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Effect of level and time of nitrogen fertilizer application on growth, yield and yield components of maize (*Zea mays* L.) at Arba Minch, Southern Ethiopia

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Maize is most important cereal crop used for human diet, livestock fed, and for many industrial applications in many parts of the world. However, the national average productivity is quite below the world average which might be attributed to nutrient deficiency among many problems. A field experiment was conducted during 2016/2017 croppping season to determine the effect of level and time of nitrogen fertilizer application on growth, yield, yield components and economics of maize cultivation. The experiment consisted of six levels of nitrogen and four times of application laid out in Randomized Complete Block Design with three replications. The analysis of variance showed that phenological and growth parameters as well as yield and yield components were significantly (P<0.05) affected due to N levels. Time of N application showed significant effect on all parameters except plant height, dry matter and ear height. The interaction between level and time of nitrogen application was significant for days to silking, number of kernels per ear and grain yield. The highest grain yield (9037 kg ha^{-1}) was recorded when applying 69 kg ha^{-1}nitrogen in three splits, while the lower grain yield (4316 kg ha^{-1}) was recorded from the control treatment. Grain yield showed high, significant and positive linear correlations with growth, phenological and yield components except days to maturity. The maximum economic benefit (51,843 Birr ha^{-1}) and high acceptable (2018%) yield were obtained when applying nitrogen at 69 kg ha^{-1} in three splits and recommended for maize cultivation at Arba Minch.

Key words: Economics, dose and time of N application, maize, nutrient, yield components.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops used in human diet, feed source for livestock, processing ethanol and for a wide range of industrial applications in many parts of the world. Maize area and production in worldwide during 2013/2014 were 177.4 million ha and 872.1 million tons, respectively, where Africa shared 34 million ha and 70.1million tons of production, and Ethiopia accounts only for 2.1 million ha

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of area and 6.1 tons production (CSA, 2014). However, maize is the most important cereal crop of Ethiopia (CIMMYT, 2014), ranking first in total production and second in area coverage after teff (FAO, 2014). It is also among the major cultivated crops in Arba Minch area accounting for 28,414 ha of area and 90,925 tons of production during 2014 (Antana, 2015).

Despite being important cereal crop, the national average yield of maize is about 3.2 t/ha (CSA, 2014) which is far below the world's average yield, 5.2 t/ha (FAO, 2012). The records of maize producers, other district stakeholders and researchers showed declining maize production in different maize producing areas of Ethiopia (Girma, 2013).The low yield was attributed to a number of factors where nutrient deficiency was among the major problems constraining development of economically successful maize agriculture (Fageria and Baligar, 2005). Among the essential mineral nutrients, nitrogen was found to be deficient in many tropical soils of Africa and one of the major production constraints in Ethiopia. The inorganic fertilizers, particularly nitrogenous, had been noted for potential alternatives used so far to supplement nutrient availability, increase production and for sustaining food insecurity.

Maize producers are widely practising a blank recommended split-application (1/2 of the dose at planting and the remainder at knee high stage). In order to improve efficiency of nitrogen utilization, and improve luxuries consumption, split application had been recommended in semi-arid zones of Central Rift valley for maize production (Girma, 2013). Grain yield response was generally maximized when applying N prior to stem elongation (Mossedaq and Smith, 1994). Rapid N-uptake and most responsive maize N- demand was documented during middle vegetative growth period and maximum N-uptake noted near silk (Hammad et al*.,* 2011).

However, maize producers around the study area were practising a blank recommendation of nitrogen dose at seedling stage (Antana, 2015) and the area lacks information on optimum fertilizer dose and time of nitrogen application. Studies addressing yield gaps between the national and world average, increasing food maize quality, rate and time of N application is essential in order to improve maize production and benefits of maize producers. Thus, the present study aims to determine the level and time of nitrogen fertilizer application on growth, yield and yield components and economics of maize cultivation at Arba Minch.

MATERIALS AND METHODS

Study site description

The field experiment was carried out during 2016/2017 cropping season at Arba Minch University research farm, located at an altitude of 1285 m.a.s.l. The study site is characterized with bimodal rainfall type, mean annual rainfall of 961.2 mm, mean minimum and maximum temperature of 17.8 and 30.2°C, respectively and soil textural class of clay roam. The soil chemical property and nutrient content at a depth of 30cm was found to be slightly alkaline, low in available phosphorus and nitrogen, high in available potassium, available zinc and cation exchange capacity, medium in organic carbon and available iron, and low in available molybdenum as suggested in previous studies (Mclean 1982; Olsen et al., 1954; Dewis and Freitas, 1975; Jackson, 1973; Lindsay and Norvell, 1978; Walkley and Black, 1934).

Treatments and experimental design

The experiment consisted of six levels of N (0, 23, 46, 69, 92 and 115kg N ha^{-1}) and four times of application (½ dose at sowing, +½ at 40 days after sowing, ½ dose at 40 days after sowing + ½ at tasseling; ¼ dose at sowing + ½ at 40 days after sowing + ¼ at tasseling and Full of the dose at 40 days after sowing). The treatments were laid out in factorial experiment in randomized complete block design (RCBD) replicated three times comprising a total of 21 treatments (5x4 combinations plus one control treatment). The treatments were tested on maize variety Bako Hybrid "BH-140". The seeds of the test variety were sown in a gross plot size of 2.5 m × 3.0 m (7.5 m^2) consisting of four rows having intra and inter row spacing of 0.25 and 0.75m to attain a population of 53,333 per hectare. The plots were spaced at 1.5 m and 2.0 m among blocks. Urea (46% N) as N source and Triple Super Phosphate (48% P_2O_5) as P source were used for the study where total phosphorus and amount of nitrogen treatment were applied at the time of sowing and the remaining rates were side dressed as per time scheduled.

Data collection and analysis

Data on days to tasseling, days to silking, days to maturity, leaf area index, plant height, number of ear per plant, ear height, dry matter, ear length, number of kernels per ear, hundred kernels weight, grain yield and harvest index were collected. All collected data were subjected to analysis of variance for factorial experiment using SAS (2008). Means of the treatments were separated using Duncan's multiple range tests (Steel and Torrie, 1960). The degree of association between growth, yield and yield components of maize was studied with correlation analysis and the functional relationships were established by analysis regression (Steel and Torrie, 1960).The mean grain yield of the selected treatment was used for partial budget analysis (CIMMYT, 1988).

RESULTS AND DISCUSSION

Plant height

The results of analysis of variance showed that plant height was significantly ($P \le 0.05$) affected by level of nitrogen application. However, the effect of time, interaction between level and time of nitrogen application was not significant (Table 1). The maximum plant height (256.1 cm) was obtained when applying nitrogen at 92 kg ha^{-1}, while the minimum value (240.1 cm) was recorded at no nitrogen application. The results were in conformity with findings of Namvar and Sharifi (2016) who

Table 1. Mean days to silking as affected by the interaction of level and time of nitrogen fertilizer application during 2016/17 cropping season at Arba Minch.

N-levels (kg ha^{-1})		Time of N application				
		Tm_1	Tm_2	Tm_3	Tm_4	Mean
23		73.7^{fgh}	79.3^{cde}	76.5^{ef}	78.7^{cde}	77.1^{c}
46		80.3^{bcd}	81.5^{abcd}	78.4^{cde}	72.4^{gh}	78.2^{bc}
69		74.5^{fg}	81.8^{abc}	81.6^{abcd}	79.8^{bcde}	79.4^{b}
92		79.7^{bcde}	78.8^{cde}	80.0^{bcd}	81.5^{abcd}	80$^{\mathbf{b}}$
115		83.0^{ab}	80.3^{bcd}	84.1^{a}	81.7^{abc}	82.3^{a}
Mean		78.2	80.3	80.1	78.8	79.4
SEM $_{(\pm)}$	1.2					
LSD $_{(0.05)}$	3.4					
CV $_{(\%)}$	2.6					
Control mean						71.02

Where Tm_1= Nitrogen application time one (½ of nitrogen dose at sowing + ½ of nitrogen dose at 40 DAS), Tm_2= Nitrogen application time two (½ of nitrogen dose at 40 DAS + ½ of nitrogen dose at tasseling), Tm_3= Nitrogen application time three (¼ of nitrogen dose at sowing + ½ of nitrogen dose at 40 DAS +¼ of nitrogen dose at tasseling), Tm_4= Nitrogen application time four (Full dose of nitrogen at 40 DAS). Mean followed by the same letters are not significantly different at P ≤ 0.05.

demonstrated that application of more N increased internodal extension, plant height and better vegetative development.

Leaf area index

Leaf area index (LAI) was significantly (P≤0.05) affected by level and time of nitrogen application. Interaction between time of nitrogen application and level of N application was not significant (Table 2). The mean LAI ranged from 3.04 to 3.87 due to level of N application. The highest LAI (3.87) was recorded from N applied at 115 kg ha^{-1} while the lowest (3.04) was recorded from no fertilizer application (control) treatment. The result indicated strong decrease in chlorophyll content (accelerated senescence) under low N application as compared to non nitrogen stressed conditions. Leaf area index was also significantly (P≤0.05) affected due to time of fertilizer application. Mean leaf area index ranged from 3.55 to 3.58 where maximum LAI was recorded from applying nitrogen in three splits (¼ dose at sowing + ½ dose at 40 days after sowing + ¼ dose at tasseling). The result is in conformity with Niaz et al. (2015) who reported increased LAI from high level and split application of nitrogen.

Dry matter production

The results of analysis variance indicated that dry matter was significantly (P≤0.05) affected due to level of nitrogen application. The interaction between the level and time of nitrogen application as well as time of nitrogen application was not significant for dry matter (Table 1). High above ground dry matter (36,594 kg ha^{-1}) was attained from 92 kg N ha^{-1} while the low biomass (24,001 kg ha^{-1}) was produced from unfertilized plot (control).

The increase in dry matter with increase in rate of N application might be due to increase in LAI, assimilation of more photons and increase in length of days to maturity which ultimately produced more dry matter. The result corresponded to the findings of Kidist (2013) who reported that an application of 174 kg ha^{-1}nitrogen resulted in dry matter yields of 36,574 kg ha^{-1}.

Days to 50% tasseling

The analysis of variance revealed that days to tasseling was significantly (P≤0.05) affected due to level and time of nitrogen application. However, the interaction effect of level and time of N application was not significant (Table 1). The result showed that application of N from 0 to 115 kg N ha^{-1} consistently increased days to tassel which ranged from 70.8 to 78.5 days. The maximum number of days to tassel was obtained from 115 kg N ha^{-1} nitrogen level. The number of days required to attain tasseling ranged from 75.1 to 77.7 days due to time of nitrogen application. Maximum days to tassel was recorded when ½ dose nitrogen was applied at 40 days after sowing+ ½ at tasseling compared to the rest treatments. The result suggested that availability of sufficient nutrient in the soil for plant uptake promoted vigorous vegetative growth and development of the plants. The results agreed with Akmal et al. (2010), Erkeno (2015) and Hafiz et al. (2012) who observed that maize took higher number of days to tassel

Table 2. Phenological and growth parameter as influenced by level and time of nitrogen application of maize at Arba Minch during 2016/2017 cropping season.

Treatment N-levels(kg N ha^{-1})	DT (DAS)	DPM (DAS)	PH (cm)	LAI	DMT (kg ha^{-1})
0	70.8^{d}	145.1^{c}	240.1^{d}	3.04^{f}	24001^{d}
23	73.9^{c}	146.1^{bc}	243.2^{cd}	3.18^{e}	27199^{c}
46	74.9^{bc}	146.3^{bc}	251.7^{ab}	3.42^{d}	28204^{bc}
69	75.9^{bc}	147.4^{bc}	252.3^{ab}	3.58^{c}	29471^{b}
92	76.9^{ab}	148.5^{ab}	256.6^{a}	3.79b	36594^{a}
115	78.5^{a}	150.4^{a}	247.1^{bc}	3.87^{a}	35489^{a}
SEM $_{(\pm)}$	0.65	0.73	1.7	0. 02	634.9
LSD $_{(0.05)}$	2.2	2.5	5.9	0. 1	2187.1
N application time					
Tm_1	75.5^{ab}	147.6^{ab}	249.3^{ab}	3.55^{ab}	31281^{b}
Tm_2	77.7^{a}	147.9^{a}	251.7^{a}	3.56^{ab}	31414^{b}
Tm_3	75.8^{ab}	148.6^{a}	252.8^{a}	3.58^{a}	31398^{a}
Tm_4	75.1^{b}	146.8^{ab}	248.1^{ab}	3.57^{a}	31472^{a}
SEM $_{(\pm)}$	0.6	0.65	1.5	0. 02	567.8
LSD $_{(0.05)}$	2.2	1.4	NS	0.08	NS
CV $_{(\%)}$	2.9	1.7	2.4	2.1	6.97
Mean	75.2	147.6	249.4	3.55	31039.6
Interaction	NS	NS	NS	NS	NS

Where DT= days to tassel, DM= days to physiological maturity, DAS= days after sowing, PH= plant height, LAI= leaf area index, DMT = dry matter,Tm_1= Nitrogen application time one (½ of nitrogen dose at sowing + ½ of nitrogen dose at 40 DAS), Tm_2= Nitrogen application time two (½ of nitrogen dose at 40 DAS + ½ of nitrogen dose at tasseling), Tm_3= Nitrogen application time three (¼ of nitrogen dose at sowing + ½ of nitrogen dose at 40 DAS + ¼ of nitrogen dose at tasseling), Tm_4= Nitrogen application time four (full nitrogen dose at 40 DAS); **= Significant at 5%; NS= Non significant. Means followed by the same letters are not significantly different at P ≤ 0.05.

with application of high amount of nitrogen fertilizer rates from 100 to 300 kg ha^{-1}.

Days to 50% silking

Days to silking was significantly (P≤0.05) affected by level and time of N fertilizer application. The result showed significant interaction between the level and time of nitrogen application (Table 2). Maximum number of days to attain silking (84.1 days) was observed under plots applied with 115 kg N ha^{-1}in three splits. The minimum number of days to attain silking (71.02 days) was recorded from unfertilized plot. The result is in agreement with the findings by Nemati and Sharifi (2012) and Alok (2015) who reported that increased amount of nitrogen fertilizer resulted in more number of days to attain silking.

Days to physiological maturity

The result indicated that days to physiological maturity was significantly affected by level and time of nitrogen application. However, the interaction of time and level of nitrogen application was not significant for days to physiological maturity (Table 2). The maximum number of days to attain physiological maturity (150.4 days) was recorded from nitrogen level of 115 kg ha^{-1} while the minimum (145.1 days) was recorded from the control treatment. The results showed that maize crop with no fertilizer application matured earlier than maize crop receiving nitrogen fertilizer suggesting crop stress escaping mechanism.

The mean number of days required to attain maturity ranged from 146.6 to 148.6 due to nitrogen application time. The result showed application of N fertilizer in three splits, ¼ doses at sowing + ½ dose at 40 days after sowing + ¼ dose at tasseling resulted in high number of days to attain physiological maturity when compared to the rest of application time. The results were in consistence with the findings by Akbar et al. (2002), who reported that number days to maturity of maize increased as fertilizer rate increased.

Number of ear per plant

A significant difference in number of ear per plant was

Table 3. Number of ear per plant, ear length, hundred kernel weight and harvest index of maize as influenced by level and time of nitrogen fertilizer application at Arba Minch during 2016/2017 cropping season.

Treatment N-levels (kg N ha^{-1})	NEPP	EL(cm)	HKW(g)	HI
0	1.09^{f}	20.0^{d}	28^{e}	18.0^{d}
23	1.32^{e}	20.9^{cd}	31.3^{d}	19.6^{cd}
46	1.36^{d}	21.5^{abc}	33.3^{bc}	23.1^{b}
69	1.64^{a}	22.4^{a}	36.1^{a}	28.5^{a}
92	1.58^{b}	22.2^{ab}	34.0^{b}	21.3^{c}
115	1.43^{c}	21.3^{bc}	31.9^{cd}	19.5^{cd}
SEM (±)	0.01	0.3	0.55	0.55
LSD (0.05)	0.038	1.1	1.9	1.87
N application time				
Tm_1	1.45^{b}	21.1^{b}	32.9^{b}	21.9^{ab}
Tm_2	1.47^{ab}	21.4^{b}	33.6^{a}	23.3^{a}
Tm_3	1.51^{a}	21.9^{a}	33.8^{a}	21.3^{b}
Tm_4	1.46^{b}	21.8^{ab}	33.1^{ab}	22.6^{ab}
SEM (±)	0.01	0.27	0.5	0.5
LSD (0.05)	0.037	0.104	0.18	1.8
CV (%)	2.6	4.9	5.7	8.4
Mean	1.45	21.6	33.05	22.1
Interaction	NS	NS	NS	NS

Where NEPP= number of ear per plant, EL=ear length, HKW=hundred kernel weight, HI=harvest index, Tm_1= Nitrogen application time one (½ of nitrogen dose at sowing + ½ of nitrogen dose at 40 DAS), Tm_2= Nitrogen application time two (½ of nitrogen dose at 40 DAS +½ of nitrogen dose at tasseling), Tm_3= Nitrogen application time three (¼ of nitrogen dose at sowing + ½ of nitrogen dose at 40 DAS + ¼ of nitrogen dose at tasseling), Tm_4= Nitrogen application time four (Full of the dose at 40 DAS),NS= Non-significant. Means values within column followed by the same letters are not significantly different at P ≤ 0.05.

observed due to level and time of nitrogen application. However, the interaction between levels and time of nitrogen application was not significant (Table 3). Application of 69 kg N ha^{-1} showed significantly high number of ears per plant (1.64) while the low number of ears (1.09) was obtained from the control treatment. The maximum number of ears per plant was produced when N was applied in three splits that is, ¼ dose at sowing + ½ dose at 40 days after sowing + ¼ dose at tasseling suggesting time and amount of nutrient application matters crop growth requirements. The results were corroborated by the findings of Matusso (2014) who reported that increasing nitrogen level from 50 to 300 kg ha^{-1} significantly increased the number of ears per plant from 1.2 to 2.05.

Ear length

The level and time of nitrogen fertilizer application significantly influenced ear length. However, the interaction between level and time of nitrogen application was not significant for ear length (Table 3). The results showed that ear length increased with increase in nitrogen level from 0 to 115 kg N ha^{-1} and the high ear length (22.4 cm) was recorded at a level of 69 kg N ha^{-1} and the short ear length (20.0 cm) was recorded from the control treatment. Maximum ear length was produced when nitrogen fertilizer applied in three splits that is, ¼ doses at sowing + ½ dose at 40 days after sowing + ¼ dose at tasseling. Similar results were also reported by Marashi (2015).

Hundred kernels weight

The seed size is an important indicator of the ultimate grain yield. As presented in Table 3, hundred kernel weights were significantly affected due to level and time of nitrogen fertilizer application. The interaction between the level and time of nitrogen application was not significant (Table 3). Maximum hundred kernel weight (36.1 g) was recorded at N level of 69 kg ha^{-1} while the minimum hundred kernel weight (28.0 g) was recorded

Table 4. Number of kernels per ear of maize as affected by the interaction between and level and time of N application during 2016 cropping season.

N-levels (kg ha^{-1})	Timing of application				
	Tm_1	Tm_2	Tm_3	Tm_4	Mean
23	532.1^{ij}	532.8^{ij}	533.4^{ij}	533.9^{ij}	533^{d}
46	600.5^{bcde}	616.4^{abcd}	579.4^{fghi}	577.1^{ghi}	593.3^{bc}
69	633.4^{abc}	625.6^{a-e}	676.0^{a}	628.6^{abcd}	640.9^{a}
92	632.5^{abc}	595.3^{cdefg}	614.1^{bcde}	602.8^{bcde}	611.2^{b}
115	570.4^{defgh}	581.1^{bcdef}	586.7^{defg}	597.3^{abcdef}	583.9^{c}
Mean	591^{b}	592.8^{ab}	593.6^{a}	587.9^{c}	
Grand mean	588.2				
Control mean	503.2				
SEM $_{(\pm)}$	21.95				
LSD $_{(0.05)}$	2.02				
CV (%)	6.5				

Where Tm_1= Nitrogen application time one (½ of nitrogen dose at sowing + ½ of nitrogen dose at 40 DAS), Tm_2= Nitrogen application time two (½ of nitrogen dose at 40 DAs + ½ of nitrogen dose at tasseling), Tm_3= Nitrogen application time three (¼ of nitrogen dose at sowing + ½ of nitrogen dose at 40 DAS + ¼ of nitrogen dose at tasseling), Tm_4= Nitrogen application time four (Full of the dose at 40 DAS), Means values within column followed by the same letters are not significantly different at P ≤ 0.05.

from the control. The maximum hundred kernel weight of 33.8 g was also recorded when applying nitrogen in three splits indicating importance of supplying nutrient at critical time of crop growth. These results corroborated by those of Abdullah (2014) and Alok (2015) who reported that maize started to take up N rapidly at sowing, the middle vegetative growth period (40 DAS) and maximum level of N uptake occurred near silking stage. Dinh et al. (2015) also reported that with increasing nitrogen level from 0 to 240 kg ha^{-1}, the kernel weight of maize increased significantly from 26.4 to 34.1.

Harvest index

Level and time of nitrogen fertilizer application also significantly affected harvest index of maize. The mean HI ranged from 18 to 28.5% due to level of nitrogen application. The highest harvest index (28.5%) was recorded when applying 69 kg ha^{-1} nitrogen while the lowest harvest index (18 %) was recorded from the control. The maximum HI (23.34%) was recorded when applying N in two splits (½ of nitrogen dose at 40 DAs +½ of nitrogen dose at tasseling) suggesting importance split application. Similarly, Erkeno (2015) and Zeidan et al. (2006) reported that the maximum harvest index of 29.5 and 39.1% was recorded with application of 180 and 225 kg N ha^{-1}, respectively.

Number of kernels per ear

Statistical analysis result indicated significant interaction between level and time of nitrogen fertilizer application for number of kernel per ear. The mean number of kernels per ear ranged from 532.1 to 676 due to level of nitrogen application where the maximum number of kernels per ear (676) was recorded from N applied at 69 kg ha^{-1}in three splits (Table 4).The interaction result showed increase in number of kernel per ear with increased nitrogen application up to 69 Kg ha^{-1} and reduced number of kernel per ear for further increase in nitrogen fertilizer level. The result suggested level of nitrogen and coincidence of time and amount of crop nutrient requirement which enhanced biomass production and photosynthesis efficiency in converting assimilates to sinks. Similar results were documented by Nemati and Sharifi (2012) who showed the maximum number of grains per ear at high nitrogen levels.

Grain yield

The analysis of variance showed that level and time of N application had significant interaction for grain yield of maize (Table 5). The interaction results showed that increase in grain yield when increasing nitrogen application up to 69 Kg ha^{-1} with each time of application and reduced grain yield for further increase in nitrogen fertilizer level. The highest grain yield (9036.7 kg ha^{-1}) was obtained when applying 69 kg N ha^{-1}in three splits (¼ of nitrogen dose at sowing + ½ of nitrogen dose at 40 DAS + ¼ of nitrogen dose at tasseling). Significantly low grain yield (5301.0 kg ha^{-1}) was recorded with 23 kg N ha^{-1} combined with Tm_1 and Tm_2. The results attained for grain yield correspond with the result attained for number

Table 5. Grain yield (kg ha^{-1}) maize as affected by the interaction between level and time of N application at Arba Minch during 2016 cropping season.

N-levels (kg ha^{-1})	Timing of application				
	Tm_1	**Tm_2**	**Tm_3**	**Tm_4**	**Mean**
23	5301.3^{j}	5301.3^{j}	5304.0^{j}	5302.3^{j}	5302.3^{d}
46	6216.3^{i}	6467.7^{ghi}	6362.3^{hi}	6892.0^{fgh}	6484.6
69	8048^{bc}	8190.3^{bc}	9036.7^{a}	8310.3^{b}	8396.2^{a}
92	7941.3^{bcd}	7312.0^{def}	8202.0^{bc}	7773.0^{bcd}	7807.1^{b}
115	6879.0^{fgh}	7071.7^{efg}	6687.0^{ghi}	7062.0^{efg}	6925^{c}
Mean	6832.5^{bc}	6868.6^{b}	7118^{a}	7112.7^{ab}	6983
Control mean	4316^{k}				
SEM $_{(\pm)}$	237.4				
LSD $_{(0.05)}$	632.02				
CV (%)	6				

Where Tm_1= Nitrogen application time one (½ of nitrogen dose at sowing + ½ of nitrogen dose at 40 DAS) Tm_2= Nitrogen application time two (½ of nitrogen dose at 40 DAs + ½ of nitrogen dose at tasseling) Tm_3= Nitrogen application time three (¼ of nitrogen dose at sowing + ½ of nitrogen dose at 40 DAS + ¼ of nitrogen dose at tasseling) Tm_4= Nitrogen application time four (Full of the dose at 40 DAS).Means values within column followed by the same letters are not significantly different at P ≤ 0.05.

of ear per plant, ear length, hundred kernel weight and harvest index where the maximum was recorded when applying nitrogen at 69 kg ha^{-1} and splitting the level into three time of application. The reduction in grain yield beyond 69 kg N ha^{-1} application might be due to excess supply of the nitrogen favoring more vegetative growth rather than grain formation process part. This present finding is consistent with that of Asnakech (2015) and Namvar and Sharifi (2016) who stated that soil organic matter is a surrogate of mineral nitrogen in the soil for plant uptake. In support of the presented result, Abdullha (2014) noted that yield reduction is primarily caused by a corresponding reduction in the number of ear per plant and number of kernels per ear.

Correlation analysis

Correlation analysis was worked out among growth, yield and yield components of maize (Table 6). Grain yield was positively and significantly association with number of ear per plant (r=0.86*), number of kernels per ear (r=0.63*), hundred kernels weight (r=0.61*), harvest index (r=0.7*), plant height(r=0.51*), leaf area index (r=0.63*), days to silking (r=0.36*) and days to tasseling(r=0.4*). Similarly, positive and significant correlation between yield and its components was documented by Dinh et al. (2015). The results suggested that the change in grain yield due to varied nitrogen level was related to and accounted for the effect of nitrogen on plant height, leaf area index and yield components.

Regression analysis

The functional relationship between level and time of nitrogen application with maize yield and yield components is depicted in Figure 1. The production function observed among the nitrogen level and maize yield and yield components was quadratic. The change in level of nitrogen varied from 0 to 115 kg ha^{-1} accounting for 90% of total variation in number of ear per plant (1.09 to 1.64), number of kernel per ear (503.2 to 640.9) and mean grain yield (4316 to 8396.2 kg ha^{-1}). Whereas the change in fertilizer rate accounted for about 94% of total variation in hundred kernels weight (20 to 22.4 g). The regression analysis result suggested a strong contribution of yield components for final grain yield.

Similarly, the change in time of nitrogen application showed significant contribution for the total variation in yield and yield components of maize. The split application of nitrogen dose at various growth time accounted for about 84, 92, 98 and 85% of the total variation in number of ear per plant, number of kernel per ear, hundred kernel weight and grain yield, respectively. The results of regression analysis for yield and yield components indicated the importance of application rate and time of nitrogen fertilizer for maize production. Similarly, Wange et al. (2014) reported significant and positive association of crop phenology to fertilizer rate and time of application.

Economic analysis

Economic analysis of maize production under varied

Table 6. Correlation coefficient between growth, yield and yield components of maize at Arba Minch during 2016/2017 cropping season.

	GY	NEPP	NKPE	HKW	PH	LAI	DM	DS	DT
GY	1	0.86*	0.63*	0.61*	0.51*	0.63*	0.2NS	0.36*	0.4*
NEPP		1	0.63*	0.61*	0.41*	0.6*	0.24*	0.4*	0.39*
NKPE			1	0.37*	0.24^{NS}	0.45*	0.16^{NS}	0.33*	0.20^{NS}
HKW				1	0.43*	0.43^{NS}	0.07^{NS}	0.2^{NS}	0.27*
PH					1	0.44*	0.04^{NS}	0.3*	0.14^{NS}
LAI						1	0.46*	0.55*	0.55*
DM							1	0.37*	0.34*
DS								1	0.46*
DT									1

Where *= significantly different at p <0.05probability level, NS= non-significant, DT= days to tasseling, DM= days to maturity, LAI= leave area index, PH= Plant height, NEPP= number of ear per plant, HKW=hundred kernels weight.

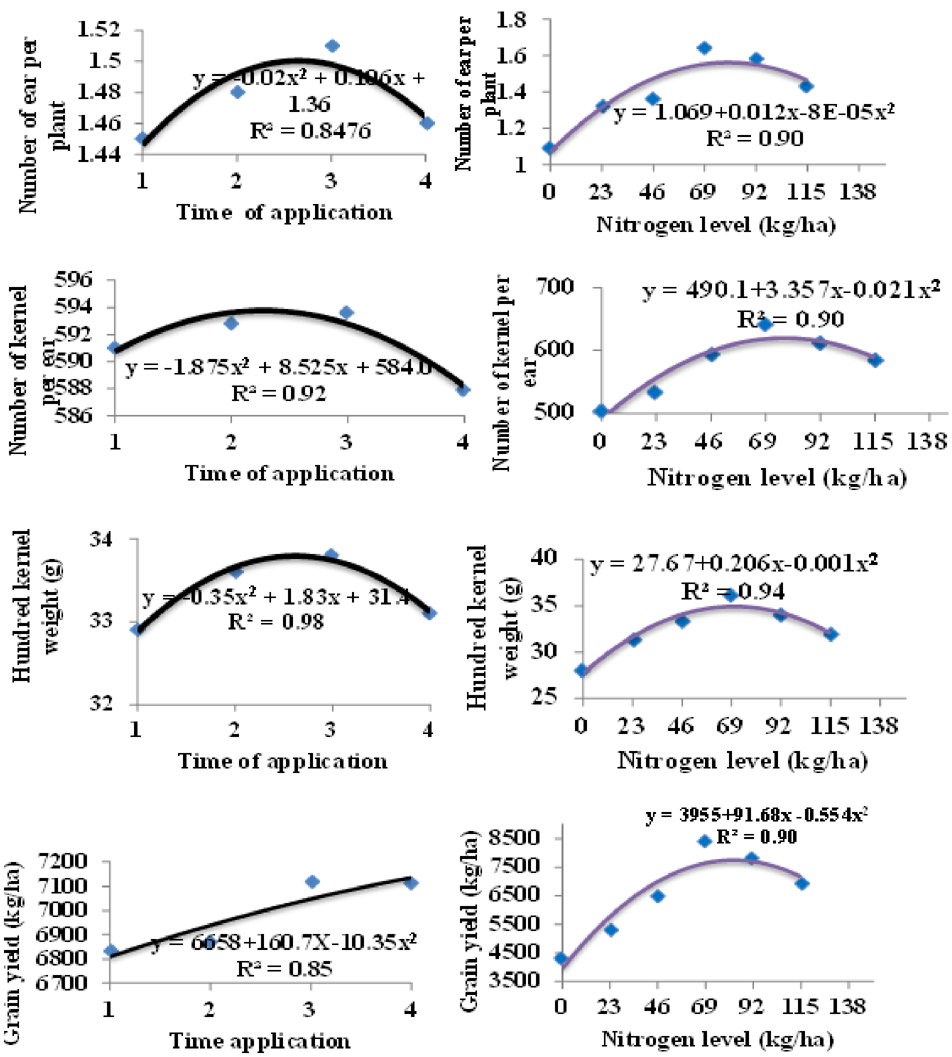

Figure 1. The relationship between level and time of nitrogen application with yield and yield components of maize at Arba Minch during 2016/17 cropping season.

Table 7. Results of partial budget analysis effect of level and time N fertilizer application of maize during 2016 cropping season.

N level (kg ha^{-1})	TVC (Birr)	Net benefit (Bir)	MRR (%)
		Time (Tm_1)	
0	0	27408	-
23	1053	32220	457
46	1685	36755	715
69	2318	46118	1479
92	2950	46334	34
115	3583	46575	38
		Time (Tm_2)	
0	0	27408	-
23	1113	32178	429
46	1745	38003	922
69	2438	45779	1122
92	3070	42674	D
115	3643	36747	D
		Time (Tm_3)	
0	0	27408	-
23	1173	32106	400
46	1805	39475	1166
69	2418	51843	2018
92	3010	47989	D
115	3703	35474	D
		Time (Tm_4)	
0	0	27408	-
23	1183	32098	396
46	1715	40173	1518
69	2448	47609	1015
92	2980	45111	D
115	3613	40510	D

Where D=dominated treatment, MRR=marginal rate return, TVC=Total Variable Cost Tm_1= Nitrogen application time one (½ of nitrogen dose at sowing + ½ of nitrogen dose at 40 DAS) Tm_2= Nitrogen application time two (½ of nitrogen dose at 40 DAs + ½ of nitrogen dose at tasseling) Tm_3= Nitrogen application time three (¼ of nitrogen dose at sowing + ½ of nitrogen dose at 40 DAS + ¼ of nitrogen dose at tasseling) Tm_4= Nitrogen application time four (full nitrogen dose at 40 DAS)

levels and time of nitrogen application was studied and is presented in Table 7. The partial budget analysis revealed that highest net benefit of 51,843 Birr ha^{-1} was obtained from three split (1/4 dose at sowing + ½ dose 40 days after sowing + ¼ dose at tasseling) applied 69 kg ha^{-1} N rate. However, the lowest net benefit of 27,408 Birr ha^{-1} was obtained from unfertilized maize plot (control). For a treatment to be considered as worthwhile to farmers, the acceptable marginal rate of return (MRR) was considered to be between 50 to100 percent (CIMMYT, 1988). The high marginal rate of return was obtained from N applied at 69 kg ha^{-1} in three split and is recommended for farmers in Arba Minch and other areas with similar agro-ecological conditions.

Conclusion

Thus, fertilization of maize crop with different level and time of nitrogen application could substantially increase grain yield. From the present study, it was concluded that application of 69 kg ha^{-1} nitrogen in three splits (¼ of the dose at sowing + ½ of the dose at 40 days after sowing + ¼ of dose at tasseling) was found to be optimum and most profitable for growth, yield and yield components of maize variety BH 140 cultivation in Arba Minch area. Further studies involving more locations, different N levels, and application times and cropping seasons should be considered to generate more reliable information.

CONFLICT OF INTERESTS

The authors declares that there is no conflict of interest regarding the publication of this article.

REFERENCES

Abdullah N (2014). Effect of Variable Nitrogen Rates and Timing schemes on Growth, Yield, Nitrogen uptake and Economic Feasibility of Maize Production. Journal Agricultural Research 52(1):77-89.

Akbar H, Ihsanullah H, Jan MT, Miftahullah J (2002). Yield potential of sweet corn Influenced by different levels of nitrogen and plant population. Asian Journal of Plant Science 6(1):631-633.

Akmal M, Akbar H, Farhufullah AM, Ur-Rehman G (2010). Response of maize varieties to nitrogen application for leaf area profile crop growth, yield and yield components. Pakistan Journal of Botany 42(3):1941-1947.

Alok SS (2015). Effect of Level and Time of Nitrogen Application on Different Growth Parameters in maize (*Zea mays* L.) in Uparjhar village of Bolangir district, India. International Journal of Agricultural 5:211-216.

Antana AA (2015). Progressive Status Report on Maize Production. Arba Minch District Agriculture Office pp. 3-5.

Asnakech MW (2015). Effect of Nitrogen Fertilizer on Growth, Yield and Yield Components of Maize (*Zea mays* L.) In Decha District, Southwestern Ethiopia. International Journal of Research 4(2):95-100.

Central Statistical Agency (CSA) (2014). Agricultural Sample survey: Report on Area and Production of Major Crops (private peasant holdings, Meher season). Statistical Bulletin (1). Addis Ababa.

Dinh HG, Sarobol E, Sutkhet N (2015). Effect of timing and nitrogen fertilizer rate on growth, nitrogen use efficiency and grain yield of different maize hybrids under rain-fed conditions in Southern Vietnam. Journal of Natural Science 49:1-12.

Dewis J, Freitas P (1975). Physical and Chemical Method of Soil and Plant Analysis. Advanced Soil Science 13(2):321-349.

Erkeno Y (2015). Effect of Rates and Time of Nitrogen Application on Growth, Yield, and Yield component of maize varieties (*Zea mays* L.) on Soil of Hawassa Area, Ethiopia. M.Sc. thesis. Haromaya, University.

Fageria NK, Baligar VC (2005). Enhancing nitrogen use efficiency in crop plants. Advanced Agronomy 88:97-185.

Food and Agriculture Organization of the United Nations (FAO) (2012). Decent rural employment for food security: a case for action. Rome, Italy.

Food and Agriculture Organization of the United Nations (FAO) (2014). Food and Agriculture Organization Statistics Data Base, Agricultural production indices. Agricultural Production Retrieved may 20, 2016, from http://www.faostat3.foa.org

Girma K (2013). Effects of Nitrogen, Phosphorus and Farmyard Manure on Growth, Yield and Nutrient Uptake in South Gamo Gofa Zone, Ethiopia.

Hafiz MH, Ashfaq A, Aftab W, Javaid A (2012).Maize response to time and rate of nitrogen application. Pakistan Journal of Botany 43(4):1935-1942.

Hammad HM, Ahmad A, Khaliq T, Farhad W, Mubeen M (2011). Optimizing rate of nitrogen application for higher yield and quality in maize under semiarid environment. Crop Environment 2(1):38-41.

Kidist AA (2013). Growth, productivity, and nitrogen use efficiency of maize (*Zea mays* L.), as influenced by rate and time of nitrogen fertilizer application in Haromaya District, Eastern Ethiopia. M.Sc. thesis, Haromaya University, Ethiopia.

Jackson MI (1973). Soil Chemical Analysis. Prentic Hall (India) Pvt. Ltd. New Delhi.

Lindsay WL, Norvell WA (1978). Development of a Diethylen etriamine pentaacetic acid methods soil test for zinc, iron, manganese, and copper. Soil science society of America Journal 42(3):421-428.

Marashi RS (2015). Effect of Split Application of Nitrogen fertilizer on Quantitative and Qualitative Characteristics of maize (S.C.704) under Water deficit Condition. Indian Journal of Fundamental and Applied Life Sciences 53(4):172-178.

Matusso J (2014). Growth and Yield Response of Maize (*Zea mays* L.) to Different Nitrogen Levels in Acid Soil. Academy Research Journal Agriculture Sciences Research 4(2):35-44.

McLean EO (1982). Soil pH and lime requirement. Methods soil analysis. Part 2. Chemical and microbiological properties, (methods of soil analysis 2) pp. 199-224.

Mossedaq F, Smith DH (1994).Timing nitrogen application to enhance spring wheat yields in a Mediterranean climate. Agronomy Journal 86(2):221-226.

Namvar A, Sharifi RS (2016). Effects of time and rate of nitrogen application on phenology and some agronomical traits of maize (*Zea may* L.). Biological 62(1):514-521.

Nemati AR, Sharifi RS (2012). Effects of rates and nitrogen application timing on yield, agronomic characteristics and nitrogen use efficiency in corn. International Journal of Agriculture and Crop Sciences 4(9):534-539.

Niaz A, Yaseen M, Arshad M, Ahmad R (2015). Response of maize yield, quality and nitrogen use efficiency indices to different rate and application timings. JAPS, Journal of Animal and Plant Sciences 25(4):1022-1031.

Olsen SR (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. United States Department Of Agriculture; Washington.

Statistical Analysis system (SAS) Institute Inc. (2008). SAS /STAT. 9.2 user's guide. Cary, NC. SAS Institute Inc. United States of America.

Steel RG, Torrie JH (1960). Principles and procedures of statistics; with special reference to the biological sciences.

The International Maize and Wheat Improvement Center (CIMMYT) (1988). From Agronomic Data to Farmer Recommendations: An Economics Workbook. Mexico, D.F: CIMMYT.

Walkley A, Black IA (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil science 37(1):29-38.

Zeidan MS, Amany A, Bahr El-Kramany MF (2006). Effect of N-fertilizer and plant density on yield and quality of maize in sandy soil. Research Journal of Agriculture and Biological Sciences 2(4):156-161.