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Full Length Research Paper

Response of maize to fertilization on alluvial soil in Arba Minch, Gamo-Gofa, Southern Ethiopia

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Assessing crop response to fertilizer application is essential to recommend or preclude the fertilizer use in an area. A field experiment was conducted on Arba Minch University research site having alluvial soil to know the response of maize crop to combined levels of N, P and K with or without farm yard manure ($N_0 P_0 K_0$, $N_{100} P_0 K_0$, $N_{100} P_{50} K_0$, $N_{100} P_{50} K_{50}$, $N_{50} P_{25} K_{25}$, $N_{50} P_{25} K_{25}$ + FYM @10 t ha^{-1}, $N_{100} P_{50} K_{50}$ + FYM @10 t ha^{-1}, $N_{150} P_{75} K_{75}$, $N_{150} P_{75} K_{75}$ + FYM @10t ha^{-1}, FYM @10 t ha^{-1}) under irrigated conditions. There was, in general, no significant response of maize (var., BH 140) in terms of growth, yield components and grain yield to the application of fertilizer nutrients in balanced and integrated manner along with farm yard manure. The grain yield without fertilization (93.4 q/ha) was at par with yield in treatment with higher level of nutrients like $N_{150} P_{75} K_{75}$ (109.5 q/ha). Therefore, for the present, fertilizer application may not be recommended for higher maize productivity on alluvial plain soils in Gamo-Gofa zone. The soils, however, need to be monitored over the years for any fertility decline and replenishment of nutrients through addition of fertilizers. The high fertility of soils may be exploited advantageously for growing of organic produce, fetching premium price in domestic and international markets.

Key words: Maize, NPK fertilizer response, Integrated nutrient management, alluvial plain soil, Southern Ethiopia.

INTRODUCTION

Maize is one of the most important cereals cultivated in Ethiopia, ranking second after teff in area coverage and first in total production. The post-Meher season crop production survey for 2012-13 indicates that out of 12.3 million ha area under grain crops, maize covered about 2 million ha (16.4%), giving 26.6% (6.16 MT) grain yields (CSA 2013). However, the national average yield of maize is still low at about 3 t ha^{-1} (CSA 2013) compared to world's average yield of about 5.2 t ha^{-1} (FAO 2011). Low soil fertility is one of the principal factors that limit maize productivity in maize growing areas of Ethiopia (Alelign and Regassa 1992, Wondesen and Sheleme 2011). To improve maize productivity, an efficient use of fertilizers has to be adopted by smallholder farmers constituting about 80 percent of Ethiopian population.

The soil fertility problem has to be approached through on-farm experiments, in which it is determined as to what levels of different kinds of fertilizer are needed, and then wide demonstrations on small plots to convince the small farmers about the benefits of proper fertilizer use (Borlaug 2004). The balanced and integrated nutrient management (INM) is considered a panacea for maintenance of soil health, high productivity and profitability of the farms (Sharma 2008, Tewodros and Belay 2015, Vanlauwe 2015). The usefulness of INM has very well been demonstrated by the All India Co-ordinated Research Project on Long Term Fertilizer Experiments of Indian Council of Agricultural Research running since 1970 (Samra 2006). The application of nitrogen alone gave very low response. The response increased with the application of phosphorus along with nitrogen, but its reduction with time was again evident in the absence of potassium. The response got stabilized at a

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higher level only with the balanced application of NPK. Further improvement in the response could not be realized merely with the addition of higher amounts of chemical fertilizers. The addition of organic manure along with chemical fertilizers was required for obtaining higher response. According to Vanlauwe et al. (2001), the conjunctive use of inorganic fertilizer and organic inputs made sense in Sub-Sahara Africa since (i) both fertilizer and organic inputs are often in short supply in smallholder farming systems due to limited affordability and/or accessibility; (ii) both inputs contain varying combinations of nutrients and/or carbon, thus addressing different soil fertility-related constraints; and (iii) extra crop produce can often be observed due to positive direct or indirect interactions between fertilizer and organic inputs.

There is also likelihood of alluvial soils of Arba Minch not responding to the fertilizer application because of their being high in inherent soil fertility (Tuma 2007, Tuma 2013, Tuma et al. 2013). The soils have not been cultivated for long that could have caused significant mining and depletion of nutrients in them. The low productivity of maize on farmers' fields may be due to other management factors, especially poor weed control and moisture stress. The farmers are, presently, applying fertilizers to maize as per the blanket recommendation of 100 kg of urea and 100 kg of diammonium phosphate per ha (64 kg of N and 46 kg of P_2O_5 ha^{-1}) made by the Ministry of Agriculture, Government of Ethiopia. Even though the recommended fertilizer rate is low, the poor farmers of area feel constrained to incur cost on fertilizer input. The money to be spent on fertilizers could, however, be saved by the farmers, provided the soils are high in fertility and do not show response to fertilizer application. For the present, there is no documented information on fertilizer response and nutrient requirements of maize crop for optimum productivity, based on real field experiments in the Arba Minch region. Therefore, the present investigation was taken up with the objective of bridging up the existing information gap in the area.

MATERIALS AND METHODS

Location of the experiment

The experiment was conducted on Arba Minch University research site in Arba Minch District of Gamo Gofa Zone, Southern Ethiopia during 2015 main cropping season. The geographical coordinates of the site are 6^0 5" N and 37^0 35' E, and altitude of 1218 meter above sea level.

Climate

The rainfall pattern is a bimodal type with a total rainfall of 830.7 mm per annum. The rains extend from April to October with maximum in the months of June, July and August. The mean minimum, mean maximum and average temperatures are 14.1, 27.9 and 20.6 ^{0} C, respectively. The area falls in the semi-arid moisture regime where evapo-transpiration exceeds precipitation. In general, the length of growing period (LGP) of Arba Minch area is 61 days (Lemma G 1996). This implies that evapo-transpiration is by far greater than rainfall and there is need to supplement moisture by irrigation for the growing of different crops.

Soil characteristics

Soil of the research site is alluvial in nature, laid in the past by the Kulfo river that drains in the adjoining Chamo lake. The different characteristics of the soil (0-15 cm) were got analysed at JIJE Analytical Testing Service Laboratory, Addis Ababa by standard methods and are given in Table 1.The soils are deep, dark in colour and have texture as clay, pH - 7.7, organic carbon - 3.1 %, total N - 0.26 %, Available P as P_2O_5 - 84.8 ppm and available K - 2.63 cmol kg^{-1}.

Treatments and experimental design

There were 10 treatments consisting of different levels of N, P and K with or without farm yard manure ((N_0 P_0 K_0, N_{100} P_0 K_0, N_{100} P_{50} K_0, N_{100} P_{50} K_{50}, N_{50} P_{25} K_{25}, N_{50} P_{25} K_{25} + FYM @10 t ha^{-1}, N_{100} P_{50} K_{50} + FYM @10 t ha^{-1}, N_{150} P_{75} K_{75}, N_{150} P_{75} K_{75} + FYM @10t ha^{-1}, FYM @10 t ha^{-1}). The treatments were designed such that we could ascertain the response of maize to N, P and K nutrients singly and in a balanced and integrated (conjunctive use of chemical fertilizer and organic manure) manner. The experiment was laid on Randomized Block Design (RBD) with three replicates. The plot size was 11.25 m^2 (4.5m x 2.5m) with 6 rows and 10 plants per row (Spacing of 75cm between rows and 25 cm between plants**)**. The maize variety used was BH 140. The experiment was conducted under irrigated conditions.

Fertilizer application

The whole amount of P and K was applied as basal doze at the time of sowing through Diammonium Phosphate (DAP) and Muriate of Potash (KCl) fertilizers, respectively. The N was applied in three splits through urea, one-third at the time of sowing alongwith P & K, another one-third at knee-high stage and remaining one-third at tasseling/silking stage.

Recording of data

The data were obtained for different growth and yield components (plant height, number of leaf/ plant, number of productive plants/m^2, number of cobs / plant, number of rows /cob, number of kernels/row, number of kernels

Table1. Mean values of selected physico-chemical properties of surface soil (0-15cm).

Parameter	Mean value	Rating
Sand (%)	12.0	
Silt (%)	37.3	
Clay (%)	50.7	
Textural class (USDA)	Clay	
pH (1:2.5::soil: water)	7.7	Slightly alkaline (Murphy 1968)
Organic carbon (%)	3.1	High (Tekalign 1991)
Total N (%)	0.26	High (Tekalign 1991)
Available P as P_2O_5 (ppm)	84.8	Very high (Cotterie 1980)
Available K (cmol / kg soil)	2.63	Very high (FAO 2006)

/cob and 1000 seed weight) and final grain yield of maize at harvest, employing five randomly selected plants within the internal four rows in the plots.

Statistical analysis

The growth, yield and yield components data were subjected to statistical analysis following SAS procedure (SAS 2002). The means were separated by Duncan's Multiple Range Test (Duncan 1955).

RESULTS AND DISCUSSION

In general, there was no significant difference in growth, yield components and grain yield of maize under treatments receiving no fertilizer (control) and those receiving graded levels of fertilizer with or without organic manure (Tables 2, 3, 4). The grain yield in control treatment (93.4 q/ha) was at par with yield in treatments like $N_{150}\,P_{75}\,K_{75}$ (109.5 q/ha) and $N_{150}\,P_{75}\,K_{75}$ + FYM (99.7 q/ha). That means the yields without fertilizer addition were as good as yields with higher levels of fertilizer application with or without organic manure. There was no significant effect of balanced application of nutrients as seen for different parameters under treatments receiving only N ($N_{100}\,P_0\,K_0$), combined NP ($N_{100}\,P_{50}\,K_0$) and combined NPK ($N_{100}\,P_{50}\,K_{50}$). There was no significant effect of nutrient management in an integrated manner either. The different parameters were non-significant with treatments receiving nutrients through fertilizers only ($N_{50}\,P_{25}\,K_{25}$, $N_{100}\,P_{50}\,K_{50}$, $N_{150}\,P_{75}\,K_{75}$) and treatments having corresponding levels of fertilizer combined with farm yard manure ($N_{50}\,P_{25}\,K_{25}$ + FYM, $N_{100}\,P_{50}\,K_{50}$ + FYM, $N_{150}\,P_{75}\,K_{75}$ + FYM). Also, application of only farm yard manure @10t ha^{-1} did not show any promise, as growth, yield and yield components of maize were statistically similar with control treatment.

This lends us to believe that lowland alluvial soil of Arba Minch is rich in soil fertility, which supplies nutrients to the crops adequately throughout the crop growth period. Almost similar growth of maize was evidenced under control and fertilized treatments with or without organic manure in the field experiment (Figures 1, 2, 3). The high fertility status of the soils is further established by the soil analyses in terms of texture, contents of organic carbon, total N, available P and available K (Table1). As per given ratings, the amounts of organic carbon, Total N, Available P and available K were in high, high, very high and very high categories, respectively. In a hectare furrow slice (taking 2 million kg soil), the amounts of N, P and K came out to be 5200, 170 and 2051 kg, respectively. The fine texture clay soil (51% clay), formed on alluvium derived from volcanic rocks (basalt, pumice etc) in the Kulfo catchment is, generally, regarded as a fertile soil.

With no limiting nutrients, the alluvial soil has a potential for higher maize productivity even under no fertilizer use. The low productivity of maize, presently, on farmers' fields may be linked to poor level of management, especially weed control and moisture stress, and not limiting nutrients. The present practice of application of fertilizers to maize crop at a blanket rate of 100 kg of urea and 100 kg of diammonium phosphate per ha (64 kg of N and 46 kg of P_2O_5 ha^{-1}) could be done away with, saving money to be spent on fertilizer input. The poor farmers of area, who cannot afford the costly fertilizer input, would feel relieved financially with no need of fertilizer addition to their soils. Our viewpoint is lent further credibility by the findings of other researchers (Getahun et al. 2000, Abera and Belachew 2011), who found return from the sale of the additional maize produced with fertilizer use not to be commensurate with the fertilizer cost in Sidama and North Omo Zones and South-eastern Ethiopia. Accordingly, the farmers of these areas were not able to repay the credit used in buying the fertilizer. There is a merit in having a relook at the necessity of fertilizer use on such apparently high fertility-low responsive soils, with a low benefit : cost ratio for fertilizer use. Most farmers of Sidama and North Omo zones in southern Ethiopia cultivated crops on black soils, which were fertile to very fertile (Getahun et al. 2000). There are also reports of poor response to fertilizer application on fertile soils of small holder farmers of Kenya (Titonell et al. 2008, Vanlauwe et al. 2006) and Zimbabwe (Zingore et al. 2007).The relative response of maize to NPK fertilizers tended to decrease with increasing soil fertility.

Table 2. The growth parameters of maize under different treatments.

Treatment	Plant height-cm	Number of leaf /plant	Number of productive plants/m^2
$N_0 P_0 K_0$	261.5a	15.0a	7.3a
$N_{100} P_0 K_0$	260.5a	14.4ab	8.0a
$N_{100} P_{50} K_0$	256.0a	14.5ab	6.7a
$N_{100} P_{50} K_{50}$	264.3a	14.5ab	8.0a
$N_{50} P_{25} K_{25}$	260.7a	14.7ab	8.0a
$N_{50} P_{25} K_{25}$ + FYM @10 t ha^{-1}	264.1a	14.1b	6.7a
$N_{100} P_{50} K_{50}$ + FYM @10 t ha^{-1}	264.5a	14.9a	7.7a
$N_{150} P_{75} K_{75}$	254.7a	14.8ab	7.3a
$N_{150} P_{75} K_{75}$ + FYM @10t ha^{-1}	257.2a	14.2b	7.3a
FYM @10 t ha^{-1}	253.7a	14.5ab	6.3a
Mean	259.7	14.6	7.3
SEm	10.8	0.3	0.9
LSD (5%)	Ns	0.6	ns
CV (%)	5.1	2.5	15.7

The treatments followed by the same letters are not significantly different from each other at 5% level of significance
ns – non significant

Table 3. Yield components of maize under different treatments.

Treatment	Number of cobs /plant	Number of rows/cob	Number of kernels/row	Number of kernels/kob	1000 seed weight (g)
$N_0 P_0 K_0$	1.0b	14.2abc	43.0ab	610.6bc	340.0ab
$N_{100} P_0 K_0$	1.1ab	13.4c	43.3ab	580.1bc	330.0ab
$N_{100} P_{50} K_0$	1.2ab	14.6abc	39.0b	567.2bc	298.3b
$N_{100} P_{50} K_{50}$	1.1ab	14.3abc	41.9ab	598.6bc	358.3ab
$N_{50} P_{25} K_{25}$	1.2ab	13.6bc	40.1b	546.2c	353.3ab
$N_{50} P_{25} K_{25}$ + FYM @10 t ha^{-1}	1.3a	14.1abc	40.6ab	572.0bc	366.7a
$N_{100} P_{50} K_{50}$ + FYM @10 t ha^{-1}	1.1ab	15.4a	42.7ab	656.6ab	331.7ab
$N_{150} P_{75} K_{75}$	1.1ab	15.3ab	45.7a	698.9a	316.7ab
$N_{150} P_{75} K_{75}$ + FYM @10t ha^{-1}	1.1ab	14.4abc	40.6ab	586.4bc	370.0a
FYM @10 t ha^{-1}	1.0b	14.5abc	42.6ab	617.2abc	341.7ab
Mean	1.1	14.4	42.0	603.4	340.7
SEm	0.1	0.7	2.2	38.9	27.8
LSD (5%)	0.2	1.5	4.6	81.2	57.9
CV (%)	11.5	6.1	6.4	7.9	10.0

The treatments followed by the same letters are not significantly different from each other at 5% level of significance.

Accordingly, the fertilizer use was recommended based on soil fertility and crop response and not as blanket recommendations made by the government bodies in sub-Saharan Africa. Most recently, the fertilizer use on such poorly responsive-high fertility soils was recommended only as ‘maintenance applications’ (Titonell and Giller 2013).

However, the continued cultivation of the farm lands without fertilizers over the years, may cause depletion of nutrients warranting their replenishment with fertilizers. The soils, therefore, need to be constantly monitored for their fertility status through soil testing or by growing a test crop under field conditions.

Given the high natural fertility status, the alluvial plain soil has great potential for growing of certain crops organically (no use of chemical fertilizers), fetching premium price in domestic and international markets. The practice can help better the socio-economic status of farming community of the area.

The findings of the study may not hold true for the maize cultivated on mid lands around Arba Minch, having depleted soils due to rampant soil erosion and land degra-

Table 4. Yield of maize under different treatments (q ha^{-1}).

Treatment	Grain yield (q/ha)	Dry biomass (q/ha)	Harvest index
$N_0 P_0 K_0$	93.4abc	238.5	39.2abc
$N_{100} P_0 K_0$	103.6ab	244.5	42.2a
$N_{100} P_{50} K_0$	83.6cd	247.8	33.3cd
$N_{100} P_{50} K_{50}$	97.4abc	242.4	40.0ab
$N_{50} P_{25} K_{25}$	91.7bcd	256.5	35.5bcd
$N_{50} P_{25} K_{25}$ + FYM @10 t ha^{-1}	76.6d	237.3	32.2d
$N_{100} P_{50} K_{50}$ + FYM @10 t ha^{-1}	92.1bcd	242.8	37.7abcd
$N_{150} P_{75} K_{75}$	109.5a	263.8	41.0ab
$N_{150} P_{75} K_{75}$ + FYM @10t ha^{-1}	99.7abc	260.5	36.7abcd
FYM @10 t ha^{-1}	88.1bcd	235.5	37.6abcd
Mean	93.6	247.0	37.5
SEm	7.1	16.1	2.5
LSD(5%)	14.8	Ns	5.3
CV (%)	9.3	8.0	8.3

The treatments followed by the same letters are not significantly different from each other at 5% level of significance
ns – non significant.

Figure 1. Maize growth without fertilizer (control).

dation. The process of soil erosion and land degradation is quite rampant and widespread in whole of Ethiopia, given the hilly and mountainous terrain, aggressive rainstorms and poor level of soil and water conservation measures (Tewodros and Belay 2015, Ludi 2004).

CONCLUSION

A field experiment was conducted under irrigated conditions on alluvial soils in Arba Minch, involving combined levels of NPK with or without organic manure. There was no significant response of maize to the fertilizer application; the grain yield without fertilizer was as good as yield with higher level of fertilizer nutrients i.e. N_{150} P_{75} K_{75} . The study revealed no need of fertilizer application, for the present, to obtain higher yields of maize on lowland alluvial soils in Arba Minch region. The soils, however, require to be constantly monitored over the years for their soil fertility decline and need for fertilizer addition. The soils rich in soil fertility, offer great opportunity for the practice of organic farming in Arba

Figure 2. Maize growth under higher level of fertilizer nutrients (N_{150} P_{75} K_{75}).

Figure 3. Maize growth under higher level of fertilizer nutrients (N_{150} P_{75} K_{75}) + farm yard manure

Minch area. The organic produce, fetching premium price in the domestic/international markets, can help transform the socio-economic status of farming community of area. The findings of the study may hold true for the similar alluvial plain soils laid by the river networks in southern part of Ethiopia.

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