International Journal of Applied Agricultural Sciences
2022; 8(6): 206-211
http://www.sciencepublishinggroup.com/j/ijaas
doi: 10.11648/j.ijaas.20220806.12
ISSN: 2469-7877 (Print); ISSN: 2469-7885 (Online)

Determination of NPS Fertilizer Levels on Yield Components, and Yield of Maize at Dugda District, East Shewa Zone, Oromia, Ethiopia

Tilahun Abera*, Tilahun Firomsa, Abdurhman Husen, Amante Lema

Natural Resource Research Directorate, Oromia Agricultural Research Institute, Batu Soil Research Center, Batu, Ethiopia

Email address:
tileabera3@gmail.com (Tilahun Abera)
*Corresponding author

To cite this article:
Tilahun Abera, Tilahun Firomsa, Abdurhman Husen, Amante Lema. Determination of NPS Fertilizer Levels on Yield Components, and Yield of Maize at Dugda District, East Shewa Zone, Oromia, Ethiopia. *International Journal of Applied Agricultural Sciences*. Vol. 8, No. 6, 2022, pp. 206-211. doi: 10.11648/j.ijaas.20220806.12

Received: August 31, 2022; **Accepted**: October 4, 2022; **Published**: November 10, 2022

Abstract: 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. Due this on-farm study of blended NPS fertilizer for maize was executed in Dugda District, East Shewa Zone of Oromia, during the main cropping seasons of 2018-2019. The main objective of the study was to assess the effect of of blended NPS fertilizer levels on yield and yield components of Maize variety (MHQ 138) and to determine economically appropriate level of blended NPS fertilizer for optimum maize crop production in Dugda District. The treatments were arranged based on already determined Phosphorous critical (Pc) and phosphorus requirement factor (Pf) and consisting of 100% Pc from TSP (Triple supper phosphate) fertilizer, 100%, 75%, 50%, 25% Pc from blended NPS fertilizer and control (no fertilizer application). Applied Phosphorus = (Critical P - Po)* Pf. Whereas Pc= 10 ppm and Pf = 4.68 ppm. The experiment was laid out in randomized complete block design (RCBD) with three replications. Inter and intra row spacing was 0.75 x 0.25m respectively. The results of the study showed that, different levels of phosphorus critical from blended NPS and TSP fertilizers did not significantly ($p < 0.05$) influenced ear height, number of rows per ear and thousand kernels weight of maize crop in study area. However, plant height, biomass yield, grain yield, harvest index and cob weight were highly significantly ($p < 0.01$) influenced by different levels of phosphorus critical from blended NPS and TSP fertilizers. The highest (2008cm) plant height, the highest (6123kg ha^{-1}) grain yield, and the highest (52.67kg ha^{-1}) cob weight were recorded by application of the highest 100% Pc (168kg ha^{-1}) while the highest (20.14 tone ha^{-1}) biomass yield and the highest (32.77%) harvest index were recorded by 100 pc TSP and 75% PC NPS respectively. The economic analysis showed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) application of 100 Pc NPS (168 kg NPS ha^{-1}) is profitable which gave the highest (35073 Birr) net return with acceptable (102%) marginal rate of return and recommended for farmers in Dugda district and other areas with similar Agro-ecological conditions.

Keywords: Applied Phosphorus, Blended NPS, Maize, Phosphorous Critical (Pc), Phosphorus Requirement Factor (Pf), Yield Components, Yield

1. Introduction

Maize (Zea mays L.) is an important cereal crop of the World. It is a member of grass family poaceae and is highly cross pollinated crop most people regard maize as a breakfast cereal. However, in a processed form it is also found as fuel (ethanol) and starch. Starch in turn involves enzymatic conversion into products such as sorbitol, dextrine, sorbic and lactic acid, and appears in household items such as beer, ice cream, syrup, shoe polish, glue, fireworks, ink, batteries, mustard, cosmetics, aspirin and paint [6].

Global Maize production in 2018 was estimated at 1147 million tons from 193 million ha area harvested with average yield of 5924 kg ha^{-1}. However, in Ethiopia Maize production in

2018 was estimated at 7360201 tons from 2235872 ha area harvested with average yield of 3293 kg ha^{-1} [7]. According to this report despite the large area under maize in Ethiopia, the national average yield of maize is 80% far below the world's average yield. Moreover, according to [13] who reported that the averaged cereals production from CSA data for over the years of 2004/05–2007/08 were 12,062,972 metric tons from a total area harvested of 8,230,211 ha. Accordingly this report showed that among cereals average Maize production in these years was estimated at 3,314,286 tons from 1,595,238 ha area harvested with average yield of 2077.6kg ha^{-1}.

The low productivity of maize is attributed to many factors like declining of soil fertility, poor agronomic practice, limited use of input, frequent occurrence of drought and insufficient technologies [15]. However, Successful maize production depends on the correct application of production inputs that will sustain the environment as well as agricultural production. These inputs are adapted cultivars, plant population, soil tillage, fertilization, weed, insect and disease control, harvesting, marketing and financial resources [6].

According to the report of [12]. Inorganic fertilizers have been the important tools to overcome soil fertility problems and they are also responsible for a large part of the food production increases worldwide and estimated that at least 30 to 50% of crop yield increment is attributable to application of commercial fertilizers. Even though, low soil fertility highly affects the growth and development of maize as compared to other crops. As a result, it is often said "maize speaks" implying that maize cannot produce maximum yield unless sufficient nutrients are available [4].

Like in other developed countries, information on soil fertility status is not adequate to meet the requirement of agricultural development programs, rational fertilizer promotions and recommendations based on actual limiting nutrients for a given crop in Ethiopia. The prevailing blanket fertilizer rate recommendation throughout the country on all soil types and agro ecological zone justifies the existence of little information on the fertility status of Ethiopia's soils.

Due to these Ethiopia has been changing from blanket recommendations of DAP and Urea, which have long been the only type of fertilizer imported for grain crops to compound fertilizers such as NPS. However, the level of this fertilizer was not determined by researchers particularly for the study area and Maize production. Therefore, this study proposed with the following objectives.

Objectives

1) To assess the effect of rates of blended NPS on yield components and yield of Maize crop.
2) To determine economically appropriate rate of blended NPS fertilizer for Maize crop production.

2. Materials and Methods

2.1. Description of the Study Site

The field experiment was conducted at Dugda district of East Shoa Zone, on farmers` farm land during 2019/2020 cropping season. It was part of the former woreda of Dugda Bora what was divided between Bora and Dugda woredas. Part of the Misraq Shewa Zone located in the Great Rift Valley, Dugda Bora is bordered on the southeast by Lake Zway, on the south by Adami Tullu and Jido Kombolcha, on the west by the Southern Nations, Nationalities and Peoples Region, on the northwest by the Debub Mirab (Southwest) Shewa Zone, on the north by the Awash River which separates it from Ada'a Chukala, on the northeast by Koka Reservoir which separates it from Adama, and on the east by the Arsi Zone. The altitude of this woreda ranges from 1500 to 2300 meters above sea level; Mount Bora Mariam (2007 meters) is the highest point.

2.2. Treatments and Experimental Design

The treatments was conducted on already determined Phosphorous critical and requirement factor and consisting of 100% Pc from TSP (Triple supper phosphate) fertilizer, 100%, 75%, 50%, 25% Pc from NPS fertilizer and control (no fertilizer application). The experiment was laid out in a randomized complete block design (RCBD) with three replications. Phosphorus fertilizer was applied according to the formula of *Applied P* = (Critical P - Po)* Pf. Whereas *Pc= 10 ppm and Pf = 1.41-4.68(3.05) ppm* (EIAR, 2017). The gross plot size was 4.5*2.5 (11.25m^2) accommodating 6 rows and 10 plants per each row. Spacing of 75 cm and 25 cm were maintained in between inter rows and intra rows respectively. The outermost one row from each side of a plot were considered as border, thus the Net plot size was 0.75m*0.25m*4 rows*10 plants (7.5m^2). Nitrogen fertilizer in the form of Urea (46%N) has used according to the recommended optimum rate of 46 kg/ha. However the amount of nitrogen found in different levels of blended NPS was deducted.

2.3. Partial Budget Analysis

The economic analysis was carried out by using the methodology described in [2].) In which prevailing market prices for inputs at planting and for outputs at harvesting were used. All costs and benefits were calculated on ha basis in Birr. The concepts used in the partial budget analysis were the mean grain yield of each treatment, the gross benefit (GB) ha^{-1} (the mean yield for each treatment) and the field price of fertilizers (the costs of NPS, TSP and Urea and the application costs). Cost of stalk yield was not included in the calculation in the benefit since the farmers in the area do not use it. Marginal rate of return, which refers to net income obtained by incurring a unit cost of fertilizer, was calculated by dividing the net increase in yield of durum wheat due to the application of each fertilizers rate. The net benefit (NB) was calculated as the difference between the gross benefit and the total cost that vary (TCV) using the formula NB= (GY x P) – TCV.

Where GY x P = Gross Field Benefit (GFB), GY = Adjusted Grain yield kg per hectare and P = field price kg of the crop.

Actual yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment.

The dominance analysis procedure as described in [2] was used to select potentially profitable treatments from the range that was tested. The discarded and selected treatments using this technique were referred to as dominated and none dominated treatments, respectively. For each pair of ranked treatments, % marginal rate of return (MRR) was calculated using the formula:-

$$\text{MRR (\%)} = \frac{Change\ in\ NB\ (NBb - NBa)}{Change\ in\ TCV\ (TCVb - TCVa)} \times 100$$

Where NB_a = NB with the immediate lower TCV, NB_b = NB with the next higher TCV, TCV_a = the immediate lower TCV and TCV_b = the next highest TCV.

The % MRR between any pair of un-dominated treatments was the return per unit of investment in fertilizer. To obtain an estimate of these returns, the % MRR was calculated as changes in NB (raised benefit) divided by changes in cost (raised cost). Thus, a MRR of 100% implied a return of one Birr on every Birr spent on the given variable input.

The fertilizer cost was calculated for the cost of each fertilizer of NPS (Birr 14.54 kg^{-1}), N/UREA (Birr 10.60 kg^{-1}) and TSP (Birr 24.5 kg^{-1}) during sowing time. The average open price of Maize at Meqi market was Birr 7 kg^{-1} in October 2019 during harvesting time. The application cost of NPS and two times urea application were 300 birr ha^{-1}.

2.4. Data to Be Collected

Plant height (cm): Was measured as the height from the soil surface to the base of the tassel of five randomly taken plants from the net plot area at physiological maturity.

Number of rows per ear: was recorded from the count of five randomly taken ears in the central net plot area.

Ear length: was measured from 10 randomly selected Ears per plot at harvesting time.

Ear height (cm): Was measured from ground level to the node bearing the top useful ear.

Number of kernels per cob: The mean number of kernels per cob was recorded as an average of five randomly taken ears from the net plot area.

Thousand kernels weight: was determined based on the weight of 1000 kernels sampled from the grain yield of each net plot by counting using electronic seed counter and weighed with electronic sensitive balance. Then the weight was adjusted to 12.5% moisture content.

Biomass Yield: The aboveground dry biomass yield was determined from plants harvested from the net plot area after sun drying to a constant weight and expressed in kg ha^{-1}.

Grain yield: was harvested from the three central rows excluding plants from either ends. Grain yield was adjusted at 12.5% moisture content.

Harvest index (HI): The harvest index was calculated as ratio of grain yield per plot to total above ground dry biomass yield per plot expressed as percent.

2.5. Data Analysis

The data was subjected to analysis of variance (ANOVA) as per the experimental design using GenStat (15^{th} edition) software [8]. The Least Significance Difference (LSD) at 5% level of probability was used to determine differences between treatment means.

3. Result and Discussion

3.1. Ear Height, Number of Rows Per Ear and Thousand Kernels Weight

The analysis of variance revealed that different rates of phosphorus critical from blended NPS and TSP fertilizers did not significantly (p <0.05) influence ear height, number of rows per ear and thousand kernels weight of maize crop at study area (Table 1).

Table 1. *Yield components and yield of maize as influenced by different rates of phosphorus critical*

Treatment	EH (cm)	NRPE	PH (cm)	BM ton ha^{-1}	GY kg ha^{-1}	HI %	TKW (gm)	Cob wt. kg ha^{-1}
100%Pc TSP	14.94	12.83	2003^{ab}	20.14^{a}	5185^{bc}	25.97^{b}	31.69	50.83^{ab}
100%Pc NPS	15.14	13.64	2008^{a}	18.95^{ab}	6123^{a}	32.46^{a}	30.36	52.67^{a}
75%Pc NPS	14.36	13.08	197.8^{b}	18.10^{bc}	5951^{ab}	32.77^{a}	29.90	51.69^{ab}
50%Pc NPS	14.58	12.44	200.4^{b}	17.47^{bc}	5432^{abc}	31.01^{ab}	29.22	50.42^{a}
25%Pc NPS	14.86	12.94	188.1^{c}	16.47^{cd}	5037^{c}	30.75^{ab}	28.34	50.63^{bc}
Control	14.64	12.36	184.2^{c}	15.25^{d}	2185^{d}	14.49^{c}	30.17	51.76^{c}
LSD (0.5)	NS	NS	6.503	1925.8	8742	5.795	NS	481.3
CV (%)	2.90	4.10	1.80	5.20	9.60	11.4	7.20	11.7

Means followed by the same letter with in the same column of the respective treatment are not significantly different (P ≤ 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= harvested index CV = Coefficient of variation, LSD = Least Significant differences, NS = not significant.

3.2. Plant Height

The analysis of variance indicated that different rates of phosphorus critical (Pc) from blended NPS and TSP fertilizers have highly significantly (p <0.01) influenced plant height of Maize crop (Table 2). Decreasing the amount of phosphorus critical from hundred to the lowest rates of blended NPS significantly decreased plant height. However there were no statistically significant difference between application of 100% phosphorus critical from NPS and 100% phosphorus critical from TSP fertilizers. The maximum application rate of 100% Pc (168 kg NPS ha^{-1}) resulted in the highest (2008 cm) plant height. While no fertilizer application has recorded the shortest plant height (184.2 cm) (Table 2). This result is parallel with [3]. who reported that application of Togo blended fertilizer NPKSBZn (26:11:11:3.5:0.15:0.6) kg ha^{-1} with micro nutrient Cu+Zn (5+5 L ha^{-1}) increased plant height of maize by 66.81% over control plot and 6.11% over recommended NP fertilizers at Kejo farmers field. Similarly, [5] reported maximum plant height of (201.51cm) by application of 100 kg NPSB.

3.3. Biomass Yield

The analysis of variance indicated that different rates of phosphorus critical (Pc) from blended NPS and TSP fertilizers have highly significantly ($p < 0.01$) influenced plant biomass yield of Maize crop. Biomass Yield has been increasing as the rate of phosphorus critical increased from the lowest rates to the highest phosphorus critical application (100% Pc) of blended NPS. However there were no statistically significant difference between application of 100% phosphorus critical from NPS and 100% phosphorus critical from TSP fertilizers. The maximum application rate of 100% Pc from TSP fertilizer (139 kg TSP kg ha^{-1}) resulted in the highest (20.14 tone ha^{-1}) biomass yield. While no fertilizer application has recorded the shortest plant height (15.25 tone ha^{-1} (Table 2). The result was also in conformity with report of [14]. Whom reported that biomass yield of Maize increased with increasing applied NP fertilizer in a consistent manner and reported highest biomass yield (19.748 t/ha) at the highest rate of (200/92 NPS/N kg ha^{-1}). Moreover, the result is in agreement with [4] who reported the highest (43.7 t ha^{-1}) by application of 150 kg ha^{-1} NPSB fertilizer.

3.4. Grain Yield

The analysis of variance indicated that different rates of phosphorus critical (Pc) from blended NPS and TSP fertilizers have highly significantly ($p < 0.01$) influenced grain yield of Maize crop. Grain Yield has been increasing as the rate of phosphorus critical increased from the lowest rates to the highest phosphorus critical application (100% Pc) of blended NPS. The maximum application rate of 100% Pc from NPS fertilizer (168 kg NPS kg ha^{-1}) resulted in the highest (6123 Kg ha^{-1}) grain yield. While no fertilizer application has recorded the lowest grain yield of (2175 kg ha^{-1} (Table 2). This result is in line with [11] who reported maximum mean grain yield (9 t ha^{-1}) from plots treated with 150 kg NPS ha^{-1}. The result is also parallel with [9] who reported the highest (7.1 t ha^{-1}) grain yield by application of 100 kg NPS ha^{-1}.

3.5. Harvest Index

The analysis of variance indicated that different rates of phosphorus critical (Pc) from blended NPS and TSP fertilizers have highly significantly ($p < 0.01$) influenced harvest index of Maize crop. Harvest index has been relatively increasing as the rate of phosphorus critical increased from the lowest rates to the highest phosphorus critical application (100% Pc) of blended NPS. The maximum application rate of 100% Pc from NPS fertilizer (168 kg NPS kg ha^{-1}) resulted in the highest (32.46%) harvest index. While no fertilizer application has recorded the lowest harvest index of (14.49%) (Table 2). This result is in parallel with [14]. That reported maximum harvest index of (43.96%) from plots treated with 200/92 kg NPS/N ha^{-1}. While the lowest (26.66%) harvest index recorded by control plot.

3.6. 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 that means 100% marginal rate of return (MRR) was the minimum acceptable rate of return [2]. As indicated in Table 2, the partial budget and dominance analysis showed that the highest net benefit 35073Birr ha^{-1} was obtained in the treatment that was treated with 100% PC blended NPS while the lowest net benefit 13766 Birr ha^{-1} was obtained in the control treatment. The result is in line with the finding of [10] who reported the highest 255% MRR by application of 150kg NPSZnB fertilizer for maize crop. Moreover, the result is consistent with the finding of [1] who reported the highest grain yield (4906.7 kg ha^{-1}) and net benefit (62640.45Eth-birr ha^{-1}) with MRR of 2926.2% from Melkassa-2 variety treated with 100 kg ha^{-1}.

Table 2. *Partial budget and marginal analysis for blended NPS, TSP and supplemented N rates of Maize crop.*

Treatment	NPS/TSP (kg ha^{-1})	Urea (kg ha^{-1})	Adjusted grain yield down wards by 10% (kg ha^{-1})	Gross Benefit (Birr ha^{-1})	Total variable cost (Birr ha^{-1})	Net return (Birr ha^{-1})	MRR %
Control	0	0	1,967	13,766	-	13,766	0
25%Pc NPS	42	100	4,533	31,733	1,895	29,838	848
50%Pc NPS	84	100	4,889	34,222	2,460	31,762	341
75%Pc NPS	126	100	5,356	37,491	2,966	34,525	546
100%Pc NPS	168	100	5,511	38,575	3,502	35,073	102
100% Pc TSP	139	100	4,667	32,666	4,341	28,324	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 = 7 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, NPS= blended NPS fertilizer.

4. Conclusion and Recommendation

Despite the large area under maize in Ethiopia, the national average yield of maize is 80% far below the world's average yield. The low productivity of maize is attributed to many factors like declining of soil fertility, poor agronomic practice, limited use of input, frequent occurrence of drought and insufficient technologies. However, successful maize production depends on the correct application of production inputs that will sustain the environment as well as agricultural production. These inputs are adapted cultivars, plant population, soil tillage, fertilization, weed, insect and disease control, harvesting, marketing and financial resources.

Some researchers reported that, inorganic fertilizers have been the important tools to overcome soil fertility problems and they are also responsible for a large part of the food production increases worldwide and estimated that at least 30 to 50% of crop yield increment is attributable to application of commercial fertilizers. However, the usual blanket fertilizer rate application throughout the country on all soil types and agro ecological zone justifies the existence of little information on the fertility status of Ethiopia's soils. Due to these Ethiopia has been moving from blanket recommendations to diversification and away from DAP and Urea to blended fertilizers such as NPS. However, the rate of this fertilizer was not determined by researchers particularly for the study area. Hence, field experiment was carried out to determine economically appropriate rate of blended NPS fertilizer for Maize crop production at Dugda district, on a farmer's field during 2018/2019 cropping season.

The experiment was conducted on already determined Phosphorous critical and requirement factor and consisting of 100% Pc from TSP (Triple supper phosphate) fertilizer, 100%, 75%, 50%, 25% Pc from NPS fertilizer and control (no fertilizer application) and laid out in a randomized complete block design (RCBD) with three replications. Phosphorus fertilizer was applied according to the formula of *Applied P* = (Critical P - Po)* Pf. Whereas Pc= 10 ppm and Pf = 1.41-4.68 (3.05) ppm.

The analysis of variance revealed that different rates of phosphorus critical from blended NPS and TSP fertilizers did not significantly ($p < 0.05$) influence ear height, number of rows per ear and thousand kernels weight of maize crop at study area. However, plant height, biomass yield, grain yield, harvest index and cob weight were highly significantly ($p < 0.01$) influenced by different rates of phosphorus critical from blended NPS and TSP fertilizers. The highest (2008 cm) plant height, the highest (6123kg ha^{-1}) grain yield, and the highest (52.67kg ha^{-1}) cob weight were recorded by application of the highest 100% Pc (168kg ha^{-1}) while the highest (20.14tone ha^{-1}) biomass yield and the highest (32.77%) harvest index were recorded by 100 pc TSP and 75% PC NPS respectively. The economic analysis revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) application of 100 Pc NPS (168kg NPS ha^{-1}) are profitable which gave the highest (35073 Birr) net return with acceptable (102%) marginal rate of return and recommended for farmers in Dugda district and other areas with similar Agro-ecological conditions.

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