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SOCIETY FOR SCIENCE AND EDUCATION

Effect of Compound (NPS) Fertilizer Type on Yield and Nutrient Use Efficiency of Maize (Zea mays L.) at Beko Village in Yeki District, Southwest of Ethiopia

Mulisa Wedajo
Ethiopian Institute of Agricultural Research, Teppi Agricultural Research Center

Selamyihun Kidanu
OCP Society Anonym Commercial Representative Offices, Addis Ababa, Ethiopia

Alemaheyu Reggasa
Jimma University Colleges of Agriculture and Veterinary Medicine

Abstract

Farmer in different part of Ethiopia use similar type of fertilizer and amount that below the crop requirements, even the low soil fertility which limit the crop production as a general. To solve the over-blanket fertilizer application over different agro-ecology Ethiopian Soil Information System (EthioSIS) mapping the soil fertility and recommended types of fertilizer for specific location. The NPS type of fertilizer where recommended for Beko village, but the rate of this fertilizer type was not studied so far. So, this field experiment was conducted to determine the rate of NPS fertilizer type and nutrient use efficiency of maize during the 2018 cropping season at Beko village. A total of eight treatments with four replications were laid out in a factorial randomized complete block design. Treatments were control (zero fertilizer), previously recommended nitrogen and phosphorus (92 kg N/ha + 30 kg P/ha), 150NPS +100 urea +100 K_2O kg/ha, 200NPS +100 urea + 100 K_2O kg/ha, 250NPS +100 urea +100 K_2O kg/ha, 150NPS +150 urea +100 K_2O kg/ha, 200NPS +150 urea +100 K_2O kg/ha, 250NPS +150urea +100 K_2O kg/ha. Data was statistical analyzed by SAS and mean treatment difference were compared by list significant difference (LSD). As analysis of variance indicated that application of NPS fertilizer were not influenced plant height, ear height, ear length, cob length, number of ears per plant, thousand seed weight, harvest index, and shelling percentage as compared to the previously recommended NP fertilizer but grain and biomass yield were influenced except application of 150NPS +100 urea. Among the treatment application of 250 NPS + 100 urea gave the highest maize grain yield (8390.1 kg/ha). The Application of NPS fertilizer improved nitrogen and phosphorus use efficiency of maize as compared to the previously recommended NP. The highest N use efficiency (57.98 kg/ha) was obtained from the application of 250 NPS +100 urea, while the lowest N use efficiency (23.89 kg/ha) was from the previously recommended NP fertilizer. As economic analysis indicated the study conclude that application of 150 NPS +150 urea recommended for the study area.

Keywords: Blanket recommended, Grain yield, biological yield, NPS

INTRODUCTION

Maize (Zea mays L.) is one of the most important food crops in Ethiopia as well as in Sheka zone. Its average productivity is below 3.67 t/ha [1] when compared to the national average to 4.7 t/ha [2] and lower than the world average yield which about 5.21 t/ha [3]. Low soil fertility is one of the bottlenecks for sustaining maize production and productivity in Ethiopia [4; 5]. Continuous crop production without improved farming practices has resulted in several deplete nutrients and soil organic matter which affect agricultural production [6; 7]. Lower biomass production and increasing demand of local organic matter of fuel and fodder also accelerate the declining of soil fertility [8; 9].

In Ethiopia farmers use similar fertilizer types commonly known as urea and DAP in different agro-ecology as a blanket recommendation [10]. Urea and DAP fertilizer provide only nitrogen and phosphorus plant nutrients. Plants require a specific amount of certain nutrients in some specific form at appropriate times for their growth and development. The role of both macro and micronutrients are crucial in crop nutrient and thus important for obtaining higher yield [11, 12; 13].

In a past decade Ethiopian Soil Information System (EthioSIS) where mapping soil fertility status of the country. Accordingly, in addition to nitrogen and phosphorus plant nutrients other nutrients like, potassium (K), Sulfur (S), boron (B), copper (Cu), manganese (Mg), iron (Fe), and zinc (Zn) where deficiencies are widespread in Ethiopian soil [14, 15; 16].

According to the EthioSIS [15] four types fertilizer (NPS, NPSB, NPSBCa and NPSCa) are suggested for Yeki District, Southwest of Ethiopia. However, the map is suggested type of fertilizer but, the rate of those fertilizer in respective to crop type is not studied. With this back ground, the present study was designed to evaluate the effect of NPS fertilizer type on grain yield, nutrient use efficiency of maize and economic feasibility in Yeki district at Beko village Southwest of Ethiopia.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted in Sheka Zone Yeki District at Beko village during 2018 main cropping season. The Yeki located in Southwest of Ethiopia in South West people of Ethiopia regional state at an elevation of 1200 m.a.s. l, latitude of 7°10’54.5’’ and longitude of 35°25’04.5″ East of Ethiopia and approximately 611km far from the capital city of Addis Ababa, Ethiopia. The average maximum and minimum annual temperatures are 29.7°C and 15.5 °C respectively. The annual rainfall in the area is unimodal distribution with average of 1559mm. The area is dominated by Nitisols [17].

Experimental Materials

A high yield medium maturity date of hybrid maize variety (BH140) was used as a test crop. Urea fertilizer as source of nitrogen, triple super phosphate (TSP) as phosphorus source, potassium chloride as a source of potassium and NPS were used. Fertilizers’ TSP and NPS were applied at planting while, urea applied in twice equal split half at knee height and the remaining at flag leaf emergence as Tolessa [4] recommendation.

Experimental Design

A field experiment was conducted in a factorial randomized block design with eight treatments with four replications, an experimental plot 3.5mx3.75m length and width respectively. The treatments consisted three level of NPS (150, 200, 250) kg/ha each combined with two levels of urea (100, 150) kg/ha and two checks were added to each block (Control and previously recommended 200 urea +150 TSP) kg/ha. The details treatment combination are given in Table 1.

Table 1.Treatment details

Treatment code	Treatment details
T1	Control (zero fertilizer)
T2	Recommended NP (92 kg N/ha + 30 kg P/ha)
T3	150 kg NPS/ha +100 kg Urea /ha +100 kg KCl/ha
T4	200 kg NPS/ha +100 kg Urea /ha +100 kg KCl/ha
T5	250 kg NPS/ha +100 kg Urea /ha +100 kg KCl/ha
T6	150 kg NPS/ha +150 kg Urea /ha +100 kg KCl/ha
T7	200 kg NPS/ha +150 kg Urea /ha +100 kg KCl/ha
T8	250 kg NPS/ha +150 kg Urea /ha +100 kg KCl/ha

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 physio-chemical properties; soil texture by Bouyoucos hydrometer method [18], soil reaction (pH) in a 1:2.5 soil water suspension by a glass electrode pH meter [19], total nitrogen by modified Kjeldahl method [20], available phosphorus by Olsen method [21], available potassium by ammonium acetate extracts flame photometer [22], available sulfur and boron by Mehlich-3 method [23], cation exchangeable capacity (CEC) [24], organic carbon by Walkley and Black method [25], organic matter was estimated as organic carbon multiplied by 1.74 assuming the average carbon concentration of organic matter is 58%. Six plants from each net plot were randomly taken to measure plant height, ear height, ear length, cob length, thousand seed weight, grain yield, biomass yield, harvest index, shelling percentage of maize. Maize grain was taken to analysis nutrient content for nutrient use efficiency analysis using procedure described by Fageria and Baligar [26]. A partial budget analysis was calculated follow as CIMMTY [27] procedure. The collected data were statistically analyzed as using SAS software package [28]. The mean differences were separated using the list significant difference (LSD) to signify the treatment differences at a 5% level of probability.

RESULTS AND DISCUSSION

Pre-Plant Soil Properties

The pre-plant composite soil sample were collected from the experimental field at Beko village, Yeki district. The various soil physio-chemical properties of the experimental site were analyzed under laboratory and the results were presented in Table 2.

Table 2. Pre-plant basic soil properties of the experimental site

Soil properties		Values	Rating	Reference
Physical properties	Clay (%)	60		[29]
	Silt (%)	26		
	Sand (%)	14		
	Texture class		Clay	
Chemical properties	Soil reaction (pH)	6.27	Slightly acid	[30]
	Total nitrogen (%TN)	0.24	Moderate	[31]
	Olsen av.P (mg/kg)	5	Low	[30]
	av. K (ppm)	550.80	High	[32]
	av. S (ppm)	13.14	Medium	[32]
	Av. B (ppm)	0.99	Moderate	[32]
	CEC cmol (+)/kg	30.89	High	[30]
	OC (%)	2.64	High	[33]

Effect Of NPS Fertilizer Application on Growth, Yield and Yield Components of Maize

The application of NPS fertilizer was none significantly ($p>0.05$) influenced plant height, ear height, ear length, cob length and number of ear per plant as compared to the previously recommended NP fertilizer (Table 3).

Table 3. Effect of NPS fertilizer on plant height, ear height, ear length, cob length and number of ear per plants of maize in Yeki district at Beko village

Treatments (Fertilizer rates kg ha^{-1})	Plant height (cm)	Ear height (cm)	Ear length (cm)	cob length (cm)	Number of ear per plants
Control (Zero fertilizer)	244.45b	126.7b	30b	13.55c	1
200 urea + 150 TSP	256.55ab	141.7a	32.95ab	15.65b	1.05
150 NPS+ 100 Urea + 100 KCl	259.15ab	137.85ab	34.85a	17.05ab	1.05
200 NPS + 100 Urea+ 100 KCl	254ab	134.5ab	36.05a	18.05a	1
250 NPS + 100 Urea + 100 KCl	263.55a	136.85ab	33.85ab	16.85ab	1.05
150 NPS+ 150 Urea + 100 KCl	253.65ab	130.95ab	34.8a	17.4a	1
200 NPS + 150 Urea + 100 KCl	254.6ab	135.6ab	35.9a	17ab	1.1
250 NPS + 150 Urea + 100 KCl	258.1ab	137.2ab	35.4a	17.55a	1.05
LSD	18.973	13.16	3.9942	1.5484	ns
CV%	5.05	6.62	7.94	6.33	7.73

The application of NPS fertilizer was none significantly ($p>0.05$) influenced thousand grain weight, harvest index and shelling percentage of maize as compared to the previous recommended NP fertilizer, while grain and biomass yield were influenced (Table 4).

Table 4. Effect of NPS fertilizer on thousand seed weight, grain yield, biomass yield, harvest index and shelling percentage (%) of maize in Yeki district at Beko village

Treatments (Fertilizer rates kg ha^{-1})	Thousand seed weight	Grain yield kg ha^{-1}	Biomass t ha^{-1}	Harvest index	Shelling Percentage
Control (zero fertilizer)	300.78c	2968.9d	7.68e	38.61b	73.79d
200 urea + 150 TSP	364.8b	5166.6c	11.77d	43.90a	80.56c
150 NPS+ 100 Urea + 100 KCl	379.53b	5682.7c	12.71d	44.67a	81.46c
200 NPS + 100 Urea+ 100 KCl	381.15b	7567.9ab	16.81bc	44.973a	84.01bc
250 NPS + 100 Urea + 100 KCl	372.89b	8390.1a	18.18a	46.12a	87.67a
150 NPS+ 150 Urea + 100 KCl	384.43b	7789.6ab	17.41ab	44.71a	83.85bc
200 NPS + 150 Urea + 100 KCl	387.03b	7015.6b	15.64c	44.79a	83.267bc
250 NPS + 150 Urea + 100 KCl	425.31a	8387.6a	18.29a	45.86a	85.15ab
LSD	34.595	831.05	1.28	2.58	3.58
CV%	6.28	8.54	5.90	3.96	2.95

When compared with the control treatment with other treatments application of NPS fertilizer influenced thousand seed weight, grain yield, biomass yield, harvest index and shelling percentage of maize. The highest thousand seed weight (425.31gm) and biomass yield was recorded from the application of 250 NPS + 150 urea + 100 KCl. The highest grain yield (8390.1kg/ha), harvest index (46.12), and shelling percentage (87.67) was recorded from the application of 250 NPS + 150 urea + 100 KCl fertilizer. The lowest thousand seed weight (300.78gm), grain yield (2968.9 kg/ha), biomass yield (38.61 t/ha), harvest index (36.61) and shelling percentage (73.79) of maize was recorded from the control treatment followed by the previously recommended NP fertilizer rate. The application of macronutrient S from NPS and K from KCl fertilizer in addition to enough urea contributed for the increment of maize thousand yield, grain yield, biomass yield, harvest index and shelling percentage over the control treatment and split nitrogen application also improve the nutrient use efficiency of the maize.

Maize request the greatest amount of potassium fertilizer. A study by Muhammad et al. [34] indicate that application of 120 kg/ha fertilizer improved maize yield by 24.21% as compared to the control. As a different study showed application of balanced fertilizer improved grain yield of different cereal crops. A study by Dagne [35] and Shiferaw et al. [36] grain yield of maize were improved under the application of blended fertilizer as compared to the control. A study on tef indicate that blended fertilizer with a recommended amount of N and P increased yield as compared with the control treatment [37; 38]. Similarly study on wheat also showed yield increments as blended fertilizer application as compared to the control [39; 40].

Effect Of NPS Fertilizer Application on Nitrogen Nutrient Uptake of Maize

The application of 250 NPS + 150 urea + 100 KCl fertilizer gave the maximum grain N uptake (119.1 kg/ha), straw N uptake (118.73 kg/ha) and total biomass N uptake (237.83 kg/ha),

while the minimum N uptake of grain (12.37 kg/ha), straw (13.35 kg/ha) and total biomass (25.72 kg/ha was from the control treatment followed by the previously recommended NP fertilizer (Table 5). This N uptake improvement of maize over the control and recommended NP could be due to the macronutrient provided from NPS, KCl and split application of nitrogen application.

The application of macronutrient improve nutrient uptake of maize both the grain and straw [35]. The N uptake and grain yield has a positive association [26]. Hence, the improved N uptake in grain yield of maize may lead to improved grain yield. A combine application of nitrogen and phosphorus increase the N uptake of maize reported [41].

Table 5. Effect of NPS fertilizer on maize N and P uptake in Yeki district at Beko village

Treatments (Fertilizer rates kg ha-1)	N and P uptake kg ha-1					
	N			P		
	Grain	Straw	Biomass	Grain	Straw	Biomass
Control	12.37	13.35	25.72	8.02	4.58	12.59
200 urea + 150 TSP	39.27	33.04	72.31	18.6	11.76	30.36
150 NPS+ 100 Urea + 100 KCl	58.53	41.44	99.97	30.69	15.98	46.67
200 NPS + 100 Urea+ 100 KCl	85.77	60.8	146.57	50.7	22.7	73.4
250 NPS + 100 Urea + 100 KCl	89.77	69.1	158.87	46.15	23.62	69.76
150 NPS+ 150 Urea + 100 KCl	106.97	83.87	190.84	41.28	23.48	64.77
200 NPS + 150 Urea + 100 KCl	99.62	72.17	171.79	60.33	17.86	78.19
250 NPS + 150 Urea + 100 KCl	119.1	118.73	237.83	41.94	22.53	64.47

Total uptake (Biomass) =grain + straw uptake

Effect of NPS Fertilizer Application on Phosphorus Nutrient Uptake of Maize

The application of 200 NPS + 150 Urea + 100 KCl gave the maximum grain P uptake (60.33) and biomass (78.19 kg/ha) yield, while the minimum P uptake (8.02 kg/ha) and total biomass P uptake (12.59 kg/ha) was recorded from the control treatment. P uptake was improved as compared to the control treatment.

Effect of NPS Fertilizer Application on Agronomic N and P Nutrient Use Efficiency of Maize

Agronomic fertilizer use efficiency of maize was influenced due to the application of NPS fertilizer type (Table 6). The highest agronomic fertilizer N use efficiency (57.98 kg/ha) was recorded under the application of 250 NPS + 100 urea, while the lowest from recommended NP fertilizer (23.89 kg/ha) and it improved by 46.10% as compared to the previously recommended NP fertilizer.

Table 6. Agronomic nutrient use efficiency of maize

Treatments (Fertilizer rates kg ha-1)	Agronomic use efficiency kg ha^{-1}	
	N	P
Control	-	-
200 urea + 150 TSP	23.89	31.85
150 NPS + 100 Urea + 100 KCl	36.43	47.61
200 NPS + 100 Urea + 100 KCl	54.75	60.51
250 NPS + 100 Urea + 100 KCl	57.98	57.07
150 NPS + 150 Urea + 100 KCl	49.44	84.57
200 NPS + 150 Urea + 100 KCl	37.82	53.25
250 NPS + 150 Urea + 100 KCl	46.51	57.04

Agronomic fertilizer use efficiency of any nutrient can be increased by increasing plant nutrient uptake and the use of nutrients by decreasing nutrient losses from the soil plant system. As Mengel et al. [42] stated the mean value of agronomic fertilizer use efficiency for a nutrient should not be less than 5 kg/ha and according Dobermann [43] in the range of 10 to 30 kg/ha. The agronomic use efficiency of the study area ranged from 23.89 to 57.98 kg/ha which was the optimum range according to Mengel et al. [42] and Dobermann, [43]. In the case of high value of agronomic use efficiency could be good field management system or at which soil N supply is low [43].

The application of NPS fertilizer was influenced agronomic P fertilizer use efficiencies of maize when compared to the recommended NP fertilizer (Table 6). The highest agronomic P fertilizer use efficiency (84.57kg/ha) was recorded from the application of 150 NPS + 150 urea, while the lowest (31.85 kg/ha) from the recommended NP fertilizer.

Economic NPS Fertilizer Application Analysis

One of the boldly important in fertilizer study is its economic advantage for smallholder farmer. According to CIMMYT, (1988) the minimum rates of return by investing any cost to the acceptable return between 50 to 100%. So, farmers select the best treatment based on minimum acceptable marginal rate of return, highest net benefit with low total variable cost. In this study a partial budget average of eight (8) treatments were calculated from income and expenses based on variable cost. Net benefit (NB) calculated as subtracting the total variable cost (TVC) from the gross field benefit (GFB) for each treatment. A gross field benefit was calculated as multiplying yield obtained by fife which is a local selling price of a kilogram of maize estimated from the average of fife year. The cost of NPS fertilizer was Ethiopian birr (ETB 13.75 kg-1, TSP was ETB 12.75/kg, KCl was ETB14.50/ kg and urea were ETB 10/kg. The cost of fertilizer transportation was considered as ETB 15 per 100 kg fertilizer and labor cost of fertilizer application ETB 18 per day for 8 hours for 100 kg fertilizer. The yield adjustment to downward by 10% is to indicate the difference between yield obtained from experimental site and the expected yield from farmers' fields [44].

The acceptable marginal rate of return (5.9%) for un-dominated treatment at the lowest total cost of variable with the highest net (16720.7 ETB/ha) was recorded from the application of 150 NPS + 150 urea (Table 7). Dominated treatment indicate that any treatment that has net benefits are less than those of a treatment with lower costs that vary. According to this study, application of 150 NPS + 150 urea along with 100 KCl is recommended for the experimental site.

Table 7. Partial budget analysis of NPS fertilizer application for maize

Treatments (fertilizer rate in kgha^{-1})	Grain Yield kgha^{-1}	Ad. grain Yield kg ha^{-1}	GFB	NB	TVC	MRR
Control	2968.9	2672.01	13360.05	13360.05	0	
150 NPS+ 100 Urea + 100 KCl	5682.7	5114.43	25572.15	9429.65	16142.5	D
200 Urea+ 150 TSP+ 100 KCL	5166.6	4649.94	23249.7	6614.7	16635	D
150 NPS+ 150 Urea + 100 KCl	7789.6	7010.64	35053.2	16720.7	18332.5	5.95
200 NPS + 100 Urea+ 100 KCl	7567.9	6811.11	34055.55	15575.55	18480	D
250 NPS + 100 Urea + 100 KCl	8390.1	7551.09	37755.45	17675.45	20080	1.31
200 NPS+ 150 Urea + 100 KCl	7015.6	6314.04	31570.2	10900.2	20670	D
250 NPS + 150 Urea + 100 KCl	8387.6		37744.2	16934.2	20810	43.1

Ad. =Adjusted grain yield to 10%, GFB=Growth field benefit, NB=Net benefit, TVC=Total cost that varies MRR= Marginal rate of return, D=dominated treatment

CONCLUSION

The application NPS fertilizer was significantly influenced maize grain yield and total biomass. The highest maize grain yield (8390.1 kg/ha) was obtained from the application of 250NPS + 100 Urea + 100 KCl kg/ha, while the lowest grains yield (2968.90 kg/ha) was obtained from the control plot. Application of NPS and urea improved nutrient uptake and agronomic use efficiency of maize, as compared with the blanket recommended NP fertilizer. The maximum grain N uptake (106.97 kg/ha) was obtained from the application of 150 NPS + 150 Urea + 100KCl kg /ha. Economically application of 150 NPS + 150 urea + 100KCl kg/ha gives 7010.64 kg/ha maize yield and 16720.7 ETB net benefits. Therefore, application of 150 NPS + 150 urea along with 100 KCl kg/ha fertilizers is recommended for maize production in Yeki district at beko village.

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