundreds kernel weight of maize. The highest hundreds kernel weight was recorded for the application of 75% Pc from NPS ha^{-1} with recommended urea (46 kg ha^{-1}), where as the lowest hundreds kernel weight (30.49 gm and 30.92 gm) was observed for application of the control and 25% Pc from NPS ha^{-1} respectively.

4.6. Harvest Index (%)

Analysis of variance showed that harvest index was significantly influenced ($P \leq 0.05$) between the treatments (table 1). The highest HI (28.73%) was obtained by application of 75% Pc from NPS ha^{-1}, followed by application of 25% Pc from NPS (27.39%) and 50% Pc from NPS ha^{-1}, while the least HI (18.53%) was obtained from control.

4.7. Partial Budget Analysis

To identify treatments with the optimum return to the farmer's investment, marginal analysis was performed on non-dominated treatments. For a treatment to be considered as worthwhile to farmers, between 50 and 100% marginal rate of return (MRR) was the minimum acceptable rate of return. All costs and benefits were calculated on hectare basis in Birr and the concepts used in the partial budget analysis were the mean grain yield of each treatment, the field price of maize grain, and the gross field benefit ha^{-1} (the product of field price and the mean yield for each treatment). As indicated in table 2, the partial budget and dominance analysis showed that the highest net benefit 60,156 Birr ha^{-1} was obtained in the treatment that was treated with 75% Pc from NPS ha^{-1} and recommended urea (46 kg urea ha^{-1}) while the lowest net benefit 21,355 Birr ha^{-1} was obtained in the control treatment.

Table 2. *Partial Budget and Marginal Analysis for NPS, TSP and Supplemented N Quantity of Maize at Shashamane District, West Arsi Zone, Oromia.*

Treatment	NPS/TSP (kgha^{-1})	Urea (kgha^{-1})	Adjusted grain yield down wards by 10% (kgha^{-1})	GrossBenefit (Birrha^{-1})	Total variable cost (Birr ha^{-1})	Net benefit (Birr ha^{-1})	MRR (%)
Control	0	0	2,669	21,355	-	21,355	0
25% Pc (NPS)	37	100	6,041	48,326	1,892	46,428	1321
50% Pc (NPS)	73	100	7,385	59,083	2,423	56,662	1955
75% Pc (NPS)	110	100	7,889	63,115	2,955	60,156	649
100% Pc (NPS)	146	100	7,064	56,513	3,487	53,030	D
100% Pc (TSP)	121	100	6,709	53,669	4,321	49,344	D

Where, NPS cost =14.54 Birr kg^{-1}, TSP cost = 24.50 birr kg^{-1}, Urea cost =10.60 Birr kg^{-1} of N, Maize grain per ha = 8 Birr kg^{-1}, NPS and Urea application cost = 300 Birr ha^{-1}, MRR (%) = Marginal rate of return, D = Dominated treatment, Control = unfertilized, TSP = Triple supper phosphate.

5. Conclusion

The current study was initiated with the objectives to assess the effect of NPS fertilizer rates on growth, yield and yield components of maize production and to determine economically appropriate NPS fertilizer rate for maize crop production in Shashamane District. The results of the study revealed that most of the parameters were significantly affected by application rates of NPS fertilizer. Analysis of variance showed that there was a significance difference between the treatments in above ground biomass yield, grain yield, ear height and HKW. Application of 100% Pc from NPS fertilizer with recommended urea (46 kg ha^{-1}) gave a maximum mean of above ground biomass yield (35.32 ton/ha) and plant height (251.1 cm). The highest mean grain yield (8766 kg ha^{-1}) was obtained by application rate of 75% Pc from NPS with recommended urea (46 kg ha^{-1}) and the lowest mean grain yield was obtained from control (without application of fertilizer). According to partial budget analysis, the highest net benefit (60,156 ETB) with marginal rate of return (649 %) was obtained from the application of 75% Pc from NPS fertilizer with recommended urea (46 kg ha^{-1}). Therefore, this treatment produced a maximum grain yield, together with the best economic benefit and recommended for the farmers in the study area instead of using blanket recommendation.

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