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Growth and Yield Responses of Maize (Zea Mays L.) to Different Nitrogen Rates under Rain-Fed Condition in Dilla Area, Southern Ethiopia

Yacob Alemayehu[1] Meshu Shewarega[2]
1.Department of Plant Sciences, College Agriculture and Natural Resources, Dilla University, Ethiopia
2.Department of Horticulture, College Agriculture and Natural Resources, Dilla University, Ethiopia

Abstract
Efficient use of N fertilizer for maize (*Zea mays* L.) production is important for maximizing economic return and minimizing NO_3 leaching and/or environmental pollution. A field experiment was conducted at the research site of Dilla University (Ethiopia) during the 2014 cropping season, to determine the effect of different levels of N on growth and yield attributes of maize. A well-adapted maize variety, *Pioneer*, was tested at four different N rates: 0, 23, 46 and 69 kg N ha^{-1}. The number of leaves $plant^{-1}$, plant height, cob length, total biomass and grain yield were significantly ($p < 0.05$) influenced by varying N levels. Among N levels, the highest mean grain yield (8.62 t ha^{-1}) was obtained by an application of 69 kg N ha^{-1}. There were 13.9%, 22.4% and 30.8% increases in grain yield from the application of 23, 46 and 69 kg N ha^{-1}, respectively, over the control. Maximum plant height (2.97 m), and total biomass (16.72 t ha^{-1}) were obtained by an application of 69 kg N ha^{-1}, whereas maximum cob length (36.3 cm) and yield component (3.39 t ha^{-1}) were recorded from 46 kg N ha^{-1}. Based on the results, it was concluded that application of N at 69 kg ha^{-1} can be recommended for achieving optimum grain yield under sub-humid environment of Dilla area.
Keywords: Growth, Grain yield, Maize, Nitrogen

1. INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereals in Ethiopia, and cultivated on large scale, ranking second largest food security crop after teff (*Eragrostis tef*). According to the CSA (2013) reports of the year 2013 main cropping season, out of the total grain crop areas of 9.60 x 10^6 hectares (ha.), maize accounts for 16% (~2.01 x 10^6 ha) area coverage with annual production of 6.1 million tons (t), and an average yield of 2.24 t ha^{-1}. It is mainly produced in southern, western, central and eastern regions of Ethiopia (MoARD, 2009). But specifically, the mid-altitude, sub-humid agro-ecology (1,000-1,800 m above sea level) is the most important maize producing environment in Ethiopia (Wende, 2013).

Despite its large area of production and importance, the national average yield of maize is low (2.24 t ha^{-1}) far below the global average yield of 4.9 t ha^{-1} (Michael, 2009). This low productivity of maize is mainly attributed to many factors including frequent occurrence of drought, declining soil fertility (IFPRI, 2010), poor agronomic practice, limited use of inputs, poor seed quality, disease and pests (FAO, 2012; Wende, 2013). Among these, declining soil fertility (due to continuous cultivation with low input) is a major limitation to crop production and productivity in smallholder farms in Ethiopia (Tesfa *et al*., 2012). According to FAO (2001; 2012), nitrogen (N) and phosphorus are the most limiting nutrients for food production in the humid highlands of East Africa.

Nitrogen is a vital plant nutrient and a major growth and yield determining factor required for maize production. It makes up to 4% of dry matter of the plants, and is a component of protein, nucleic acids and many other compounds essential for plant growth processes including chlorophyll and enzymes (Tisdale *et al*., 1999). Its availability in sufficient quantity throughout the growing season is essential for optimum maize growth. The optimal amounts of other essential elements such as phosphorus in the soil cannot be utilized efficiently, if N is deficient in plants. Several researchers (Jehan *et al*., 2006; Festus *et al*., 2007; Onasanya *et al*., 2011; Hafiz *et al*., 2011 and Mohamed and Hassan, 2011) ascribed lower yield in maize when the crop was subjected to a high dose of N, while time of N application improved N uptake and protects the soil environment. Similarly, at low N supply, crop growth rate slows down causing reproductive structures to decline, and as a result lower maize grain yield and its components (Ronald *et al*., 2005; Hafiz *et al*., 2011; Waga, 2011; Mahamed and Awale, 2013; Merkebu and Ketema, 2013), lesser harvest index and leaf area duration are achieved (Akmal *et al*., 2007; Festus *et al*., 2007).

Fertilizer recommendations in Ethiopia are based either on the pooling of trial results nationwide or extrapolating results of a specific research center (Waga, 2011), irrespective of inherent soil properties of specific areas. Such recommendations representing large geographic regions/area are generally inadequate, and may provide an erroneous N recommendation as a result of diverse soil-climate situations of the country. Reports by IFPRI (2010) also emphasized lack of site specific fertilizer recommendations as among the major challenges of soil fertility and crop production in Ethiopia. This is the evidence that a wide range of N rates for maize were reported for various places of Ethiopia. Reports from Mizan-Teferi (southwestern Ethiopia) by Merkebu and Ketema (2013) indicated that highest maize yield was obtained from 60 kg ha^{-1} N application. On-farm trials, in the Shebedino area (southern Ethiopia), showed that better yield could be obtained from 46 kg N ha^{-1} (ARC, 1993). In a similar experiment, Mahamed and Awale (2013) reported that maximum grain yield was at 100 kg N ha^{-1} in eastern Ethiopia. Although various research studies have been conducted on high and mid-altitude areas of Ethiopia, there are as yet many maize-producing areas deprived of new technology, including appropriate rate of fertilizer. The sub-humid area of Gedeo Zone (southern Ethiopia) is the one among these. In this area, maize is a staple food crop for a large number of people, and its production covers about 4,874.5 ha (56%) of the total area of land for cereals (8,734.8 ha) under cultivation (CSA, 2013). To feed this large number of people and ever-increasing population, increasing crop productivity per unit area should be given due emphasis.

Proper N application is critical to meet crop needs, and provides considerable opportunities for improving crop productivity and sustaining soil fertility in intensive cropping systems. Conversely, excessive application of N is uneconomical, environmentally unsafe and potentially detrimental to the crop. Considering its high purchasing cost and detrimental effects due to deficient/overdose on crop production and environmental threat, information on crop response to N fertilizer application is crucial to develop profitable and sustainable crop production. In view of this, the present study was aimed at: (1) investigating the effect of different rates of N fertilizer application on growth and yield of maize; (2) providing the optimum N rate for productivity of maize under rain-fed condition of Dilla area, southern Ethiopia.

2. MATERIALS AND METHODS

2.1. Site descriptions

The experiment was conducted at the research farm of Dilla University, during 2014 main cropping season. The research site is located at 6^{0} 25' 24" N, 38^{0} 17" 10 E, in Dilla, southern Ethiopia; at about 365 km south of the capital, Addis Ababa at an elevation of 1,452 m above sea level. Dilla area receives an average annual rainfall of 1,245 mm with monthly maximum and minimum temperatures of 21.5 and 12.6 ^{0}C, respectively (Figure 1) (World weather online, 2015). The experimental growing period was between June and October. The total rainfall for the growing year and the growing period were 1,245.1 mm and 547.1 mm, respectively. The fifteen years (2000-2014) average rainfall from June to October was 628 mm. This shows that the total rainfall for the crop growing months was lower than the mean total rainfall trend of similar months of the area in the past fifteen years.

The dominant soil type of Dilla area is Nitisols, which is characterized by a highly developed, deep soil profile. Topsoil (30 cm) of the study site was clay in texture, and moderately acidic in reaction with a pH of 5.8. The total nitrogen content of the soil was 0.35%, which is within the medium range based on the ratings set by Tekalign (1991). The available P content (1.8 mg kg^{-1}) was within low range, according to the ratings set by Olsen *et al*. (1954), indicating the necessity of P-fertilizer application to correct the deficiency of the soils.

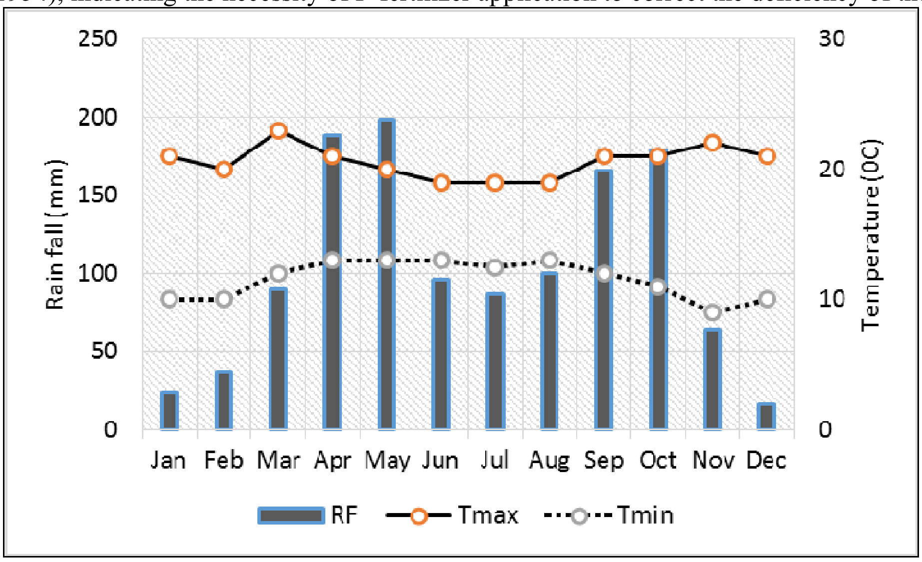

Figure 1. Monthly mean maximum and minimum temperature, and rain fall of the study area (2000-2014).

2.2. Treatments, experimental design and procedures

The experiment consists of four treatments of N level (N_1 = 0 kg ha^{-1} (control), N_2 = 23 kg ha^{-1}, N_3 = 46 kg ha^{-1}, N_4 = 69 kg ha^{-1}) laid out in randomized complete block design (RCBD), with three replications of each treatment. Maize variety namely: *pioneer* was used as a test crop, which is well-adapted and commonly used by farmers of the study area. The experimental area was cleaned, ploughed and prepared well, and each plots levelled up to 5 cm. An area of 11.25 m^2 (3 x 3.75 m) was used as experimental unit (plot), accommodating 5 rows of each 3m length. Spacing between row and plants was 0.75 m and 0.25 m respectively. The outer-most rows of each plot were considered as borders and the three middle rows were used as harvestable rows.

Urea (46-0-0) was used as N fertilizer source. Nitrogen was applied in two equal splits, wherein 1/2 of N-rate applied as basal at planting and the remaining 1/2 dose was side-dressed at six-leaf stage (35 DAS). In addition, phosphorus fertilizer at a rate of 20 kg ha^{-1} was applied to all treatments, in which the total dose of phosphorus was applied by banding at the time of planting. All other agronomic practices like hoeing, weeding, pest and disease control were kept similar manner to all the plots during the experimental period.

2.3. Data Collection and Analysis

Crop phenology data *viz.* days to emergence, tasseling and physiological maturity were recorded when 50% of the plants in a plot emerged and flowered, and 80% of the plants attained yellow coloration, respectively. The growth parameters: leaf number per plant, cob length, and plant height were measured from six randomly selected plants from the central rows in each plot. Plant height (cm) was measured from the base of the plant to the upper most leaves. Number of functional leaves $plant^{-1}$ was determined by visual count when the plant attained silking stage, and cob length (cm) was measured during harvesting the crop. Grain yield, yield components and total biomass yield were determined from the net plot area (3m x 2.25m = 6.75m^2) excluding the boarder rows, and expressed as tonnes per hectare basis. Grain yield was measured using an electronic balance and then adjusted to 12.5% moisture content. Harvest index (%) was calculated as the ratio of grain yield to total biomass yield.

The collected data were subjected to the analysis of variance (ANOVA) procedures, using SAS 9.2 software (SAS Institute Inc., 2002). Differences among the treatments means were compared using Least Significant Difference (LSD) test at 0.05 probability level. In addition, Pearson's correlation coefficient analyses were performed to determine the relationships among selected growth and yield related attributes.

3. RESULTS AND DISCUSSION

3.1. Phenological and growth attributes

The analysis of variance (ANOVA) result indicated that days to emergence of maize was not significantly ($p > 0.05$) affected by N level (Table 1). On average, seedlings took about 10 days to emerge more than 50% of maize in each plot (Table 2). During germination the seedling mostly depends on stored food rather than on external nutrients. Favorable moisture condition due to uniformly distributed rainfall during sowing and good seedbed preparation also contributed to germination of maize on similar dates. Because of this, significant variation might not be observed on days to emergence by fertilizer application.

Days to tasseling and physiological maturity of maize were significantly ($p < 0.05$) influenced by N levels (Table 1). Delay in tasseling time of maize was greater at higher rates of N, though treatment N_2 (46 kg N ha^{-1}) had shorter days to tasseling than others. Tasseling was delayed by 3 days when 69 kg N ha^{-1} was applied compared with the control, and it was significantly higher than the others (Table 2). Similarly, the maximum days to physiological maturity of maize (141.7 days after sowing, DAS) was achieved by N_3 (69 kg N ha^{-1}), followed by N_2 (135 DAS) where N was applied at the rate of 46 kg ha^{-1}. Delay in maturity of maize was greater at higher rates of N, as about 16 more days were required for the 69 kg ha^{-1} N treatment compared to the control which took 125 days to maturity (Table 2). This might be attributed to the behavior of the N fertilizer, which increases vegetative growth of the crop when more N is applied. This result disagrees with the findings of Merkebu and Ketema (2013); however it is quite in line with Jehan *et al*. (2006) and Mahamed and Awale (2013) who reported that days to tasseling and maturity were significantly affected by the successive additions of N, and with increasing rates of N fertilizer, the crop took a shorter period to mature than the treatments receiving either no or lower rates of N.

Table 1. Analysis of variance for phenology, growth parameters and yield and yield components of maize as influenced by different level of N application at Dilla, during 2014 main cropping season.

Parameters	Sources of variation			Treatment F value	
	MSB (2)	MST (3)	MSE (6)	F	*Pr> F*
Days to emergence	0.083	0.033	0.41	0.08 ns	0.70
Days to tasseling	0.08	11.64	0.64	18.22**	0.002
Days to maturity	3.08	176.33	2.74	64.12***	<0.0001
Plant height (cm)	0.013	0.126	0.004	37.12***	0.0003
Leaf number plant^{-1}	0.083	3.64	0.64	5.70*	0.0344
Cob length (cm)	0.33	34.89	1.89	18.47**	0.002
Yield (t ha^{-1})	0.09	1.16	0.16	7.26*	0.02
Yield components (t ha^{-1})	0.09	7.49	0.038	196.38***	<0.0001
Total biomass (t ha^{-1})	0.28	13.04	0.16	82.44***	<0.0001
Harvest index	0.0002	0.018	0.0004	48.95***	0.0001

*MSB=Mean squares of block; MST=Mean squares of treatment; MSE=Mean squares of error; *, **, ***=Significant at 0.05, 0.01 and 0.001 probability levels respectively; ns=non-significant; Values in parenthesis indicates the degrees of freedom.*

In a similar experiment, Hafiz *et al.* (2011) concluded that maize crop took 50 days for tasseling and 103 days for maturity when N was applied at 130 kg ha^{-1} under rain-fed condition. The results presented in Table 1 showed N application rate had a significant effect on the height of maize plant. Maximum plant height (2.97 m) was produced in treatment N_3 (69 kg ha^{-1}) followed by (2.85 m) in N_2 (46 kg N ha^{-1}) and minimum plant height (2.5 m) was recorded from the control (Table 2). All treatments significantly enhanced the plant height over the control (N_0). This tendency can be attributed to higher dose of N, which greatly helps the plant to expose its potential to grow vigorously. Our results are in conformity with those of Jehan *et al.* (2006) and Festus *et al.* (2007) who observed a consistent increase in plant height due to N fertilization.

Table 2. Mean values of crop phenology and growth parameters as affected by different level of nitrogen.

Treatments (N kg ha^{-1})	Days to emergence	Days to Tasseling	Days to Maturity	Plant height (m)*	Leaf No plant^{-1}
N_0 (Control)	10.67	73.33^{b}	125.00^{c}	2.50^{d}	13.3^{b}
N_1 (23)	9.88	73.33^{b}	127.00^{c}	2.67^{c}	14.3^{b}
N_2 (46)	10.67	71.67^{c}	135.00^{b}	2.85^{b}	14.7^{ab}
N_3 (69)	10.67	76.00^{a}	141.67^{a}	2.97^{a}	16.0^{a}
LSD (0.05)	ns	1.597	3.313	0.117	1.597
CV (%)	6.05	1.92	3.55	2.124	5.45

*Means within a column followed by the same letter(s) are not significantly different at p <0.05 (LSD); ns=non-significant; *Plant height was recorded at maturity.*

3.2. Grain yield and yield related attributes

The ANOVA result showed that cob length was significantly affected by N application rates (Table 1). The highest cob length (36.3 cm) was in case of 46 kg N ha^{-1}, followed by 34.0 cm where 69 kg N ha^{-1} was applied. On the other hand, treatment N_0 where no N was applied produced minimum cob length of 30.0 cm, which was statistically similar with N_1 (23 kg N ha^{-1}) application. The reason for the better cob length might be, in fact, adequate supply of N attributed to more photosynthetic activities of the plant.

Grain yield is the end result of many complex morphological and physiological processes occurring during the growth and development of the crop (Ronald *et al.*, 2005). Nitrogen application rate showed highly significant ($p < 0.05$) effect on grain yield (Table 1) as well as its response was linear with increasing N rates (Figure 2). The highest mean value for grain yield (8.62 t ha^{-1}) was obtained from treatment N_3 (69 kg N ha^{-1}), whereas the lowest grain yield (6.59 t ha^{-1}) was recorded from the control (Table 3). The two top N rates (46 and 60 kg ha^{-1}) were statistically at par from each other and they were significantly higher than the other two treatments. There were about 13.9%, 22.4% and 30.8% increases from the application of 23, 46 and 69 kg N ha^{-1}, respectively, over the control. From the results it is clear that N availability must be adequate at vegetative stage to ensure the maximum grain yield. Hence, such a noticeable variations in grain yield among N rates were mostly due to significant differences in growth parameters such as plant height, cob length and total biomass values; these differences result in a significant change in the grain yield among the treatments. This can be supported by strong and positive correlation of grain yield with plant height (r = +0.77; $p < 0.01$), cob length (r = +0.60; $p < 0.05$), yield components (r = +0.75; $p < 0.001$) and total biomass (r = +0.87; $p < 0.001$) (Table 4). In line with this, results of a number of studies (Jehan *et al.*, 2006; Festus *et al.*, 2007; Akmal *et al.*, 2007; Hafiz *et* *al*., 2011, and Mohamed and Hassan, 2011; Merkebu and Ketema, 2013) also reported increasing trends of grain yield with increased rates of applied N fertilizer.

Biological yield is a measure of total dry matter production of the crop during its lifespan, and it reflects the relative growth rate with regard to net assimilation (Ronald et al., 2005). Data pertaining to biomass yield (presented in Table 1) was significantly ($p < 0.001$) influenced by N rate. Significantly highest total biomass (16.72 ha^{-1}) was recorded under N_3 (69 kg ha^{-1}); followed by 15.6 t ha^{-1} obtained from 46 kg N ha^{-1} (Table 3). On the other hand, the biomass yield of two N rates (0 and 23 kg ha^{-1}) were statistically at par from each other and they were significantly lower than the other two treatments. Similarly, a significant difference ($p < 0.001$) in yield components among treatments was observed (Table 1), and it was consistently increased with N rates up to 46 kg N ha^{-1} (Table 3).

Table 3. Mean values of cob length, grain yield, yield component, total biomass and harvest index of maize as affected by different level of nitrogen.

Treatment (N level kg ha^{-1})	Cob length (cm)	Grain yield	Yield component	Total biomass	Harvest Index (%)
		----------------------	t ha^{-1}	----------------------	
N_0 (Control)	30.67^{c}	6.593^{b}	2.890^{c}	11.973^{c}	55.1^{b}
N_1 (23)	31.66^{bc}	7.513^{ab}	2.670^{c}	12.847^{c}	58.5^{a}
N_2 (46)	36.33^{a}	8.073^{a}	3.393^{a}	15.606^{b}	53.6^{b}
N_3 (69)	34.00^{b}	8.617^{a}	3.053^{b}	16.720^{a}	50.4^{c}
LSD (0.05)	2.746	0.797	0.340	1.795	3.12
CV (%)	4.08	5.35	4.74	3.49	2.90

Means within a column followed by the same letter(s) are not significantly different at p < 0.05 (LSD).

Like grain yield, total biomass of maize also increased linearly with increased in N rates from 23 to 69 kg N ha^{-1}, showing more dry matter allocation in favor of the stover under heavier N rates. Total biomass yield was positively and significantly correlated with plant height (r = +0.94; $p < 0.001$), number of leaves $plant^{-1}$ (r = +0.71; $p < 0.01$) and grain yield (r = +0.87; $p < 0.001$) and yield components (r = +0.88; $p < 0.001$), (Table 4).

Nitrogen showed a highly significant ($p < 0.01$) effect on harvest index of maize crop (Table 1). As indicated in Table 3, harvest index invariably declined with increasing levels of applied N. The harvest index recorded with the application of N fertilizer at the rate of 23 kg N ha^{-1} was statistically at par with that at 0 kg N ha^{-1}, while further increase in applied N beyond 23 kg ha^{-1} resulted in significant reduction of harvest index (Table 3; Figure 2).

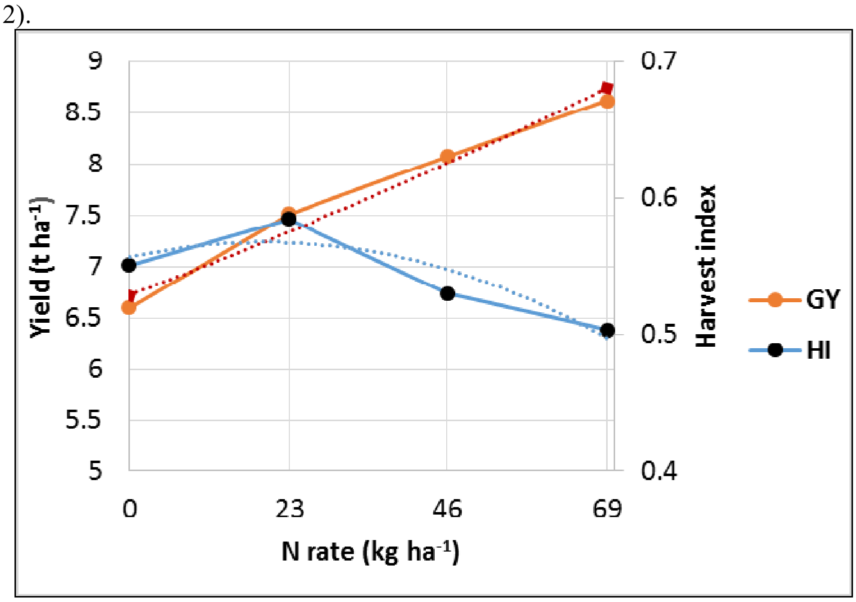

Figure 2: Relationship between N rate, grain yield (GY) and harvest index (HI).

Table 4. Pearson's correlation coefficients among the selected growth and yield related attributes (n=12)

	PH	LN	CL	GY	YC	BM	HI
PH	1.00						
LN	0.77**	1.00					
CL	0.61*	0.34ns	1.00				
GY	0.87***	0.73**	0.60*	1.00			
YC	0.77**	0.54ns	0.89**	0.75**	1.00		
BM	0.94***	0.71**	0.64ns	0.87***	0.87***	1.00	
HI	0.59ns	-0.37ns	0.93***	0.58*	0.95***	0.69**	1.00

, **, * = significantly different at p <0.05, p <0.01, p <0.001 probability level, respectively; ns=non-significant; PH=plant height; LN=number of leaves plant^{-1}; CL=cob length; GY=grain yield; YC=yield components; BM=total biomass yield; HI=harvest index.*

The result is in agreement with a number of related studies (Ronald et al., 2005; Xie *et al*., 2005; Jehan *et al*., 2006; Festus *et al.*, 2007; Onasanya *et al*., 2009; Hafiz *et al*., 2011) which have shown decreasing trends of harvest index with increased rates of applied N fertilizer. This explains that vigorous vegetative growth of the maize plants promoted by higher rates of N application results in lower harvest index by favoring higher dry matter accumulation in the vegetative parts than in the grains of maize.

Conclusion

Nitrogen fertility of soil has a major role in maintaining and/or maximizing the productivity of maize; however, a number of other factors limit yields even when N fertility is optimal. The results from this study revealed that significant differences were observed for the growth parameters, as well as grain yield, harvest index and yield components of maize due to different rates of N application. Growth traits were enhanced as N fertilizer rate increased. The control treatment without N application showed the least performance in terms of growth parameters, yield components and grain yield. Generally, an increasing trend for the measured parameters was observed for increasing rates of N fertilizer, except harvest index. Results of the study indicate that farmers at Dilla area need to apply about 69 kg N ha^{-1} in order to improve the productivity of maize grown under rain-fed conditions. Therefore, in light of the significant response of maize to N fertilizer, further studies aimed at promoting integrated soil fertility management and formulation of fertilizer recommendation on soil test basis over locations are desirable**.**

4. REFERENCES

Akmal M, Hameed-Ur R, Farhatullah M, Asim H (2010). Response of maize varieties to nitrogen application for leaf area profile, crop growth, yield and yield components. Pak. J. Bot. 42(3):1941-1947.

ARC (1993). Research progress report. Hawassa, Ethiopia. pp. 180-196.

CSA (Central Statistical Authority) (2013). Area and Production of crops: private peasant holdings, Maher season. Statistical bulletin 532. Issue I. Addis Ababa, Ethiopia. pp. 10-12.

FAO (2001). Soil fertility management in support of food security in sub-Saharan Africa. Rome.

FAO (2012). Current world fertilizer trends and outlook to 2016. Food and Agriculture Organization of the United Nations, Rome. 43p.

Festus K, Wilkson M, Gudeta S, Oluyede C, David M (2007). Synergistic effect of inorganic N and P fertilizers and organic inputs from *Gliricidia sepium* on productivity of intercropped maize in southern Malawi. Plant Soil. 294: 203-217.

Hafiz M, Ashfaq A, Aftab W, Javaid A (2011). Maize response to time and rate of nitrogen application. Pak. J. Bot. 43(4):1935-1942.

IFPRI (International Food Policy Research Institute) (2010). Fertilizer and soil fertility potential in Ethiopia: constraints and opportunities for enhancing the system. Working paper. pp. 26-53.

Jehan B, Shakeel A, Mohammad T, Habib A, Mohammad S (2006). Response of maize to planting methods and fertilizer N. J. Agric. Bio. Sci. 1(3):8-14.

Mahamed B, Awale D (2013). Effect of different planting methods and nitrogen fertilizer rates on growth and yield of maize under rain-fed condition. J. Agric. 1(1):71-79.

Merkebu G, Ketema B (2013). Yield related traits and yield of maize as affected by green manuring and nitrogen levels at Mizan Teferi, southwest Ethiopia. Int. J. Agro. Plant Prod. 4(7):1462-1473.

Michael D (2009). Increasing crop productivity to meet global needs for feed, food, and fuel. Plant Physiol. 149:7-13.

MoARD (Ministry of Agriculture and Rural Development) (2009). Animal and plant health regulatory: Directorate crop variety register. Issue 12. Addis Ababa, Ethiopia. pp: 36-51.

Mohamed M, Hassan A (2011). Effect of different nitrogen sources on growth, yield and quality of fodder maize

(*Zea mays* L.). J. Saudi Soc. Agric. Sci. 10:17-23.

Olsen SR, Cole CV, Watanabe FS. Dean LA (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA circular 939. U.S. Govt. Printing, Washington D.C. pp. 1-19.

Onasanya R, Aiyelari O, Onasanya A, Oikeh S, Nwilene F, Oyelakin O (2009). Growth and yield response of maize (*Zea mays* L.) to different rates of nitrogen and phosphorus fertilizers in southern Nigeria. World J. Agric. Sci. 5(4):400-407.

Ronald J, John P, Larry D, Barney W (2005). Corn yield response to nitrogen rate and timing in sandy irrigated soils. Am. Soc. Agron. 97:1230-1238.

SAS Institute Inc (2002). SAS Users Guide. Version 9. SAS Institute Inc. Cary, NC. USA.

Tekalign M, Haque I (1991). Phosphorus status of some Ethiopian soils. III. Evaluation of soil test methods. Trop. Agric. 68:51-56.

Tesfa B, Tolera A, Tewodros M, Gebresilasie H, Temesgen D, Tenaw W, Waga M, Hussen, H (2012). Status and future direction of maize research and production in Ethiopia. In: Worku M, Twumasi S, Wolde L, Tadesse B, Demisie G, Bogale G, Wegary D, Prasanna, BM (Eds.). Meeting the challenges of global climate change and food security through innovative maize research. Proceedings of the 3rd national maize workshop of Ethiopia. 18-20 April 2011. Addis Ababa, Ethiopia. pp. 24-33.

Tisdale S, Havlin J, Nelson L, Beaton D (1999). Soil fertility and fertilizers. 6th ed. Macmillan Publishing. USA. pp. 85-196.

Waga M (2011). Effects of methods and rates of phosphorus fertilizer application and planting methods on yield and related traits of maize on soils of Hawassa area. Innov. Syst. Design and Eng. 2(4):315-335.

Wende A (2013). Genetic diversity, stability, and combining ability of maize genotypes for grain yield and resistance to NCLB in the mid-altitude sub-humid agro-ecologies of Ethiopia. PhD thesis. University of KwaZulu-Natal. South Africa. pp. 2-3.

World Weather Online (2015). Dilla monthly climate average, Ethiopia. *www.worldweatheronline.com*. (Accessed on 18th July, 2015).

Xie J, Zhang K, Wang X, Wang L, Zhang G, Yin C (2004). High quality maize response to nitrogen, phosphorus, and potassium in Jilin. Better Crops. 88(4):28-30.