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The Response of Hybrid Maize (*Zea mays*) to N and P Fertilizers on Nitisols of Yeki District, Sheka Zone

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አህፅሮት

በኢትዮጵያ ዝቅተኛ የአፈርለምነት በተለይም ናይትሮጅን እና ፎስፎረስ፣ ለሰብል ምርታማነትን ለመጨመር ማነቆ የሆኑ ንጥረ ነገሮች ናቸው፡፡ በዘልማዳዊ ናትሮጂን እናፎስፎረስ ማዳበሪያ ምክረሃሳብ ምክኒያት በኢትዮጵያ በብሔራዊ ደረጃ የተዳቀለ የበቆሎ ዝርያ ምርት ዘላቂ እና አጥጋቢ አይደለም፡፡ ስለዚህ የናይተሮጂን እና ፎስፎረስ ማዳበሪያን መጠን እና አጠቃቀም በበቆሎ ምርት ላይ አጥጋቢ ምላሽ ለመፈለግ በደቡብ ምዕራብ ኢትዮጵያ የኪ ወረዳበ 2008 ዓ.ም ሁለት የተለያዩ ቦታዎች ላይ የመስከ ሙከራ አድረገን ነበር፡፡ ጥናቱ ሁለት ዓይነት ሙከራዎችን ያካተተ ነበር፤ የመጀመሪያው ጥናት ሰባት የተለያዩ የናይትሮጂን ማዳበሪያ ደረጃዎች ማልትም 0፤ 23፤ 46፤ 69፤ 92፤ 115 እና 138 ኪሎ ግራም በሄክታር ለእያንዳንዳቸው 30 ኪሎ ግራም ፎስፈረስ በሄክታር በመጨመር፤ ሁለተኛው ጥናት ደግሞ ሰባት የተለያዩ የፎስፈረስ ማዳበሪያ ደረጃዎችን ማለትም 0፤ 10፤ 20፤ 30፤ 40፤ 50 እና 60 ኪሎግራም በሄክታር እያንዳንዳቸው 92 ኪሎ ግራም ናይትሮጂን በሄክታር የያዘ ነበር፡፡ እነዚህ የናይትሮጂን እና የፎስፎረስ ደረጃዎች በአራት ረድፎች ውስጥ የተደረደሩ ሲሆን በእያንዳንዱ ረድፍ ሁለም የማዳበሪያ ደረጃዎች የዘፈቀዲዊ አኳኋን እንዱቀመጡተ ደርጓል፡፡ ውጤቶቹ የሚያሳዩት የናይትሮጂን እና የፎስፎረስ ደረጃዎች በበቆሎ ምርት፤ ፎስፎረስ እና ናይትሮጅን ንጠረ ነገሮችን የመጠቀም አቅም እና ዘዴ ላይ ከፍተኛ ተጽዕኖ ያሳደረ መሆኑን ነው፡፡ በአጠቃላይ ፎስፎረስ እና ናይትሮጅን ማዳበሪያ ደረጃዎች በከፍተኛ ፍጥነት ሲጨምሩ ፎስፎረስ እና ናይትሮጅን አጠቃቀም ፍጆታ ይቀንሳል፡፡ ፎስፎረስ እና ናይትሮጅን ማዳበሪዎችን መጨመር በሁለቱም ቦታዎች ላይ ከፍተኛ የሆነ የበቆሎ የጥራጥሬ መጠን፤ የ 1000 ጥራጥሬዎች ክብደት እና ከመሬት በላይ ምርት ጨምሩዋል፡፡ ከፍተኛ የሆነ ምርት ማለትም 8093 ኪሎ ግራም በቆሎ በሄክታር በቴፒእና 8158 ኪሎ ግራም በቆሎ በሄክታር በአዲስ አለም የማምረት አቅምከ 92 እና 69 ኪሎ ገራምና ይትሮጂን ማዳበሪያ በሄክታር በመጨመር በቅደም ተከተል ተገኝቷል፡፡ከፍተኛ ምርት ማለትም 8918 ኪ.ግ በሄክታር በቴፒ እና 8298 ኪ.ግ በሄክታር በአዲስአለም፤ በሁለቱም ቦታዎች 40 ኪ.ግ ፎስፎረስ በሄክታር በመጨመር ማግኘት ተችሉዋል፡፡ በሁለቱም ቦታዎች 69 ኪሎ ግራም ናይትሮጂን በሄክታር፤ እንዲሁም 30 እና 40 ኪሎ ገራም ፎስፎረስ በሄክታር በመጨመር በአዲስአለም እና ቴፒ በቅደም ተከተል በጣም ብዙ ትርፍ ተገኝቷል፡፡

Abstract

Low soil fertility, particularly nitrogen(N)and Phosphorus(P) are among the most yield-limiting nutrients in Ethiopia. Due to blanket NP application at the national level, the response of hybrid maize in Ethiopia is inconsistent and not satisfactory. Hence, a field experiment was initiated to investigate the response of hybrid maize (Zea mays L.*) to the application of N and P fertilizer rates and their use efficiency on Nitososl. The study comprised two sets of experiments set I had seven levels of N each with30 kg P ha^{-1}(0, 23, 46, 69, 92, 115 and 138 kg N ha^{-1}) while set II had seven levels of phosphorus each with 92 kg N ha^{-1}(0, 10, 20, 30, 40, 50, and 60 kg P ha^{-1}). Both sets of experiments were replicated in two locations. The treatments were laid out separately in a randomized complete block design with four replications. Results showed that N and P rates of application significantly influenced yield and yield components, uptake and nutrient use efficiency. Generally, N and P use efficiency decreased with increased N and P fertilizer rates. Application of NP significantly increased the number of Kernels Cob^{-1}, 1000-kernel weight, and above-ground dry biomass by at both locations. The maximum maize grain yield of 8093 kg ha^{-1}at Tepi and 8158 kg ha^{-1}at Addis Alem were obtained from 92kg N ha^{-1}and 69kg N ha^{-1}, respectively. The maximum grain yields of 8918kg ha^{-1}at Tepi and 8298 kg ha^{-1}at Addis Alem were produced by the application of 40kg Pha^{-1}for both sites. Applications of 69kg Nha^{-1} at both sites, and 30 and 40 kg P ha^{-1}were found to be most profitable rates at Addis Alem and Tepi, respectively.*

Introduction

Although many efforts have been made in different locations, blanket fertilizer recommendation is the major cause of low maize production and productivity in smallholder farms in Ethiopia (Gete *et al*., 2010; Tesfa*et al*., 2012; Addis *et al*., 2015). It isalso the causes of poor fertilizer use efficiency and often not balanced with crop requirements and other nutrients (Dobermann and Dawe, 2002).Over- or under-application of fertilizers, associated with the use of blanket recommendation could result in reduced nutrient use efficiency or losses in yield and crop quality, unnecessary input cost and reduced profitability. Heisey and Mwangi(1996) reported nutrient use efficiency, which is yield per kg nutrient applied, of maize in Ethiopia to be only 9-17 kg of grain per kg of applied N. In Kenya and Tanzania, equivalent nitrogen use efficiencies are varied within 7-36 and 18-43,respectively. Such differences between the two aforementioned east African countries and Ethiopia in terms of nutrient use efficiency indicate the need forsite-specific fertilizer recommendations. An important management strategies to improve nutrient use efficiency are judicious use of fertilizers (adequate rate, effective source, methods, and time of application), supply of adequate water, and control of diseases, insects, and weeds (Baligar and Fageria,2015). It was suggested that higher nutrient recovery and agronomic efficiency could be achieved by lower nutrient application rate in the nutrient overuse areas. Therefore, the objectives of this study were to assess the response of hybrid maize to the application of N and P rates, to evaluate the N and P use efficiency of hybrid maize at different levels of N and P rates; and to evaluate the economic feasibility of fertilizer for maize production.

Materials and Methods

The study area

The study was conducted in Yeki District at Tepi National Spice Research Center (TNSRC) and on farmers field. 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^{o}C and 15.5^{o}C, respectively.

Composite representative soil samples from each experimental site were collected before planting using an auger from a depth of 0-30 cm. The collected samples were air dried, ground and sieved to pass through 2 mm for analysis of major soil chemical parameters (soil pH, soil organic matter, total nitrogen, available phosphorus and CEC).

Experimental set-up and procedure

Pioneer hybrid maize variety, Shone (30G19), was used for this study. The productivity of this varietyis7-11 t ha^{-1} and 6.5 - 8 ton ha^{-1} under on-station and on-farm experiments, respectively (MoA, 2013). Urea (46% N) and TSP (46% P_2O_5) were used as sources of N and P, respectively. This study consisted of two sets of the experiment. The first set of experiments contained seven levels of N (0, 23, 46, 69, 92, 115,138 kg ha^{-1}) with uniform P rate at 30 kg ha^{-1}. The second set of experiments contained seven levels of P (0, 10, 20, 30, 40, 50 and 60 kg ha^{-1}) with uniform N rate at 92 kg ha^{-1}.The treatments were arranged in a randomized complete block design (RCBD) with four replications for both sets of experiments. The spacing of 75 cm between rows and 25 cm between plants was used.Planting was done on27 April 2016 at both sites.

At the time of sowing, fertilizers were applied in a band at a depth of 5–8 cm and then covered by the soil. Seeds were sown on the same row after covering the applied fertilizer with soil. Full does of all levels of P fertilizer were applied once during planting, while, inorganic N fertilizer was applied at three different growth stages of maize: 1/3 of the dose at planting, 1/3 at the first weeding (30 days after planting) and the rest 1/3atsecond (45 days after planting)(Tolessa*et al*., 1994). All agronomic practices (time of weeding, time of harvesting and time of fertilizer application) were constant or uniform for all treatments. The spacing of 75 cm between rows and 25 cm between plants was used. A plot size of 4.5 mx3 m (13.5 m^2) was used. The distance between the experimental unit and blocks maintained was 1 m. To avoid border effects, yield data were collected from the four central rows, with a net plot size of 7.5 m^2. At harvest, all relevant agronomic parameters comprising a number of kernels cob^{-1}, 1000-kernels weight, total biomass yield, and grain yield were collected.

Nutrient use efficiency indices

The nitrogen and phosphorus use efficiencies of maizewere calculated according to Fageria and Barbosa (2007) and Getachew et al. (2016).

Agronomic efficiency: is the economic production obtained per unit of nutrient applied. This value was calculated by:

$$AE\,(kgkg^{-1}) = \frac{Gf - Gu}{Na} \text{ ,}$$

where G_f is the grain yield of the fertilized plot (kg), G_u is the grain yield of the unfertilized plot (kg), and Na is the quantity of nutrient applied (kg).

Physiological efficiency: is the biological yield obtained per unit of nutrient uptake and was calculated as:

$$PE\,(kg\ kg^{-1}) = \frac{BYf - BYu}{Nf - Nu} \text{ ,}$$

Where BY_f is the biological yield (grain plus straw) of the fertilized plot (kgha^{-1}), BY_u is the biological yield of the unfertilized plot (kg), N_f is the nutrient uptake (grain plus straw) of the fertilized plot (kg ha^{-1}), and N_u is the nutrient up taken (grain plus straw) of the unfertilized plot(kg ha^{-1}).

Agro-physiological efficiency: is the economic production (grain yield in case of annual crops) obtained per unit of nutrient uptake and was calculated as:

$$APE(kgkg^{-1}) = \frac{Gf - Gu}{Nuf - Nuu} .$$

Where Gf is the grain yield of fertilized plots (kg ha^{-1}), G_u is the grain yield of the unfertilized plot (kg), $N_{uf}$is the nutrient uptake (grain plus straw) of the fertilized plot (kg ha^{-1}), N_{uu} is the Nutrient uptake (grain plus straw) of unfertilized plot (kg ha^{-1}).

Apparent recovery efficiency: is the quantity of nutrient uptake per unit of nutrient applied and calculated as:

$$ARE(\%) = \frac{(Nf - Nu)}{Na} \times 100 ,$$

Where N_f is the nutrient uptake (grain plus straw) of the fertilized plot (kg ha^{-1}), N_u is the nutrient uptake (grain plus straw) of the unfertilized plot (kg), and Na is the quantity of nutrient applied (kg ha^{-1}).

Statistical analysis

Data were analyzed using the GLM procedure of SAS Version 9.2 statistical analysis software. The treatment means were compared using least significant difference (LSD) value at 5% significance level (Gomez and Gomez, 1984).The economic analysis was performed according to CIMMYT (1988).

Results and Discussion

Selected soil chemical properties

The initial surface soil test characteristics indicated that the range of pH values was moderately acid. Soil organic matter (OM)content was within the range of high, and the total nitrogen content was moderate at both sites according to Tekalign(1991). The CEC of the soil was high, according to Landon (1991).According to Jones (2003), the available P for both sites was very low (Table 1).

Table 1. Characteristics of experimental soils before planting at depth of 0–30 cm at Tepi and Addis Alem

Soil parameters	Tepi	Addis Alem
pH	5.9	5.53
Available P (Olsen P)(mg kg^{-1})	8.85	6.75
Total N (%)	0.22	0.18
OM (%)	6.26	5.66
CEC (cmol (+) kg^{-1})	36	29

Yield and yield components of maize

Number of kernels cob^{-1} was affected significantly by the N rates at both locations. Number of kernels cob^{-1}was obtained with the application of 92kg N ha^{-1}at Tepi and 69kg N ha^{-1}at Addis Alem, beyond which reduced at both locations (Table 2). Increase the number of kernels may be because of sufficient N nutrition that is the basis for plant growth and development. Yihenew (2015) also reported that number of kernels cob^{-1}was improved with the application of N up to the rate of 200 kg ha^{-1}. The number of kernels cob^{-1} increased significantly up to P application rate of 40 kg ha^{-1} at both locations, beyond this rate number of kernels was not significantly declined (Table 3). This result might be due to the decreased number of infertile kernels because of sufficient nutrient supplementation. Similarly, Yihenew Gebre Selassie (2016) indicated that te phosphorus affected number of kernels with the application rate of 0 kg P ha^{-1} to 66 kg P ha^{-1} and the minimum kernel number was obtained from the control.

Thousand-kernel weight was affected significantly by the N rates at both locations. The highest 1000-kernels weight was obtained with the application of 92kg N ha^{-1}Tepi and 69 kg N ha^{-1} at Addis Alem, beyond which reduced at both locations (Table 2). The lowest 1000-kernels weight per cob was recorded from the control (without N application). This might be due to the increase in kernel size because of enough food storage. Similarly, Addis and Kim (2014) reported that application of N at the rates of 75 and 100 kg ha^{-1}resulted in the highest1000-kernels weight of maize. Thousand-kernel weight was significantly influenced by the P rates. The highest 1000-kernels weight was recorded from 50 kg P ha^{-1} at Tepi and 40 kg P ha^{-1} at Addis Alem (Table 3). This could be due to a balanced supply of nutrients from the soil because of optimum P throughout the growth and development stages of the plant. Similarly, Yihenew(2016) reported that the highest 1000-kernel weight obtained from the application of 30 kg P ha^{-1}.

Total aboveground dry biomass yield was affected significantly by the N rates. Increasing N rate from 0to 92 kg ha^{-1} N consistently increased biomass yield at both locations (Table 2). Similar to the effect of N application rates, this trait consistently increased with rates up to 50 kg ha^{-1} P at both locations, beyond which it was depressed (Table 3). The increase in total biomass is directly related to the increase in plant height, leaf area, and vegetative growth which is due to sufficient availability of P to the plants. At different locations in Ethiopia, 40kg Pon*Alfisol*and45 kg P ha^{-1} resulted in the highest total dry weight of maize (Yihenew,2016; Osbome *et al*.,2004).

Grain yield increased with N rates, but only up to the application rate of 92 kg ha^{-1} N at Tepi and up to 69 kg ha^{-1} N at Addis Alem, beyond which the N application tended to reduce grain yield non-significantly (Figure 1). The highest grain yield increments of30% and 38.6% were recorded at Tepi and Addis Alem, respectively, due to the application of N compared to the unfertilized control. The possible reason for the yield increases was due to a higher number of kernels per cob and weight of kernels. Likewise, application of 90 kg N ha^{-1}significantly increased grain yield of maize (Yihenew,2015).In the current study, the decline in maize yield response to N application above these rates could be the presence of yield-limiting nutrients other than N and/or toxicity which result in stunted plant growth. In this regards, Fanuel *et al*. (2016) reported the presence of other nutrient deficiency besides N and P in acidic soils of Ethiopia. Grain yield of maize consistently increased with the increase in the P application rates up to 40 kg ha^{-1} at both sites (Figure 2). The increase in yield with an application rate of 40 kg P ha^{-1} at Tepi and Addis Alem relative to the control was 29% and 52%, respectively. The reduction of yield beyond this P application rate could probably be as a result of reduced plant growth due to deficiency of Zn induced by high P levels. Kogbe and Adediran (2003) reported a similar result in the reduction of maize grain yield beyond 40 kg P ha^{-1} application rate.

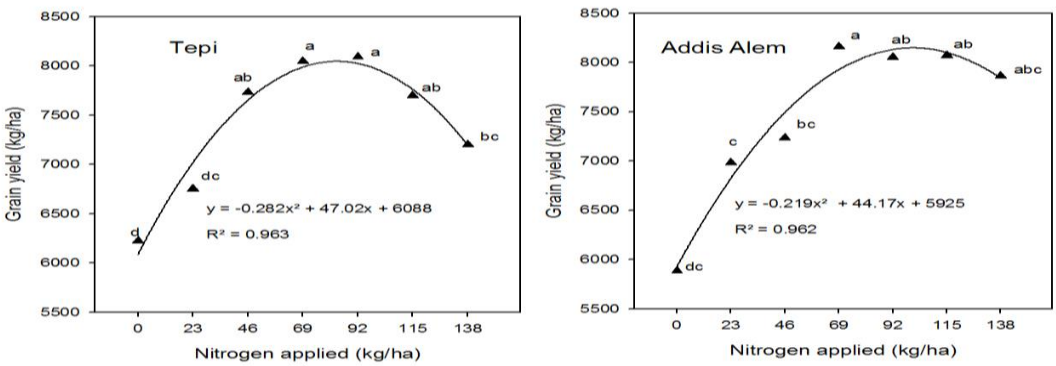

Figure 1. Maize grain yield as affected by nitrogen rates applied at Tepi and Addis Alem

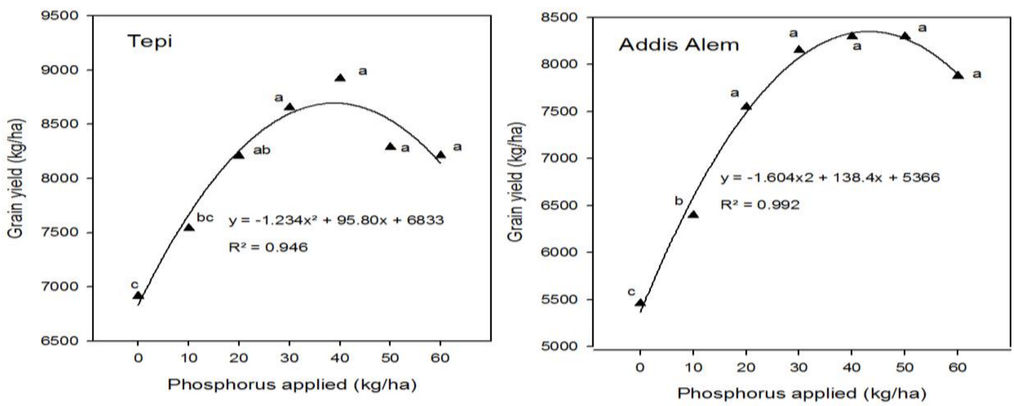

Figure2. Maize grain yield as affected by the phosphorus rates applied at Tepi and Addis Alem

Table 2. Effect of N fertilizer on 1000-kernels weight (g),aboveground dry biomass yield (kg ha^{-1}), number of kernels $cob^{-1}$and harvest index at Tepi and Addis Alem

kg N ha^{-1}	Tepi			Addis Alem		
	Number of kernel Cob^{-1}	1000-kernels weight(g)	Aboveground dry biomass yield (kg ha^{-1})	Number of kernels Cob^{-1}	1000-kernel weight(g)	Above ground dry biomass yield (kg ha^{-1})
0	490^{b}	294^{c}	16337^{c}	566^{e}	342^{b}	16501^{c}
23	518^{ab}	342^{ab}	17135^{bc}	589^{de}	379^{a}	18048^{b}
46	539^{ab}	342^{ab}	1834^{ab}	596^{dc}	381^{a}	19134^{a}
69	541^{ab}	370^{a}	18781^{a}	649^{a}	401^{a}	19875^{a}
92	556^{a}	369^{a}	19276^{a}	638^{ab}	399^{a}	19920^{a}
115	556^{a}	350^{ab}	18895^{a}	647^{ab}	399^{a}	19691^{a}
138	556^{a}	315^{bc}	18764^{a}	621^{bc}	386^{a}	19495^{a}
LSD (0.05)	54	38	1438	27	33	1006
CV (%)	6.74	7.53	5.30	2.99	5.77	3.57

Means in columns followed by the same letter are not significantly different (P<0.05) according to LSD test; CV: Coefficient of variation; LSD = Least significant difference

Table 3. Effect of P fertilizer on 1000-kernels weight (g), above-ground dry biomass yield (kg ha^{-1}), number of kernels $cob^{-1}$and harvest index at Tepi and Addis Alem.

kg P ha^{-1}	Tepi			Addis Alem		
	Number of kernel Cob^{-1}	1000-kernels weight(g)	Above-ground dry biomass yield (kg ha^{-1})	Number of kernels cob^{-1}	1000-kernel weight(g)	Above ground dry biomass yield (kg ha^{-1})
0	463^{c}	297^{c}	16881^{c}	461^{c}	330^{b}	16092^{c}
10	513^{b}	339^{b}	18189^{b}	523^{b}	345^{b}	17046^{bc}
20	555^{ab}	355^{ab}	18504^{ab}	552^{ab}	392^{a}	17908^{ab}
30	573^{a}	349^{ab}	19499^{a}	585^{a}	402^{a}	18844^{a}
40	582^{a}	355^{ab}	19366^{a}	599^{a}	419^{a}	19065^{a}
50	578^{a}	360^{a}	19537^{a}	589^{a}	404^{a}	19211^{a}
60	579^{a}	345^{ab}	19342^{a}	578^{a}	394^{a}	18843^{a}
LSD (0.05)	47	19	1144	50	36	1677
CV(%)	5.80	3.69	4.10	6.09	6.31	6.20

Means in columns followed by the same letter are not significantly different (P<0.05) according to LSD test; CV: Coefficient of variation; LSD = Least significant difference

Nitrogen and P use efficiency of maize

Total N uptake increased with the N rate up to 92 kg ha^{-1}at Tepi and up to 115kg ha^{-1}at Addis Alem beyond which it was non-significantly declined (Figure 3).The highest total N uptake was at 92 kg N $ha^{-1}$and 115 kg N ha^{-1} at Tepi and Addis Alem, respectively (Figure 3). The decrease in N uptake beyond these N application rates might be due to the increase in crop growth with the application of N may increase crop demands for micronutrients, and micronutrient deficiencies may occur, thereby decreasing yield. According to Fageria (2003), the decrease in N uptake at higher N rate may be related to saturation of N-uptake capacity of the plants at higher N rates. Similarly, Wenxu*et al*. (2003) reported that despite the reduction of grain and stover yield nitrogen uptake by maize increased significantly with increasing rate of N fertilizer application at both the pre-tasseling and maturity stage. Nitrogen, total uptake was higher by the grain than by the stover. The maximum P uptakes of 44.5 and 43 kg ha^{-1}were achieved at of 40 kg P ha^{-1} at Tepi and 50 kg P ha^{-1}at Addis Alem, respectively, beyond this level uptake was declined (Figure 3).The possible reason may be associated with a relative decrease in grain and stover yields with successive increment in P rates as reported by Fageria*et al.* (2011).

Nitrogen and P significantly (P<0.05) influenced the N and P use efficiency of maize at both sites(Table 4). Generally, the highest N use efficiency was recorded at a lower rate of N application, while the lowest N use efficiency was recorded at the highest rate of N (138 kg N ha^{-1}) at both sites (Table 4). This result was in agreement with Tolessa *et al.* (2007) who reported that N agronomic, the physiological and apparent recovery efficiency of maize was consistently higher at the range of 69-92 kg N ha^{-1} than in the N level range of 92–115 kgha^{-1}. According to Dobermann (2005), the common value of agronomic efficiency of N for cereals ranges between 10 to 30 kg grain kg^{-1}.If AE is greater than 30 kg kg^{-1}, it is in a well-managed systems or at low levels of N use or low soil N. At the same time, the author indicated that common value of N physiological efficiency of cereals is 30 to 60 kg kg^{-1}, and if the physiological efficiency is higher than 60 kg kg^{-1}, it is in well-managed systems or at low levels of N use or low soil N supply. The current value was within this common range (Table 4). Likewise, the use efficiency of P by maize was significantly influenced by P rates. It decreased with increasing P application rates at both locations. This could be attributed to small yield increment at higher P application rate than the lower rate. Fageria *et al.*(2013 and 2015) reported that in rice plant P use efficiency was lower at 200 kg P_2O_5kg ha^{-1}than at 25 P_2O_5 kg ha^{-1}.In line with this study, the apparent recovery efficiency of P decreased with the increasing application rate of P (Fageria and Baligar, 2016). Baligar and Bennett (1986) reported that the recovery efficiency of fertilizer P by crops are only 10 to 30% of the quantity applied to the soil and the remaining 70 to 90% have been accounted by fixation and immobilization. Fageria *et al.*(2013) also reported that the APE of rice plants varied from 15.2 to 41.2%.

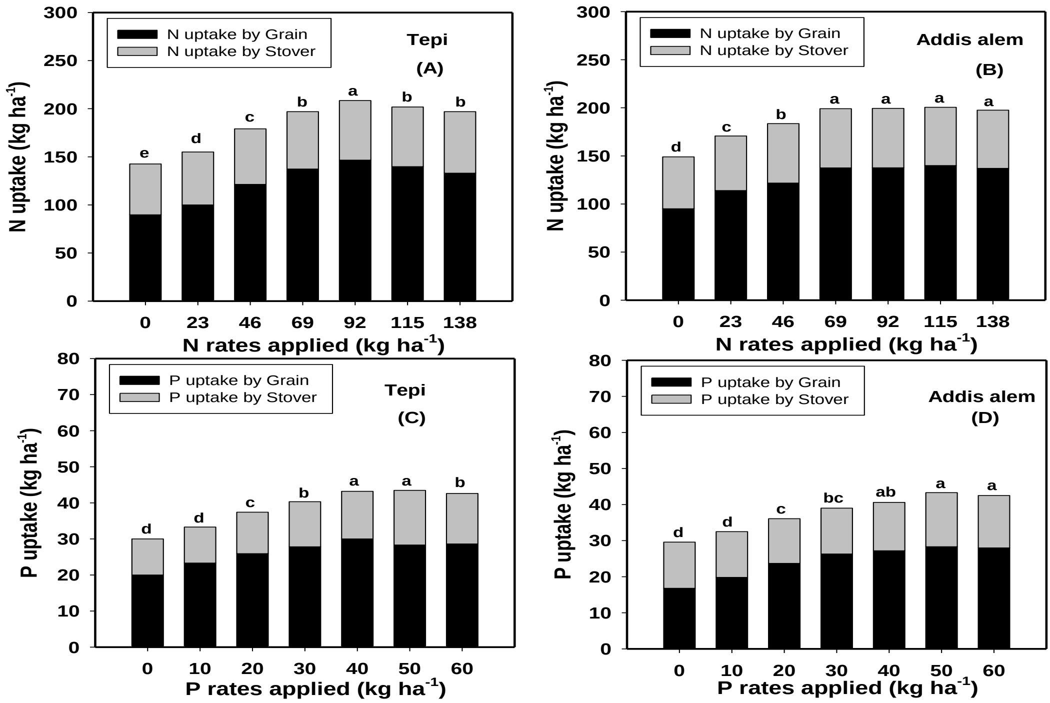

Figure 3. Maize N and P uptake as influenced by N and P fertilizer rates

Economic analysis

The partial budget analysis of fertilizer rates revealed that the maximum net benefit was attained from the application of 69 kg N ha−1 and 40 kg P ha−1 at Tepi, while the least gross margin was obtained from the unfertilized treatment (Table 5). Similarly, at Addis Alem, the partial budget analysis of fertilizer rates revealed that the maximum net benefit was attained from the application of 69 kg N ha^{-1} and 30 kg P ha^{-1} while the least net benefit was obtained from the unfertilized treatment (Table 6). The marginal rate of return (MRR) analysis showed that the treatment with 46 kg N $ha^{-1}$and 20 kg P ha^{-1} gave the highest MRR % at Tepi. Likewise, at Addis Alem, the highest MRR % was attained from the application of 69 kg N ha^{-1} and 20 kg P ha^{-1}.

Table 4. Effect of N and P rate on use efficiency of N and P at Tepi and Addis Alem

(kg N/ha)	Tepi				Addis Alem			
	AE (kg^{-1})	PE (kg^{-1})	APE (kg^{1})	ARE (%)	AE (kg^{-1})	PE($kgkg^{1}$)	APE ($kgkg^{1}$)	ARE (%)
0	-	-	-	-	-	-	-	-
23	24^{c}	67^{a}	38^{a}	55^{c}	45^{a}	69^{bc}	52^{a}	80^{a}
46	33^{a}	55^{b}	42^{a}	79^{a}	30^{b}	78^{a}	37^{b}	69^{a}
69	30^{a}	49^{c}	32^{b}	77^{a}	29^{b}	71^{b}	44^{b}	68^{a}
92	20^{d}	44^{c}	28^{b}	67^{b}	22^{c}	70^{bc}	40^{b}	51^{b}
115	11^{e}	32^{d}	14^{c}	48^{c}	17^{dc}	66^{bc}	40^{b}	46^{bc}
138	8^{e}	30^{d}	9^{d}	39^{d}	13^{d}	64^{b}	37^{b}	37^{c}
LSD (0.05)	3.40	5.90	4.80	7.50	7.00	6.89	7.60	13.39
CV (%)	8.90	7.02	9.80	6.88	14.80	5.50	10.00	12.50
0	-	-	-	-	-	-	-	-
10	73^{a}	486^{a}	284^{a}	26^{ab}	92^{ab}	358^{a}	339^{a}	29^{a}
20	72^{ab}	260^{b}	196^{ab}	28^{a}	102^{a}	275^{b}	334^{a}	29^{a}
30	65^{bc}	264^{b}	176^{bc}	30^{a}	84^{b}	272^{b}	282^{b}	27^{ab}
40	60^{c}	225^{b}	151^{c}	30^{a}	68^{c}	215^{c}	266^{bc}	25^{bc}
50	34^{d}	221^{b}	119^{d}	28^{a}	47^{d}	168^{d}	228^{dc}	23^{c}
60	25^{e}	211^{b}	115^{d}	20^{b}	43^{d}	171^{d}	204^{d}	20^{d}
LSD (0.05)	8.38	58.00	26.00	6.40	11.72	36.64	49.58	2.80
CV (%)	8.40	11.40	8.33	13.00	8.87	8.28	9.89	6.00

Means in columns followed by the same letter are not significantly different ($P<0.05$) according to LSD test; = grain yield; CV= Coefficient of variation; LSD = Least significant differences, AE = agronomic efficiency, PE = Physiological efficiency, APE = Agro-physiological efficiency and ARE = apparent recovery efficiency

Table 5. Partial budget and dominance analysis of maize yield response for different N and P fertilizer rates at Tepi

N (kg ha^{-1})	Grain yield (kg ha^{-1})	Adjusted grain yield (kg ha^{-1})	Gross income (birr ha^{-1})	Variable cost (birr)			Net Benefit (birr ha^{-1})	Cost dominance	MRR%
				Fertilizer	Fertilizer application	Total			
0	6220.75	5598.67	36391.36	0.00	0.00	0.00	36391.36		
23	6751.35	6076.21	39495.39	632.98	1666.50	2299.48	37195.91	Non-dominated	34.99
46	7731.45	6958.31	45229.01	1265.96	1666.50	2932.46	42296.55	Non-dominated	805.81
69	8042.26	7238.03	47047.20	1898.94	1666.50	3565.44	43481.76	Non-dominated	187.24
92	8092.67	7283.41	47342.15	2531.92	1666.50	4198.42	43143.73	Dominated	
115	7694.81	6925.33	45014.64	3164.90	1666.50	4831.40	40183.24	Dominated	
138	7197.20	6477.48	42103.61	3797.88	1666.50	5464.38	36639.23	Dominated	
P (kgha^{-1})									
0	6914.61	6223.15	37338.91	0.00	0.00	0.00	37338.91		
10	7539.17	6785.26	40711.54	675.00	555.50	1230.50	39481.04	Non-dominated	174.09
20	8203.76	7383.39	44300.31	1350.00	555.50	1905.50	42394.81	Non-dominated	431.67
30	8653.83	7788.44	46730.67	2025.00	555.50	2580.50	44150.17	Non-dominated	260.05
40	8918.38	8026.54	48159.27	2700.00	555.50	3255.50	44903.77	Non-dominated	111.64
50	8287.09	7458.38	44750.27	3375.00	555.50	3930.50	40819.77	Dominated	
60	8208.27	7387.44	44324.66	4050.00	555.50	4605.50	39719.16	Dominated	

Non-dominated are treatments that gave higher gross margin than treatments with lower N and P fertilizer rates; dominated is the treatment that gave lower grossmargin than treatments with lower N fertilizer rates

Table 6. The marginal rate of return analysis of non-dominated maize grain yield response for different N and Pfertilizer rates at Addis Alem

N (kg ha^{-1})	Grain yield (kg ha^{-1})	Adjusted grain yield (kg ha^{-1})	Gross income (Birr ha^{-1})	Variable cost			Net Benefit (birr ha^{-1})	Cost dominance	MRR%
				Fertilizer	Fertilizer application	Total			
0	5884.55	5296.09	34424.59	0	0	0.00	34424.59		
23	6980.84	6282.75	40837.90	632.98	1666.50	2299.48	38538.42	Non-dominated	649.91
46	7233.62	6510.26	42316.68	1265.96	1666.50	2932.46	39384.22	Non-dominated	133.62
69	8158.46	7342.62	47727.02	1898.94	1666.50	3565.44	44161.58	Non-dominated	754.74
92	8052.51	7247.26	47107.20	2531.92	1666.50	4198.42	42908.78	Dominated	
115	8030.84	7227.76	46980.43	3164.90	1666.50	4831.40	42149.03	Dominated	
138	7861.63	7075.46	45990.51	3797.88	1666.50	5464.38	40526.13	Dominated	
P (kgha^{-1})									
0	5458.91	4913.02	29478.14	0	0	0	29478.14		
10	6396.38	5756.74	34540.46	675	555.5	1231	33309.96	Non-dominated	311.40
20	7699.37	6929.43	41576.58	1350	555.5	1906	39671.08	Non-dominated	942.39
30	8152.63	7337.37	44024.20	2025	555.5	2581	41443.70	Non-dominated	262.61
40	8258.59	7432.73	44596.39	2700	555.5	3256	41340.89	dominated	
50	8294.70	7465.23	44791.39	3375	555.5	3931	40860.89	Dominated	
60	7876.07	7088.46	42530.77	4050	555.5	4606	37925.27	Dominated	

Non-dominated are treatments that gave higher gross margin than treatments with lower N and P fertilizer rates; dominated is the treatment that gave alower gross margin than treatments with lower N fertilizer rates

From the results of the experiment, it is possible to conclude that nitrogen and phosphorus fertilizer had a significant influence on maize productivity in the study sites.The economics of fertilizer rates revealed that the maximum net benefit was attained from the application of 69 kg N ha^{-1} and 40 kg P ha^{-1} at Tepi. Similarly, the partial budget analysis of fertilizer rates revealed that the maximum net benefit was attained from the application of 69 kg N ha^{-1} and 30 kg P ha^{-1} at Addis Alem. From this study, it has been clearly understood that N and P application to maize in these sites beyond these rates may not be economical and desirable. Therefore,since fertilizer recommendation is not site-specific, these application rates may save farmers from incurring extra costs for blanket fertilizer recommendations, which is in excess for the study areas.

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