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Research Article

Response of Maize Yield and Yield Related Components to Different Levels of Nitrogen and Phosphorus Fertilizers

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Abstract

A field experiment was conducted to investigate the effects of nitrogen and phosphorus fertilizers on yield and yield components of maize and to determine agronomically optimum levels of N and P for recommendation at Abol woreda. Factorial arrangements of five levels of N (0, 30, 60, 90 and 120 kg N/ha) and five levels of P (0, 15, 30, 45 and 60 kg P/ha) were laid out in a randomized complete block design (RCBD) with three replications. Highly significant effects ($P < 0.01$) were observed on almost all agronomic parameters studied due to the main effects of N and P and their interaction. Similarly, days to 50% tasseling, silking and physiological maturity were significantly ($P < 0.01$) affected due to N and P applications. The highest grain yield (6,155 kg/ha) were obtained with the highest rate of N (120 kg N/ha) and P (45 kg P/ha) while the nitrogen use efficiency was greatest due to 90 kg N/ha as against all other N rates. Likewise, application of N and P significantly ($P < 0.01$) influenced dry biomass yield, 1000 kernel weight, harvest index, leaf area index, plant height, ear length, and number of cobs per plant. Grain yield and biomass yield exhibited significantly positive association with almost all parameters considered except with days to 50% physiological maturity, which had a negative correlation. Based on the present finding, the maximum grain yield (6155 kg/ha) was obtained due to highest level of N (120 kg N/ha) and 45 kg P/ha. However, it is too early to reach at a conclusive recommendation since the experiment was conducted only at one location for one cropping season. Therefore, further studies replicated in season and across locations are needed to recommend agronomically optimum and economically feasible levels of nitrogen and phosphorus fertilizers rate for Gambella.

Keywords: Maize; Nitrogen; Nitrogen Use Efficiency; Phophorus; Fertilizer; Grain Yield

Introduction

Maize (*Zea mays* L.) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions and successful cultivation in diverse seasons and ecologies for various purposes. It is cultivated on nearly 150 million hectares in about 160 countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36% (782 million tons) of the global grain production [1].

In Ethiopia, maize is a major crop in terms of production, 39.32 million quintals/year during 2008 and 009 main-season [2], consumption and income generation for both resource constrained men and women. The crop is one of the three most popular crops grown widely. Its total annual production (3,900,000,032tons) and productivity (2.24 tons/ha) exceeded all other cereal crops, only Teff surpassed it in area coverage [2]. In Gambella regional state, maize is grown over a relatively large area of land (6,001.69 hectares) with the highest yield of all crops grown in the region (138,417.82 quintals) yielding 23.06 quintals per hectare.

Increased plant population especially above a critical optimum, on a particular environment results in increased plant height and lodging before grain filling, very small ears of maize, and often barren stalks and ultimately reduce the grain yields. Farmers usually plant 3-4 plants per hill and these spacing results in over competition and decrease a yield [3-13].

The maize variety; *Gambella composite* (*Gussau*) which is used in this study is released for production particularly under agroecological zone of Gambella region. Despite the larger area of the region under maize production; the average yield of the crop under farmers' production is 22.69 q/ha as compared to 65q/ha reported from experimental field. The low productivity of maize is attributed to many factors especially poor agronomic practices like using of inappropriate plant population density and fertilizer rate. This study is therefore, aimed at evaluating the effect of various levels of phosphorus and nitrogen fertilizers on the yield and yield components of maize.

Materials and Methods

Description of the study area

The field experiment was conducted during 2017 main cropping season under rain-fed conditions at Abol woreda of Gambella region. Annual mean minimum and maximum temperatures in Gambella are 25^{0}C and 42^{0}C, respectively. Mean annual rainfall of the area varies from 800mm to 1500 mm with a long-term average of 1400 mm. The site is located at an altitude of 526 meter above sea level Most of the soils of the region are fluvisols (alluvial soil type) which have pH of 6.1 and it is slightly acidic.

Treatments, Experimental Designs and Procedures

Gambella composite (*Gussaw*) variety was used for the study. The fertilizer treatments included five levels of nitrogen (0, 30, 60, 90 and 120 kg N/ha) and five levels of phosphorus (0, 13.3, 26.6, 39.9 and 53.2 kg P/ha). The experiment was laid out in a Randomized Complete Block Design (RCBD) of 5 x 5 factorial arrangements with three replications. Nitrogen was applied in two equal splits (half at sowing and the other half at knee height stage) as Urea (46% N). Unlike nitrogen, the full rate of Phosphorus was applied at sowing as Di-ammonium phosphate. 3.75m x 4m plot size was used as an experimental unit.

Results

The application of N alone had greatly delayed tasseling, silking, and crop physiological maturity as compared to the application of P alone and N and P in combination. Increasing N from 0 to 120 kg N/ha did not show consistent increment of days to 50% tasseling and silking, whilst days to 50% maturity showed consistently increased when increased levels of N was applied alone.

Application of P alone had a highly significant ($P < 0.01$) influence on days to 50% tasseling, silking, and physiological maturity. But no significant difference was observed between 0, 15, 30,45 kg P/ha in days to 50% tasseling and significant difference due to P alone obtained only at 60 kg P/ha (Table). For days to 50% silking there was significant difference between all P levels. Similarly, for 50% physiological maturity no significant difference was observed between 15 and 30 kg P/ha and between 45 and 60 kg P/ha. Application of P had no remarkable effect on days to 50% tasseling and silking, while its hastened days to 50% physiological maturity from 2-6 days as compared to the control treatment (Tables 1, 2, 3).

	P rate (kg/ha)					
N rate (kg/ha)	**0**	**15**	**30**	**45**	**60**	**Mean**
0	75.7bcd	75.3cde	75.7bcd	75.3cde	77.3a	75.8ab
30	77.3a	75.3cde	74.7def	75.3cde	77.3a	76.0a
60	77.0ab	75.7bcd	75.7bcd	74.0efg	74.0efg	75.3b
90	76.7abc	74.0efg	73.3fgh	73.0gh	72.0h	73.8c
120	77.0ab	74.0efg	68.7i	68.7i	69.0i	71.5d
Mean	76.7a	74.9b	73.6cd	73.3d	73.9c	
SEM±	0.16	0.16		0.13		
LSD0.01	0.62	0.62		1.38		

Table 1: Days to 50% tasseling of maize as influenced by applied N and P.

Means followed by the same letter are not significantly different at 1% probability level according to Duncan's Multiple Range Test.

	P rate (kg/ha)					
N rate (kg/ha)	0	15	30	45	60	Mean
0	84.7abc	84.7abc	84.0cde	83.7cde	83.7cde	84.1a
30	85.7a	84.3bcd	83.6cde	83.0efg	83.0efg	83.9a
60	84.7abc	83.3def	83efg	82.3fgh	81.3h	82.9b
90	85.3ab	82.3fgh	80.0i	77.3jk	77.3jk	80.5c
120	84.3bcd	82.0gh	76.7jk	77.7j	76.3k	79.4d
Mean	84.9a	83.3b	81.5c	80.8d	80.3d	
SEM±	0.17	0.17		0.13		
LSD0.01	0.64	0.64		1.10		

Table 2: Days to 50% silking of maize as influenced by applied N and P.

Means followed by the same letter are not significantly different at 1% probability level according to Duncan's Multiple Range Test.

	P rate (kg/ha)					
N rate (kg/ha)	0	15	30	45	60	Mean
0	114.3b	112efg	112efg	109h	108h	111.1c
30	114.3b	114.3b	113.7bcd	112efg	112.3def	113.3a
60	114.3b	114.3b	112efg	110.7g	110.7g	112.4b
90	116a	112.7cde	111fg	107.7hi	108.7h	111.2c
120	117a	114bc	112efg	108h	106.3i	111.2c
Mean	115.2a	113.5b	112.1c	109.5d	109.2d	
SEM±	0.16	0.16		0.12		
LSD0.01	0.61	0.61		1.37		

Table 3: Days to 50% physiological maturity of maize as influenced by applied N and P.

Means followed by the same letter are not significantly different at 1% probability level according to Duncan's Multiple Range Test.

Increased nitrogen application in combination with P decreased days to 50% physiological maturity by 1 - 3 days while no significant difference was observed between 0, 90, and 120 kg N/ha. Similarly, application of P in combination with N decreased days to 50% physiological maturity by 1 - 5 days while no significant difference was observed between 45 and 60 kg P/ha.

The analysis of variance revealed statistically significant ($P < 0.01$) difference in plant height due to main effects of N and P and the interaction of N and P applications (Table 4). Increasing N from 0 to 120 kg N/ha increased plant height consistently. As compared to the check treatment, the increment ranged from 4 to 17%. This increment in plant height due to N fertilization may be due to the increase in cell elongation.

Application of N and P in combination gave higher maize plant height as compared to N or P alone. The highest plant height (216.1 cm) was obtained by the highest rates of N and P (120 kg N/ha and 60 kg P/ha) while the lowest plant height of 170.5 cm was obtained from the control plot (0 kg N/ha and 0 kg P/ha).

Ear length was measured after harvest and it showed statistically significant ($P < 0.01$) difference due to main effects of N and P levels and interaction of N and P application (Table 5). Increasing N from 0 to 120 kg N/ha and P levels from 0 to 60 kg P/ha showed a consistent ear length increment.

The mean separation for the interaction effect revealed that no significant ear length difference was observed between 90 and 120 kg N/ha when applied in combination with 30 kg P/ha indicating that application of N ferilizers beyond 90 kg N/ha did not significantly increase ear length.

P rate (kg/ha)						
N rate (kg/ha)	0	15	30	45	60	Mean
0	170.5k	177.7j	189.9hi	186.9i	189.1i	182.8e
30	177.3jk	193.2fghi	197.5efgh	193.4fghi	204.0cde	193.1d
60	190.5hi	198.6efg	192.4fghi	207.9bc	210.0abc	199.9c
90	191.9ghi	206.4bcd	211.2abc	211.5abc	211.7abc	206.5b
120	199.7def	210.5abc	212.5ab	213.5ab	216.1a	210.4a
Mean	185.9d	197.3c	200.7b	202.7b	206.2a	
SEM±	0.81	0.81		0.63		
LSD0.01	3.09	3.09		6.89		

Table 4: Plant height (cm) of maize as influenced by applied N and P levels.

Means followed by the same letter are not significantly different at 1% probability level according to Duncan's Multiple Range Test.

P rate (kg/ha)						
N rate (kg/ha)	0	15	30	45	60	Mean
0	12.0i	11.9i	13.2efgh	12.7ghi	13.6defg	12.7e
30	12.3hi	12.9fghi	13.4defg	13.5defg	13.9def	13.2d
60	12.8fghi	13.6defg	13.6defg	15.2bc	15.6b	14.2c
90	13.4defg	14.0de	15.4b	15.1bc	15.7b	14.7b
120	14.0de	14.4cd	15.8b	16.7a	17.1a	15.6a
Mean	12.9d	13.4c	14.3b	14.6b	15.2a	
SEM±	0.11	0.11		0.08		
LSD0.01	0.41	0.41		0.92		

Table 5: Ear length (cm) of maize as influenced by applied N and P levels.

Means followed by the same letter are not significantly different at 1% probability level according to Duncan's Multiple Range Test.

Grain Yield

The analysis of variance indicated that highly significant ($P < 0.01$) grain yield differences due to the application of N, P and their interactions. Increasing N levels from 0 to 120 kg N/ha showed linear and consistent yield increment. The average maize grain yield for the various N treatments ranged from 2604 to 4185 kg/ha with a yield increment of 18 to 89% over the control treatment, respectively. Similarly, increasing P levels from 0 to 60 kg P/ha also showed linear and consistent grain yield increment due to P application.

The average maize grain yield for the various P treatments ranged from 2789 to 3706 kg/ha with a yield increment of 26 to 67% over the control treatment, respectively.

The highest maize grain yield (6155 kg/ha) was obtained from the highest levels of N (120 kg/ha) and P (60 kg/ha) applied in combination (Table 6). The mean of separation for the main effect N and the interaction indicated that still there exists a room for increasing maize grain yield through the application of N fertilizers beyond 120 kg N/ha whilst in case of P the mean separation for the interaction effect showed no significant grain yield difference ($P < 0.01$) was observed between 45 and 60 kg P/ha when applied in combination with 120 kg N/ha. Therefore, application of fertilizers beyond 45 kg P/ha did not significantly increase maize grain yield (Table 7). The low yield in N unfertilized plots might have been due to reduced leaf area development resulting in lesser radiation interception and, consequently, low efficiency in the conversion of solar radiation.

P rate (kg/ha)						
N rate (kg/ha)	0	15	30	45	60	Mean
0	10	10	10	10	10	10b
30	10	10	10	10	10	10b
60	10	10	10.3	10.6	10.6	10.3ab
90	10	10	10.6	11	11.3	10.6a
120	10	10.6	10.3	11.3	11.6	10.8a
Mean	10c	10.1bc	10.2abc	10.6ab	10.7a	
SEM±	0.15	0.15		0.11		
LSD0.01	0.56	0.56		NS		

Table 6: Number of cobs per 10 plants of maize as influenced by applied N and P levels.

Means followed by the same letter are not significantly different at 1% probability level according to Duncan's Multiple Range Test.

P rate (kg/ha)							
N rate (kg/ha)	0	15	30	45	60	Mean	Increase over control
0	2216m	2556kl	2670jk	2760ijk	2816hij	2604d	17.5
30	2683jk	2346lm	2653jk	2673jk	2893ghij	2650d	19.5
60	2930ghi	2750ijk	3113efg	3153def	3390d	3073c	38.6
90	3040fgh	3106efg	3923c	4306b	4273b	3373b	68.3
120	3073efg	3310de	4323b	5060a	5156a	4185a	88.8
Mean	2789d	2814d	3336c	3596b	3706a		
SEM±	25.71	25.71		19.91			
LSD0.01	97.52	97.52		218.10			

Table 7: Grain yield (kg/ha) of maize as influenced by applied N and P levels.

Means followed by the same letter are not significantly different at 1% probability level according to Duncan's Multiple Range Test.
Increase over control (%) is from 0 kg N and 0 kg P/ha treatment.

Conclusion

Fertilization needs to be rationally used in order to avoid a negative ecological impact and undesirable effects on the sustainability of agricultural production system.

It was observed that, the application of N and P significantly affected all the agronomic traits studied. The interaction effects of N and P also brought highly significant effect on these traits except number of cobs per plant. The highest grain yield (6155 kg/ha) was recorded at 120 kg N/ha and 60 kg P/ha while the productivity index was more for the 90 kg N/ha. Even if, maximum yield was obtained at 60 kg P/ha, no significant difference was observed between 45 and 60 kg P/ha when applied in combination with 120 kg N/ha. Mean separations for the main effects of N and interaction effect indicated that still there exists a room for increasing maize grain yield through the application of N fertilizers beyond 120 kg N/ha while mean separation for the main effect of P and the interaction effect revealed that application of P beyond 45 kg P/ha did not significantly increase maize grain yield.

The main effects of N and P and their interaction significantly affected phonological events like days to 50% tasseling, silking and physiological maturity. Increasing N fertilization from 0 to 120 kg N/ha significantly delayed days to 50% physiological maturity of maize where the maximum days (117days) was recorded at 120 kg N/ha. Unlike N, increasing P application from 0 to 60 kg P/ha significantly hastened days to 50% physiological maturity. The minimum days (108) to maturity were recorded at 60 kg P/ha when it was applied alone. The application of N in combination with P reasonably hastened the days to 50% physiological maturity and the minimum days (106.3) was recorded at 120 kg N/ha and 60 kg P/ha.

Based on the present finding, the maximum yield (6155 kg/ha) was obtained by the highest levels 120 kg N/ha and 53.2 kg P/ha while no significant difference was observed between 45 and 60 kg P/ha as the mean of separation for the interaction effect revealed. It is too early to reach at a conclusive recommendation since the experiment was carried out only in one location for one cropping season; hence further detail studies replicated in season are needed to recommend agronomically optimum and economically feasible levels of N and P fertilization.

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