



Validation of Nitrogen and Phosphorus Fertilizers Application Rates for Maize (*Zea mays* L.) in Yeki District, Southwest of Ethiopia

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To cite this article:

Mulisa Wedajo, Shiferaw Temteme, Guta Amante, Beniam Yaziz. Validation of Nitrogen and Phosphorus Fertilizers Application Rates for Maize (*Zea mays* L.) in Yeki District, Southwest of Ethiopia. *Agriculture, Forestry and Fisheries*. Vol. 10, No. 1, 2021, pp. 16-20.

doi: 10.11648/j.aff.20211001.13

Received: November 12, 2020; **Accepted:** November 23, 2020; **Published:** March 10, 2021

Abstract: Maize (*Zea mays* L.) is an important smallholder crop grown in Ethiopia. Its yields are low because of a decline in soil fertility, insufficient use of fertilizers, and blanket use of fertilizer. However, there is no Nitrogen and Phosphorus fertilizer recommendation for Maize in Yeki District. A three-year field experiment was conducted to verify the effects of nitrogen and phosphorus fertilizer rates for maize. The experiment consisted of three treatments; 92 kg N ha⁻¹ + 69 kg P₂O₅ ha⁻¹, 64 Kg N ha⁻¹ + 46 kg P₂O₅ ha⁻¹ and no fertilizer (control) laid out using a randomized complete block design with four replications. The replication represents the four locations selected for the test. The results of the study showed that the application of 92 kg N ha⁻¹ + 69 kg P₂O₅ ha⁻¹ significantly increased the growth parameters and yield of maize when compared to the other treatments. The highest maize grain yield (10052.9 kg ha⁻¹) was obtained from the application of 92 kg N ha⁻¹ with 69 kg P₂O₅ ha⁻¹. This study further confirms the significant role of nitrogen and phosphorus fertilizers for maize production. From the result of the study, the application rate of 92 kg N ha⁻¹ + 69 kg P₂O₅ ha⁻¹ is recommended for increasing maize yield, particularly in the study area, and also it is economically feasible.

Keywords: Blanket Recommendation, Nitrogen, Phosphorus and Yield

1. Introduction

Poor soil fertility is recognized as the major constraint to food production and food security in the world. The problem might be more in the case of developing countries like Ethiopia, due to high population density, fragmented farmland as well as continues farming and untailed fertilizer application. Ethiopia has potentially rich land resources but agricultural productivity has been below optimum yield. This is mainly due to a range of factors including soil erosion, acidity and nutrient depletion, lack of soil fertility replenishment, nutrient mining, and lack of balanced fertilization [1-3]. Crop yield tends to decrease when the soil gets depleted of its nutrients. The proper rates of plant nutrients requirements are determined by knowledge about; the nutrient requirement of the crop and supplying

capacity power of the soil.

Maize (*Zea mays* L.) is an important cereal crop grown in Ethiopia as well as in the Yeki area [4]. The greatest potential for maize production is fully realized with adequate fertilizer application. Nitrogen and Phosphorus fertilizer recommendations are determined for maize in different agro-ecology of Ethiopia. For instance, in Southern West Ethiopia, farmers apply 100 kg ha⁻¹ both DAP and Urea for maize irrespective of the heterogeneity of the farm areas. However, there is no fertilizer recommendation rate for maize production in Yeki District. The present study aimed at validating the NP fertilizer rate recommended for maize (92 N and 69P₂O₅) kg ha⁻¹ Wakene *et al.*, [5] at Oromia Region on Nitisol of Jimma District to SNNPR state at Yeki District (Figure 1).

2. Materials and Methods

2.1. Description of the Study Area

The study was carried out in Yeki District Sheka zone of the SNNPR state (Figure1). The mean annual rainfall of the area is 1559 mm that extends from April to December, with hot to warm humid lowland agro-ecology. The maximum and minimum average temperatures of the area are 29.7°C and 15.5°C, respectively.

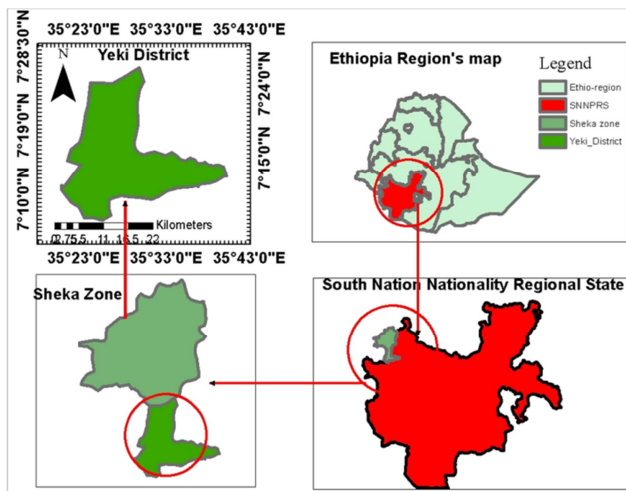


Figure 1. Map of study District.

2.2. Experimental Materials

A high yielding medium maturing hybrid maize variety (BH140) was used as a test crop. It performs well at an altitude range of 1000-1800 m.a.s.l with rainfall of 1000-1200 mm. It can give (7.5-8.5 and 4.7-6) t ha⁻¹ grain yields on-station and on-farm experiments respectively with maturity date of 145 and 25 kg ha⁻¹ seed rate. The nitrogen and phosphorus sources used for the experiment were Urea and Triple Superphosphate (TSP), respectively.

2.3. Experimental Design and Procedure

The experiment was laid out in a randomized complete block design with four replication at four locations (Fide, Kubito, Shosha and Teppi on station), those four locations considered as replication. Three treatments (T1: Control, T2: blanket recommendation of 64 N and 46 P₂O₅ and T: 92 N and 69 P₂O₅) kg ha⁻¹ (Table 1) was tested in each location indicated above for three consecutive cropping season of 2017 to 2019. The area of each plot was 10 m x 10 m length and width respectively and then the three treatments were randomly assigned to each experimental unity. The spacing between block and plant were 75 cm x 25 cm between row and between plants were used for plating of the maize respectively.

Table 1. Details of treatment arrangements.

Treatment codes	Descriptions of treatment code
T1	Control
T2	Blanket recommendation of 64 N and 46 P ₂ O ₅ kg ha ⁻¹
T3	Recommended NP (92N + 69 P ₂ O ₅) kg ha ⁻¹

Fertilizers' TSP was applied at planting and while urea was applied in twice equal split half at knee height and the remaining half at flag leaf emergence [6, 7]. The first side dressing was 30 days after emergence (knee height stage) just after the first weeding and again 60 days after emergence just after the second weeding or before tasseling. All other agronomic management practices; land ploughed three times with oxen, time of sowing (early April), seed rate 25kg ha⁻¹ and two times hand weeding were applied as per recommendation for the maize production.

2.4. Data Collection

Soil: Compositated topsoil sample was collected from each experimental site at the depth of 0-20cm before sowing. The collected samples air-dried and passed through 2mm sieve to remove large particles, debris, and stones. The sieved samples analyzed for pH in 1:2.5 soils to water ratio using Coleman's pH meter. Organic carbon was determined [8]. Organic matter estimated as organic carbon multiplied by 1.724. Total Nitrogen was determined by the micro Kjeldahl method [9]; available phosphorus was extracted by Bray's II method [9] and read from the atomic absorption spectrometer. The textural analysis was determined by hydrometer method.

2.4.1. Maize Agronomy

Plant height (cm): It was measured as the height from the soil surface to the base of the tassel at maize physiological maturity before harvesting from ten plants sampled randomly from the central rows and summed and divided by the number of plants to get the height of each plant.

Number of ear per plant: was visually counted from a single maize plant of ten randomly sampled from the central rows and summed and divided by the number of plants to get the number of ear of each plant.

Ear height (cm): It was measured from ground level to the node bearing the top useful ear before harvesting from ten sampled plants randomly from the central rows and summed and divided by the number of plants to get the ear height of each plant.

Thousand grain weight (g): It was determined from 1000 randomly taken grains from each plot and weighed using sensitive balance.

Grain yield (kg ha⁻¹): Maize crop harvesting was done after the crop had reached physiological maturity. Then, husk was removed and the grains were shelled manually and their weights were recorded by electronic balance. The grain was sun-dried until it had constant weight and reweighed to

determine moisture content. After drying the grain yield adjusted to 12.5% moisture content, the final dry weight was determined and recorded and then convert to a hector basis.

2.4.2. Economic Analysis

Partial budget and Marginal analysis of economic concepts were used to analyze the data. Partial budget is a method of organizing experimental data and information about the costs and benefits of various alternative treatments. Marginal analysis is a method for comparing the costs that vary with the net benefits for selecting the best technology for recommendations from the experiment.

2.5. Data Analysis

The collected data statistically analyzed using the Analysis of Variance (ANOVA) procedures. The treatment means were separated using the Least significant difference) at a 5% level of probability.

3. Results and Discussion

Pre-planting topsoil (0-20cm) physical and chemical properties of experimental site during 2017 cropping season were shown in (Table 2). The soils were clay texture in Teppi on-station, Fide and Shosha and clay loam in case of Kubito. The soil texture controls water contents, water intake rates,

aeration, root penetration and soil fertility.

Landon [10] provided guidelines for interpreting soil pH values for environmental evaluation as pH > 9.0, 9.0–8.5, 8.4–7.9, 7.8–7.4, 7.3–6.6, 6.5–6.1, 6.0–5.6, 5.5–5, 5.0–4.5 very strongly alkaline, strongly alkaline, moderately alkaline, mildly alkaline, neutral, slightly acid, moderately acid, strongly acid and very strongly acid respectively. Therefore, according to Landon, [10] the soil pH of Teppi on station was neutral whereas Fide, Kubito and Shosha were slightly acidic. Maize has been found to do well in pH values of 6.5-8 but the optimum growth is attained at pH 5.5-7 and any pH below these values will affect its growth.

According to Tekalign and Haque [11] the soil total N and available P of all location were high and medium, respectively. Available soil Potassium of the experimental area rated as low (Table 2). Horneck *et al.* [12] reported that soils with potassium content of <150 ppm low, 150-250 ppm medium, 250-800 ppm high and >800 ppm excessive. The Cation Exchangeable capacity of the soil rated as high [10]. The percentage of organic matter and organic carbon were moderate. Hazelton and Murphy [13] classified soil organic carbon percentages of < 0.60, 0.6 – 1.0, 1.0 – 1.80, 1.80 – 3.0, and >3 as very low, low, medium, high, and very high, respectively. Therefore, the soil of all experimental sites has high organic carbon content.

Table 2. Physical and chemical properties of the soil before planting.

Location	L1				L2			L3			L4		
	Duration												
Soil properties	2017	2017	2018	2019	2017	2018	2019	2017	2018	2019	2017	2018	2019
pH H ₂ O 1:2.5	7.1	6	5.73	6.4	6.1	6.59	5.54	5.9	5.96	5.78			
TN (%)	0.26	0.27	9.29	0.31	0.26	52.32	0.23	0.27	89.42	0.3			
av.P mg kg ⁻¹ of soil	14.56	13.32	0.21	17.44	11.66	0.27	6.41	24.96	0.25	13.82			
av.K mg kg ⁻¹ of soil	67.5	66.4	-	-	68.72	-	-	64.15	-	-			
CEC meq per 100 gm of soil	34.13	36.4	21.4	26.37	33.92	27.06	20.41	34.11	38.85	35.56			
OC (%)	4.45	5.52	-	-	3.27	-	-	8.53	-	-			
OM (%)	7.67	9.51	-	-	5.64	-	-	14.7	-	-			
Clay (%)	46	42	-	53.33	30	-	58.67	40	-	58			
Silt (%)	34	26	-	26.67	30	-	28.67	32	-	27.33			
Sandy (%)	20	32	-	20	40	-	12.67	28	-	14.67			
Textural class	clay	clay	-	Clay	clay loam	-	Clay	clay	-	Clay			

L1=location one, L2= location two, L3= location three and L4= location four, missed values was not reported

Plant height and thousand grain weight were not significantly (p>0.05) affected by the fertilizer application. The fertilizer treatments was significantly (P<0.05) affected the number of ear per plant, ear length and grain yield. The maximum number of ear per plant (1.26) was recorded from the application of 92 N + 30 P kg ha⁻¹, while the minimum number ear per plant (1.01) from the control treatment (Table 3).

The maximum ear length (17.76 cm) was recorded from the application of 92 N + 30 P kg ha⁻¹, while the minimum ear length (15.15cm) from the control treatment. An increase in ear length at higher N and P could be due to good photo-assimilates supply which facilitates photosynthesis. Increase in photosynthesis activities account for growth under an

adequate supply of nitrogen and phosphorus [14]. The maximum assimilates supply should be available during maize grain filling with a split application of nitrogen [Arif]. Moraditochae *et al.* [15] reported that increasing the nitrogen level from 50 to 200 kg ha⁻¹ significantly increased the ear length of maize from 10.17 to 15.69 cm.

The result obtained from this study showed that different application rates of nitrogen and phosphorus fertilizers significantly improved maize grain yield. Application of 92 kg N ha⁻¹+ 30 kg P ha⁻¹ fertilizer was significantly (p<0.05) affect number of ear per plant, ear length and grain yield (Table 3). This was followed by 64 Kg N ha⁻¹+ 20 kg P ha⁻¹ (blanket application) and the lowest grain yield was recorded from control treatment (no fertilization).

This result agree with the finding of Sheferaw *et al.* [4] who found that maximum grain yield of maize was attained with the application of 92kg N ha⁻¹ and 40 kg P ha⁻¹ in Yeki District at Teppi Southwest of Ethiopia. Application of NP fertilizer significantly influences plant height, number of ear per plant, ear length, grain yield and above dry biomass of

maize [16]. Ali *et al.* [17] reported combined application of nitrogen and phosphorous increase maize yield by 112.05% as compared to the control plot. An application of NPK increase grain yield, dry matter and N uptake of maize [18] and 60 kg P ha⁻¹ of increases maize grain yield and improved P nutrient uptake [19].

Table 3. Effect of Nitrogen and Phosphorus rates on the yield and yield components of maize overall three year (2017-2019) in Yeki District.

Treatments (Fertilizer kg ha ⁻¹)	Plant height cm	Number of ear per plant	Ear length cm	Thousand seed weight gm	Grain yield kg ha ⁻¹
Control	246.05	1.01 ^c	15.15 ^c	337.97	7706.3 ^b
64 N+ 46 P ₂ O ₅	253.62	1.14 ^b	16.45 ^b	325.25	8747.9 ^{ab}
92 N + 69 P ₂ O ₅	259.24	1.26 ^a	17.76 ^a	342.69	10052.9 ^a
LSD	ns	0.055	0.72	ns	1461.2
CV (%)	17.58	5.75	5.24	6.68	19.77

LSD =List significant difference at p<0.05, CV%= coefficient variation, Means with the same letter are not significantly different

Economic analysis was performed to investigate the economic feasibility of the treatments (fertilizer rate). Partial budget is a method of organizing experimental data and information about the costs and benefits of various alternative treatments. Marginal analysis is a method for comparing the costs that vary with the net benefits for selecting the best technology for recommendations from the experiment.

Partial budget averaged of the three (3) treatment calculated from income and expenses based on variable cost (Table 4). Net benefit calculated by subtracting the Total Variable Cost (TVC) from the gross field benefit (GFB) for each treatment. All variable costs calculated excluding the price of other agronomic practices such as cost of seed, land plowing, sowing, weeding, protection of the farm and harvesting because it was uniform for all treatments. Cost of fertilizer TSP was Ethiopian birr (ETB 13.75 kg⁻¹ and urea was ETB 11 kg⁻¹). The cost of fertilizer transportation considered as ETB 20 per 100 kg fertilizer and labor cost of fertilizer application ETB 27 per day for 8 hours for 100 kg fertilizer. The Local market-selling price of one-kilogram of

maize in Ethiopia birr at the Teppi area was five birr. The variable costs were summed up and subtracted from gross field benefits, which taken as net benefit. The average yield adjusted downward by 10% and used to reflect the difference between the experimental field and the expected yield from farmers' fields with farmers' practices from the same treatments [20]. Dominance analysis led to the selection of treatments ranked in increasing order of total variable costs. For each pair of ranked treatments, the percent marginal rate of return (MRR) was calculated. The MRR (%) between any pair of un-dominated treatments was the return per unit of investment in fertilizer. It calculated by dividing the change in net benefit to the change in variable costs. Analysis of marginal rate of return (MRR) carried out for non-dominated treatments and the MRRs compared to a minimum acceptable rate of return (MARR) of 100% to select the optimum treatment [21].

The highest net benefit of 41042.55 ETB ha⁻¹ was obtained from the application of 92 kg N ha⁻¹ + 69 kg P₂O₅. On the other hand, the lowest net benefit (34678.35 ETB ha⁻¹) was obtained from control plot.

Table 4. Partial budget and marginal analysis of fertilizer verification on maize in Yeki district.

Treatments (Fertilizer kg ha ⁻¹)	Grain yield kg ha ⁻¹	Adjusted grain down to10%	GFB	TVC	NB	MRR%
Control	7706.3	6935.67	34678.35	0	34678.35	
64 N + 46 P ₂ O ₅	8747.9	7873.11	39365.55	3142.5	36223.05	49.15
92 N + 69P ₂ O ₅	10052.9	9047.61	45238.05	4195.5	41042.55	457.69

GFB=growth field benefit, TVC=total variable cost and MRR=marginal rate of return

4. Conclusion

Applications of NP fertilizer rate were significantly affect yield and yield component of maize. The highest maize grain yield (10052.9 kg ha⁻¹) and the lowest (7706.3 kg ha⁻¹) were obtained from the application of 92 kg N ha⁻¹ with 69 kg P₂O₅ ha⁻¹ and control plot respectively. Also the highest number of ear per plant (1.26) and the lowest (1.01) were obtained from the application of 92 kg N ha⁻¹ with 69 kg P₂O₅ ha⁻¹ and control plot respectively. Application of 92 kg N ha⁻¹ with 69 kg P₂O₅ ha⁻¹

gave the highest net return of EB 41042.55 with highest marginal rate of return of 457.69%. Application of 92 kg N ha⁻¹ with 69 kg P₂O₅ ha⁻¹ was improved maize grain yield by 30.45% and 14.92% as compared to the control plot and blanket recommended fertilizer application and also economically feasible. Therefore; application of 92 kg N ha⁻¹ with 69 kg P₂O₅ ha⁻¹ were recommended for maize production in Yeki District and similar agro-ecologies of Southwest of Ethiopia. This result is basic to further determination of the balanced fertilizer application rate for maize in Yeki district.

Acknowledgements

We would like to thank to Teppi Agricultural Research Center for facilitating the experiment. Very special thanks to Mr. Tesfanej Ejegu for his support in field experiment to completion.

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