Academic Journal of Plant Sciences 13 (2): 33-41, 2020
ISSN 1995-8986

DOI: 10.5829/idosi.ajps.2020.13.2.33.41

Effect of Nitrogen Fertilizer Rates and Time of Applications on Phenology, Growth, Yield and Yield Components of Maize (*Zea mays* L.) Varieties at Bako, Western Oromia, Ethiopia

[1]Megersa Debele, [2]Tolera Abera and [3]Tedesse Debele

[1]Oromia Agricultural Research Institute (OARI), Bako Agricultural Research Center,
P.O. Box: 03. Bako, West Shewa, Oromia, Ethiopia
[2]Natural Resources Management Research Process, Ambo Agricultural Research Center,
Ethiopia Institute of Agricultural Research, P.O. Box: 382, Ambo, West Showa, Oromia, Ethiopia
[3]Ambo University, College of Agriculture, Department of Plant Sciences, Ethiopia

Abstract: The production and productivity of maize is highly influenced by different factors, among several factors nitrogen rates and time of nitrogen application are once. Thus, a field experiment was conducted to determine the effect of nitrogen fertilizer rates and time of applications on yield and yield components of hybrid maize varieties. Factorial combinations of two maize varieties (BH-546 and BH-547), two levels of nitrogen 75% recommended rates (82 kg ha^{-1}) and 100% recommended rates (110 kg ha^{-1}) and four nitrogen application times (1/2 dose N at sowing + 1/2 dose of N at Knee height, 1/2 dose of N at sowing + 1/2 dose of N at tasseling, 1/3 dose of N at sowing + 1/3 dose of N at knee height + 1/3 dose of N at tasseling and 1/2 dose of N at knee height +1/2 dose of N at tasseling) were laid out in Randomized Complete Block Design with three replications. Varieties were showed significant ($P<0.05$) difference on days to 50% tasseling and thousand seed weight of maize. Application of nitrogen rates were showed highly significant ($P< 0.01$) effects on days to 50% tasseling and days to 90 % physiological maturity, leaf area index, plant height, grain yield, harvest index of maize varieties. Similarly, nitrogen application time had significant effect on leaf area index, dry biomass and harvest index of maize. The interaction of varieties and nitrogen rates showed that application of 82.5 kg N ha^{-1} with BH-546 significantly resulted in the highest leaf area (7315 cm^2) and leaf area index (3.25) of maize. Likewise, the interaction of nitrogen rates and nitrogen application time were significantly influenced mean dry biomass of maize. Significantly higher grain yield (8998 kg ha^{-1}) was recorded from 100% recommended rates (110 kg N ha^{-1}) fertilizer rate and N applied 1/2 dose at knee height + 1/2 dose of N at tasseling of maize and lower grain yield 3898.46 was recorded from control.

Key words: Hybrid Maize · Time of Nitrogen Application · Grain Yield · Nitrogen Rate

INTRODUCTION

Maize (*Zea mays* L.) is the world's widely grown cereal and primary staple food crop in many developing countries [1]. In the world production of maize is ranked as the third major cereal crop after wheat and rice [2]. Maize is Ethiopia's most important cereal crop both in terms of level of production and area coverage. About 80 % of the total farmers produced eight million tons of maize from two million hectares [3]. Approximately 88% of maize produced in Ethiopia is used as food, in both green cobs and grain [4]. Ethiopia is one of the largest maize producing countries in Africa [5]. The total land area of about 12, 677, 882.27 hectares is covered by grain crops and out of the total grain crop area, 80.71% was under cereals. Maize covered 16.79% about (2, 128, 948.91) hectares and gave 83, 958, 87.244 ton of grain yields [3]. Despite the large area under maize, the national average yield of maize about 3.94 tha^{-1} [3]. This is by far below the world's average yield which is about 5.2 tha^{-1} [6].

Corresponding Author: Tolera Abera, Natural Resources Management Research Process, Ambo Agricultural Research Center, Ethiopia Institute of Agricultural Research, P.O. Box: 382, Ambo, West Showa, Oromia, Ethiopia.

Even though many biotic and a biotic factor can contribute to these big yield gaps, soil fertility depletion and poor nutrient management are among the major factors contributing to low productivity [7]. Though maize adapted to wide ranges of agro-climate condition and plays among several factors, by nitrogen rate and plant density [8]. Maize is an exhaustive feeder of nutrients; its nutrients requirements are high. The demand of nitrogen fertilizer is greater than that of the other nutrients. If nitrogen deficiency occurs at tasseling and silking stages may significantly affect crop failure. However, amount of nitrogen to be applied for maize plant depends upon maize variety, soil type, soil fertility status, location and yield [9]. Nitrogen is a macro essential nutrient of plants and is applied in the largest quantity for most annual crops. Nitrogen is one of the key factors for higher grain production of hybrid maize. The use of improved varieties and optimal use of nitrogen fertilizer is important for exploiting yield potential of maize [10]. Most soils in Ethiopia are responsive to split-application of nitrogen [11]. Time of nitrogen application at appropriate crop growth stage is also another main focus to enhance nitrogen use efficiency and increase maize productivity. All applied nitrogen is not absorbed by the crop since leaching is one of the main challenges for nitrogen loss in high rainfall areas. . In high and medium altitude maize growing areas where rainfall is high, most of the nitrogen is lost through leaching and denitrification making the nutrient unavailable during the critical stages of crop growth [12].

The split application of nitrogen after the good establishment of the crop markedly reduces nitrogen losses [13]. Farmer's at study area applying nitrogen two split application times (1/2 dose at planting and ½ dose at knee height) however nitrogen fertilizer application at planting is loss through leaching and volatile because of less up-take plant at germination. Use efficiency even two to three time's applications considerably enhance nitrogen absorption in good rainy seasons [14]. Nitrogen rate and time of application are among the major abiotic factors limiting the production and productivity of maize. The use of optimum level of nitrogen and timely application is beneficial to get higher maize production. Therefore, this research was initiated to test right nitrogen rates and time of applications recommendation on improved varieties of maize (BH-546 and BH-547) in the study area. Therefore, the objective was to determine optimum nitrogen fertilizer rates and time of applications on growth, yield and yield components of maize varieties.

MATERIALS AND METHODS

Description of the Study Area: The experiment was conducted at Bako Agricultural Research Center during 2019 main cropping season in western Oromia Regional National State, East Wollega Zone, at about 250 km away from the capital city Addis Ababa in Gobu Sayo district. Bako lies at an altitude of 1650 meter above sea level. The center was located at about 09°6' North latitude and 37°09' East longitudes. The study area has a warm humid climate with annual maximum and minimum temperature of 28.7 and 13.5°C, respectively. The area receives an average annual rainfall of 123.7mm mainly from May to October with maximum precipitation in the month of June to August. The predominant soil type of the area is Nitisols which is characteristically reddish brown with a pH that falls in the range of very strongly acidic to very acidic according to rating done by Jones [15].

Experimental Materials: Two medium maturing hybrid maize (BH- 546 and BH-547) varieties were used for the execution of the treatments. The varieties were recently released by Bako National Maize Research Center and it can be grown in a range of 1000-2000?m above sea level and it requires an annual rainfall of 1000–1500 mm with uniform distribution in its growing periods. The yield potential of both varieties was 85-115 and 65-75 kg ha^{-1} on Research station and farmer field respectively. The nitrogen fertilizers used were 75%recommended rates (82) and 100%recommended rates (110) kg N ha^{-1} from urea (46% N) and applied as per treatment arrangements.

Treatments and Experimental Design: The treatments consisting of three factors, namely two types of maize varieties (BH-547 and BH-546), two nitrogen rates 75% recommended rates (82 $kgha^{-1}$) and 100 % recommended rates (110 kg N ha^{-1}) and four different nitrogen application times (1/2 dose at planting +1/2 dose at knee height, 1/2 dose at planting + 1/2 dose at tasseling time, 1/3dose at planting + 1/3 dose at knee height +1/3dose at tasseling, 1/2 dose at knee height and 1/2 at tasseling). The treatments were arranged as factorial combinations in randomized complete block design with three replications. Total treatments were eighteen with control (two non-fertilizer applications). The gross plot comprised of 6 rows of 3m length, 4.5 widths and one row each from both sides of the plot was left as a border. Thus, the central 4 rows were used for data collection and as net plot size 3mx3m= $9m^2$. Fertilizer used TSP for p source.

Experimental Procedures and Field Management: The land was ploughed by tractor, disked and harrowed. All cultural practices were applied as per the recommendations. Triple superphosphate was applied in the row on all treatments and mixed with soil just at the time of planting. Application time of N was done within the stated time ranges, but at the same date as per treatment arrangements. The crop was seeded at spacing of 75cm between row 30cm between plants, respectively. The spacing between blocks and plots was 1.5 m and 1 m, respectively. Two seeds were sown per hill and then it was thinned to one plant after seedling emergence. The trial was planted in June 2019. All other management practices were given as per the recommendations.

Soil Sampling and Analysis: Prior to planting, composite soil samples were collected from representative sites at the depth of 0-20 cm (in zigzag manner). The collected soil samples were air dried ground and sieved using a 2 mm mesh sieve size for analysis of selected soil physicochemical properties. The selected soil physicochemical properties were analyzed at Bako Agricultural Research Center Soil Laboratory section. Particle size distribution was done by hydrometer method. Soil pH (H_2O) was determined potentiometrically using pH meter with combined glass electrode in a 1:2.5 soil to water supernatant suspension [16]. Determination of soil organic matter was carried out by oxidizing the soil organic carbon under standard condition with potassium dichromate in sulfuric acid solution as described by Diaz-zorita [17]. The base titration method which involves saturation of the soil sample with 1M KCl solution and titrating with sodium hydroxide was employed to determine exchangeable acidity.

Soil total nitrogen was determined by the Kjeldahl method using micro- Kjeldahl distillation unit and Kjeldahl digestion stand as described by Jacson [18]. Available soil phosphorus was extracted by the Bray II procedure [19] and determined calorimetrically by spectrophotometer. Cation exchange capacity (CEC) of the soil was determined by 1M ammonium acetate (NH_4OAc) saturated sample at pH 7 [20] where the standard paste is distilled to estimate the ammonium liberated by titration with acid.

Collected Data: Data on plant basis was recorded from the four central rows (9 m2) out of the six rows per plot. The crop data collected include: Days to 50% tasseling: was recorded as number of days from date of sowing to the time when 50% of the flowered in each plot. Days to 90% physiological maturity: was recorded as the number of days after sowing to the formation of a black layer at the point of attachment of the kernel with the cob. Plant height: was measured in (cm) from five plants sampled randomly from the central four rows one week before harvesting. The total measured plant height was summed and divided by the number of plants to get the mean height the plants. Leaf area Index: was also calculated as the ratio of total leaf area of five plants (cm^2) per area of land occupied by the plant. Dry biomass yield: was a harvested plant after physiological maturity and weighed after sun drying. Thousand kernels weight: - was counted and weighed from the bulk of shelled grain at 12.5 % moisture level and expressed as in gram. Grain yield: was recorded after harvesting from the central four rows of the net plot. Unshelled grain yield, from total ears harvested, was measured from the central four rows. Grain yield was adjusted to 12.5% moisture level. The adjusted grain yield per plot of maize at 12.5% moisture level was converted to kg ha^{-1} and used for the analysis. Harvest index: was calculated as the ratio of grain yield to total aboveground biomass yield.

Statistical Analysis: All collected parameters were subjected to analysis of variance using of SAS GLM version 9.1. Whenever the effects of the treatments were found to be significant, the means were compared using Least Significance Difference test at 5% level of significance [21].

RESULTS AND DISCUSSION

Soil Physicochemical Properties of the Experimental Site: Physicochemical properties of the soil are indicated in (Table 1). The soil textural class of the experimental site was clay with a proportion of 18% sand, 10% silt and 72% clay. The soil reaction (pH (H_2O)) of the experimental site was 5.61 showing moderate acidity [22]. The soil has organic matter of 4.37% which was considered as medium [23]. The soil had a moderate total nitrogen content of 0.22 % [24]. The soil available P content of experimental sites was 8.5 ppm and low [24]. The average CEC of the soil was 21 Cmol (+)/kg, which is rated as medium [25]. The soil cation exchange capacity describes the potential fertility of soils and is an indicator of the soil texture, organic matter content and the dominant types of clay minerals present. In general, soils high in CEC contents are considered as agriculturally fertile.

Table 1: Some physicochemical properties soil of the experimental site at BARC in 2019

Soil property	Amount	Rating
Particle size distribution (%)		
Sand (%)	18	
Silt (%)	10	
Clay (%)	72	
Textural Class	Clay	
pH (H_2O) 1:2.5	5.61(acidic)	
Organic carbon (%)	2.54	Moderate
Total N (%)	0.22	Moderate
Available phosphorus mg/kg soil	8.5	Low
CEC%	21	Medium

Days to 50% Tasseling: The days to 50% tasseling of maize were significantly affected by the main effect of varieties and nitrogen level (Table 2). Main effect of time of nitrogen application and their interaction were showed no significant effect on tasseling date (Table 2). Higher days to 50 % tasseling (79 days) were observed from both main effect of variety (BH-547) and main effect of nitrogen rates 100RR (110 kg N ha^{-1}) while the minimum days to 50% tasseling 78 days were recorded from variety (BH-546) and nitrogen rates 75%RR (82 kg N ha^{-1}) (Table 2). This indicates increase in N level might have enhanced the vegetative growth and delayed tasseling time of the maize crop while the low-level applied plot took short days to tassel. The delay in days to tasseling of maize plants in response to the increased N level might be due to the availability of sufficient nutrient in the soil for plant uptake that promoted vigorous vegetative growth and development of the plants. Likewise, Moosavi *et al.* [26] reported that tasseling was significantly delayed at the highest N fertilizer level compared to the lowest level of nitrogen. Moges [27] reported that nitrogen fertilizer increasing N from 0 to 128 kg N ha^{-1} that increased duration of tasseling time of maize.

Days to 90% Physiological Maturity: The mean days to 90% physiological maturity of maize significantly (P<0.01) affected by main effect of rate of nitrogen application (Table 2) but the interaction of two ways and three ways was non-significant for days to 90 % maturity of maize (Table 2). The maximum number of days to attain maturity (129 days) was recorded from application of 110 kg N ha^{-1}, while the minimum (127 days) was recorded from application of 75%RR (82 kg N ha^{-1}). The control treatment was taking shorter days to 50% physiological maturity when compared with maize crop applied with nitrogen fertilizer (Table 2).

Mean days to 90 % maturity of maize has a direct relationship with days to 50% tasseling and days to 50% silking. The mean days to 90 % maturity of maize was delayed when the N rate was increased. This might be due to application of N delayed leaf senescence, sustained leaf photosynthesis during active crop growth stage and extended the duration of vegetative growth. Similarly, Zerihun and Hayilu [12] found that the excessive use of nitrogen in the plants causes continued growth and results in late maturation period. Shrestha *et al.* [28] reported that number of days to physiological maturity was affected by nitrogen rates. Also, Akbar *et al.* [29] reported that the maturity days of maize increased as fertilizer rate increased.

Plant Height: The effects of nitrogen level on mean plant height of maize is presented in (Table 3). Mean plant height was significantly (P<0.05) affected by level of nitrogen application but main effect of varieties, time of nitrogen application, two way and three-way interaction were non-significant. The maximum plant height (272cm) was obtained with application of 100%RR (110 kg N ha^{-1}), while the shorter plant height (270cm) was recorded from application of 75%RR (82 kg N ha^{-1}). The tallest plant height was recorded from treatment that received nitrogen fertilizer (treated) as compared to control or without N (Table 3).

The increase in plant height with increase in N application indicated continuation of vegetative growth of the plants at higher N availability to the plant. Similarly, Namvar and Sharifi [30] found that increase in plant height due to more N may be attributed to better vegetative development which was influenced by mutual shading. Assefa and Zenebe [31] indicated that plant height was significantly affected by level of nitrogen application.

Leaf Area Index: The main effect of time of nitrogen fertilizer application had highly significant (P ≤ 0.01) influence on leaf area index of maize (Table 3). The interaction effect of variety and nitrogen rates had significant effect on leaf area index (Table 4). Main effect time of nitrogen application significant (P<0.01) effect on the leaf area index when the application of nitrogen in two splits, *i.e.* 1/2 dose at sowing, 1/2 dose at knee height as compared to others. The highest leaf area index (3.27) was recorded from application of 1/2 dose at sowing + 1/2 dose at knee height of nitrogen; while the lowest (2.9) was recorded from 1/2 dose at sowing +1/2 dose at tasseling of nitrogen but control plots produced lower leaf area index as compared with nitrogen treated plots (Table 3). The interaction of varieties and nitrogen rates were significantly different on leaf area index of maize (Table 4).

Table 2: Main effects of varieties, nitrogen rates and time of application on days to 50% tasseling, days to 50% silking and days to 90% physiological maturity of maize at BARC in 2019 cropping season

Treatment	Days 50% Tasseling	Days 50 % silking	Days to 90% Physiological maturity
Varieties			
BH-546	78^{b}	81^{b}	129
BH-547	79^{a}	82^{a}	129
LSD (5%)	0.555	0.641	Ns
Nitrogen rates (Kg N ha^{-1})			
75% RR (82.5)	78.29^{b}	81.21^{b}	127.7^{b}
100%RR (110)	79.17^{a}	82.33^{a}	129.4^{a}
LSD (5%)	0.93	1.075	0.4295
Time of nitrogen application			
1/2 sowing +1/2 Knee height	78	81^{b}	128
1/2 sowing +1/2 Tasseling	78	81^{b}	128
1/3 sowing +1/3 Knee height 1/3 tasseling	79	82^{a}	128
1/2 knee height +1/2 Tasseling	79	82^{a}	128
LSD (5%)	Ns	0.98	Ns
CV (%)	1.3	1.4	0.6
Control mean	78	82	127^{b}
Treated mean	79	82	129^{a}
LSD (5%)	NS	NS	1.4843
CV (%)	0.674	0.564	0.33

RR= recommended rates, Number followed by the same letter on column was non-significantly different at 5 % probability levels, NS= non-significant difference

Table 3: Main Effects of varieties, N-rates and time of N application on mean plant height, leaf area, leaf area index and dry biomass of maize at BARC in 2019 cropping season

Varieties	Plant height (cm)	Leaf area (cm^{-2})	Leaf area index	Dry biomass (kg ha^{-1})
BH-546	271	7203.7	3.20	20578.7
BH-547	272	7059.0	3.14	20555.6
LSD (5%)	NS	NS	NS	NS
Nitrogen rates (Kg N ha^{-1})				
75%RR (82.5)	270^{b}	7094.6	3.15	20093
100%RR (110)	273^{a}	7168.1	3.18	21042
LSD (5%)	1.7485	NS	NS	NS
Time of nitrogen application				
1/2 sowing +1/2 Knee height	272	7362.6^{a}	3.27^{a}	20740.7^{ab}
1/2 sowing +1/2 Tasseling	271	7269.7^{a}	3.23^{a}	18981.5^{b}
1/3sowing +1/3 Knee height 1/3 tasseling	272	6668.7^{b}	3.21^{a}	21481.5^{a}
1/2 knee height +1/2 Tasseling	271	7224.4^{a}	2.94^{b}	21064.8^{a}
LSD (5%)	NS	402.06	0.2143	2053.884
CV (%)	1.091221	3.67	6.9	10.4
Control mean	262.65^{b}	4776.45^{b}	2.12^{b}	10277.78^{b}
Treated mean	271.32^{a}	7066.02^{a}	3.14^{a}	21597.22^{a}
LSD (5%)	1.5396	1080.8	0.4857	1049.3
CV (%)	0.16	5.196	5.25	1.87

RR=recommended rates, Number followed by the same letter on column was non-significantly different at 5 % probability levels, NS= non-significant difference

Table 4: Interaction effect of varieties and nitrogen rates on mean leaf area index of maize at BARC in 2019 cropping season

	Nitrogen rates (kg ha^{-1})	
Varieties	75%RR (82)	100%RR (110)
BH-547	3.055b	3.220ab
BH-546	3.152ab	3.251a
LSD (5 %)	0.179	
CV (%)	6.8	

RR=recommended rates, Number followed by the same letter on column was non-significantly different at 5%Probability level

The highest leaf area index (3.25) was recorded from interaction of BH-546 variety with application of (100%RR) 110 kg N ha^{-1} while the lowest leaf area index (3.05) was recorded from interaction of BH-547 variety applied with (75%RR) 82 kg N ha^{-1} (Table 5). Likewise, Moges [27] reported that increase in leaf area with the increase of nitrogen level from 0-128 kg N ha^{-1} and attributed to the more vegetative growth due to nitrogen application, as it is a general truth that N enhances vegetative growth in maize. Also, Kidist [32] reported that increasing the rate of N from 0 to 130.5 kg N ha^{-1} linearly increased leaf area index of maize.

Dry Biomass Yield: Dry biomass yield of maize was significantly ($P<0.05$) affected by interaction effects of different levels of nitrogen and time of N application is presented in Table 5. The interaction effect of nitrogen rates and time of N application was showed significant ($P < 0.01$) effects on mean dry biomass of maize varieties (Table 5) but main effect of varieties, nitrogen rates and three way interaction were non-significant (Table 3). The higher mean dry biomass 22963 kg ha^{-1} recorded from application of (100%RR) 110 kg N ha^{-1} with three split application(1/3 dose at planting + 1/3 dose at knee height + 1/3 dose at tasseling) as compared to rest of the treatment combination. While the lowest dry biomass 18148 kg ha^{-1} recorded from application of (100%RR) 110 kg N ha^{-1} with two split application 1/2 dose at sowing 1/2 dose at tasseling of time of nitrogen application (Table 5). Similarly, Zerihun and Hayilu [12] reported that the interaction of nitrogen rates and time of application also showed significant effects on biomass yield of maize that the heights biomass 21.2 t ha^{-1} was obtained with application of 115 kgN$ha^{-1}$and four time split application of equal doses but the lowest biomass obtained from treatment that non fertilizer applications. Amanullah *et al.* [33] found that biomass yield at various growth stages increased significantly with increase in N rate.

Grain Yield: Main effect of N rates had highly significant ($P<0.001$) effects on mean grain yield of maize varieties (Table 6). Significantly higher grain yield (8998 kg ha^{-1}) of maize was obtained with application of (100%RR) 110 kg N ha^{-1} while lower grain yield (8217 kg ha^{-1}) was recorded from application of (75%RR) 82 kg N ha¹ (Table 6). Fertilizer treated plots produced maximum mean grain yield of maize compared to control plots (Table 6). The interaction of nitrogen rate and time of N application was statistically non-significant. Increase in grain yield with higher nitrogen levels might be due to the lower competition for nutrient that allowing the plants to accumulate more biomass with higher capacity to convert more photosynthesis into sink resulting in more grains yield.

This result was in agreement with Begizew *et al.* [34] founded that Grain yield was increased with increasing nitrogen rate up to optimum. The maximum grain yield (7713 Kg ha^{-1}) was obtained at application of 115 Kg N ha^{-1}, while minimum grain yield was recorded from nitrogen rate at 62 kg N ha^{-1}. Lawrence *et al*. [35] founded that nitrogen is the principal factor in controlling the growth and development of the crop. Desta [36] also indicated that grain yield was significantly increased with the application of N fertilizer. Matusso and Materusse [37] Grain yield was significantly ($P \leq 0.001$) affected by nitrogen application level.

Harvest Index: The main effects of nitrogen rate and time of application had significant ($P<0.05$) influence on harvest index of maize while the interaction was not significant (Table 6). The highest harvest index (43 %) was obtained from (100% RR) 110 kg N ha^{-1} of nitrogen rates, while lowest harvest index (41%) was recorded from (75%RR) 82 kgha^{-1} nitrogen rates. Harvest index significantly influenced by time of nitrogen application. The highest harvest index (44 %) was obtained from 1/2 dose at planting + 1/2 dose at tasseling, while the lowest harvest index (40 %) recorded from 1/2 dose at knee height + 1/2 dose at tasseling of time of nitrogen application (Table 6). The lowest harvest index was obtained from control plots when compared to treated plots (Table 6). In conformity, Zeidan *et al.* [38] reported that the maximum harvest index (39%) was recorded with application of 225 kg N ha^{-1} and minimum (34%) was recorded without fertilizer application. Similarly, Merkebu and Ketema [39] reported that harvest index of maize was significantly increased when the application of N increased from 0 to 60 kg ha^{-1}.

Thousand Seed Weight: Mean thousand seed weight of maize was significantly ($P<0.01$) affected by main effect of varieties (Table 6). But main effect of nitrogen rates, time of nitrogen application and interaction between parameters were non-significant. The highest thousand kernels weight (351g) was recorded from BH-547 variety, while the lowest (303 g) was recorded from BH-546 variety (Table 6). Likewise, Ahmad *et al*. [40] indicated that thousand grain weights were significantly affected by cultivars and interaction between cultivars and nitrogen levels was no significant. Yusuf *et al.* [41] reported that hundred seed weight significant different due to maize varieties.

Table 5: Interaction effect of nitrogen rates and applications timing on mean dry biomass of maize in BARC 2019 cropping season

	Time of nitrogen application			
Nitrogen rates (kg ha^{-1})	AT1	AT2	AT3	AT4
75%RR (82)	20926abc	19815cd	19630cd	20000bcd
100RR (110)	20556abcd	18148d	22500ab	22963a
LSD (5%)	2342.721			
CV (%)	9.7			

RR=recommended rates, AT1 = 1/2 at sowing + 1/2 at knee height, AT2= 1/2 at sowing + 1/2 at Tasseling, AT3 = 1/3 at sowing + 1/3 at knee height + 1/3 at Tasseling, AT4=1/2 at knee height +1/2 at Tasseling. Number followed by the same letter on column was non-significantly different at 5 % probability levels

Table 6: Main effects of varieties, N-rate and N-time of application on grain yield, harvest index and thousand seed weight of maize at BARC in 2019 cropping season

Varieties	Grain yield(kg ha^{-1})	Harvest index (%)	1000 Seed Weight (g)
BH-546	8694.7	42.4583	303.35[b]
BH-547	8520.7	41.7083	351.24[a]
LSD (5%)	NS	NS	14.26
Nitrogen rates (Kg N ha^{-1})			
75%RR (82)	8217[b]	41.14[b]	330.6
100%RR (110)	8998[a]	43.06[a]	324.0
LSD (5%)	770.16	0.028	NS
Time of nitrogen application			
1/2 sowing +1/2 Knee height	8728.9	42.25[ab]	323.4
1/2 sowing +1/2 Tasseling	8303.5	44.08[a]	322.8
1/3sowing +1/3 Knee height 1/3 tasseling	8916.6	41.33[b]	331.4
1/2 knee height +1/2 Tasseling	8481.9	40.66[b]	331.5
LSD (5%)	NS	0.031	NS
CV (%)	10.3	7.3	8
Control mean	3898.46[b]	39.49[b]	279.61[b]
Treated mean	8979.29[a]	41.39[a]	333.56[a]
LSD (5%)	919.98	NS	32.79
CV (%)	4.063	3.128	3.044

RR=recommended rates, Number followed by the same letter on column was non-significantly different at 5 % probability levels, NS= non-significant

CONCLUSION

This study provides basic information for additional research and development effort for scientific recommendation of nitrogen rates and time of application with varieties for sustainable maize production. Therefore, (100% recommended rate) 110 kg N ha^{-1} fertilizer rates with two times application 1/2 does at knee height + 1/2 does at tasseling gave higher yield for study area and recommended for wider use in Bako area and similar agro ecology.

ACKNOWLEDGEMENTS

We would like to thanks Almighty to God, who gave us health and strength that we required to complete this work. We would like to thank OARI in general specifically Bako Agricultural Research Centre especially Pulse and Oil Research Team and Seed Technology Multiplication team for their contribution in guards and daily labor wage supports. And our great heartfelt also for AGP-II program in covering all research budgets till its completion. Also, thanks to Beley Taressa, Alemayo Dabasa, Eshetu Mogasa and Mamo Mekonnen and all technical and field assistants of Seed Research and Technology multiplication team for unreserved effort during executing the experiment

REFERENCES

1. Kandil, E., 2013. Response of Some Maize Hybrids (*Zea mays* L.) to Different Levels of Nitrogenous Fertilization. Journal of Applied Sciences Research, 9(3): 1902-1908.
2. Zamir, M., G. Yasin, H. Javeed, A. Ahmad, A. Tanveer and M. Yaseen, 2013. Effect of different sowing techniques and mulches on the growth and yield behavior of spring planted maize (*Zea mays* L.). Cercetãri Agronomice în Moldova, 46(1): 77-82.

3. CSA, 2018. Agricultural sample survey 2017/2018. Volume I. Report on Area and Crop Production of Major Crops (Private Peasant Holdings Main Season). Statistical Bulletin 586, Addis Ababa, Ethiopia.
4. Mandefro, N., D. Tanner and S. Twumasi-Afriyie, 2001. Enhancing the contribution of maize to food security in Ethiopia in, in Proceedings of the Second National Maize Workshop of Ethiopia, pp: 12-16, Addis Ababa, Ethiopia.
5. FAO, 2013. World Food and Agriculture Organization and World food and agriculture Statistical pocketbook.
6. FAO, 2018. World Food and Agriculture Organization and World food and agriculture Statistical Pocketbook, pp: 254.
7. Mourice, S., S. Tumbo, A. Nyambilila and C. Rweyemamu, 2015. Modeling potential rain-fed maize productivity and yield gaps in the Wami River sub-basin, Tanzania, Acta Agriculturae Scandinavica Section B: Soil and Plant Science, 65(2): 132-140.
8. Shrestha, J., 2013. Effect of nitrogen and plant population on flowering and grain yield of winter maize. Skye Journal Agricultural Research, 2: 64-68.
9. Shrestha. J., A. Chaudhary and D. Pokhrel, 2018. Application of nitrogen fertilizer in maize in Southern Asia: a review. Peruvian Journal of Agronomy, 2(2): 22-26.
10. Sharma, R., P. Adhikari, J. Shrestha and P.B. Acharya, 2019. Response of maize (*Zea mays* L.) hybrids to different levels of nitrogen. Archives of Agriculture and Environmental Science, 4(3): 295-299.
11. Tadesse, T., A. Alemayehu, L. Minale and T. Zelalem, 2013. Effects of nitrogen split-application on productivity, nitrogen use efficiency and economic benefits of maize production in Ethiopia. International Journal of Agricultural Policy and Research, 1(4): 109-115.
12. Zerihun, A. and F. Hayilu, 2017. Effects of nitrogen rates and time of application on yield of maize: rainfall variability influenced time of N application. International Journal of Agronomy, pp: 1-10.
13. Sawyer, J., 2008. Nitrogen application timing, forms and additives, American Society of Agricultural and Biological Engineers.
14. Limon-Ortega, A., N.A. Ruiz-Torres, G. Vazquez-Carrillo and A. Baez-Perez, 2016. Environment and nitrogen influence on rainfed maize yield and quality. Crop Science, 56(3): 1257-1264.
15. Jones, J.B., 2003. Agronomic Handbook: Management of crops, soils and their fertility. CRC Press LLC, Boca Raton, Florida, USA, pp: 482.
16. Van Reeuwijk, L.P., 1992. Procedure for soil analysis 2nd edition, Int. Soil Reference and Information Center (ISRIC), the Netherlands.
17. Diaz-Zorita, M., 1999. Soil organic carbon recovery by the Walkley-Black method in a typic hapludoll. Communications in Soil Science and Plant Analysis, 30(5-6): 739-745.
18. Jackson, M.L., 1958. Nitrogen determinations for soil and plant tissue. Soil Chemical Analysis, pp: 183-204.
19. Bray, R.H. and L.T. Kurtz, 1945. Determination of total, organic and available forms of phosphorus in soils. Soil Science, 59(1): 39-46.
20. Chapman, H.D., 1965. Cations exchange capacity. Methods of Soil Analysis: Part 2 Chemical and Microbiological Properties, 9: 891-901.
21. Steel, R.G.D., J.H. Torrie and D.A. Dicky, 1997. Principles and Procedures of Statistics, A Biometrical Approach. 3rd Edition, McGraw Hill, Inc. Book Co., New York, pp: 352-358.
22. FAO, 2008. World Food and Agriculture Organization and World food and agriculture Statistical Pocketbook
23. FAO, 2006. World Food and Agriculture Organization and World food and agriculture Statistical Pocketbook, pp: 23.
24. Tekalign, M., L. Haque and E.A. Aduayi, 1991. Working Document: Soil, Plant, Fertilizer, Animal Manure and Compost Analysis Manual, International Livestock center for Africa, No. B13, Addis Ababa, Ethiopia.
25. London, J.R., 1991. Booker tropical soil manual: A hand book for soil survey and agricultural land evaluation in the tropics and subtropics. Longman.
26. Moosavi, S.G., M.J. Seghatoleslami and A. Moazeni, 2012. Effect of planting date and plant density on morphological traits, LAI and forage corn (Sc. 370) yield in second cultivation. International Research Journal of Applied and Basic Sciences, 3(1): 57-63.
27. Moges, A., 2015. Effect of nitrogen fertilizer rates and plant densities on yield and yield related traits of maize (*Zea mays* L.) under irrigation in Southern Tigray, Ethiopia. MSc Thesis. Haramaya University, Haramaya, Ethiopia.
28. Shrestha, J., D.N. Yadav, L.P. Amgain and J.P. Sharma, 2018. Effects of nitrogen and plant density on maize (*Zea mays* L.) phenology and grain yield. Current Agriculture Research Journal, 6(2): 175-182.

29. Akbar, H., H. Ihsanullah, M.T. Jan and J. Miftahullah, 2002. Yield potential of sweet corn influenced by different levels of nitrogen and plant population. Asian Journal of Plant Science, 6(1): 631-633.
30. Namvar, A. and R. Sharifi, 2016. Phenological and morphological response of chickpea (*Cicer arietinum* L.) to symbiotic and mineral nitrogen fertilization. Zemdirbyste-Agriculture, 98(2): 121-130.
31. Assefa, K. and M. Zenebe, 2019. 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.
32. Kidist, A., 2013. Growth, productivity and nitrogen use efficiency of maize (*Zea mays* L.) as influenced by rate and time of nitrogen fertilizer application in Haramaya District, Eastern Ethiopia. MSc Thesis, Haramaya University, Haramaya, Ethiopia.
33. Amanullah, H., K.B. Marwat, P. Shah, N. Maula and S. Arifullah, 2009. Nitrogen levels and its time of application influence leaf area, height and biomass of maize planted at low and high density. Pakistan. Journal of Botany, 41(2): 761-768.
34. Begizew, G., H. Messele and Y. Lemme, 2019. Effect of N Fertilizer Level and Plant Density on Grain Yield of Newly Released Maize Variety. Agricultural Research and Technology: Open Access Journal, 20(5): 234-239.
35. Lawrence, J.R., Q.M. Ketterings and J.H. Cherney, 2008. Effect of nitrogen application on yield and quality of corn. Agronomy Journal, 100(1): 73-79.
36. Desta, H., 2015. Response of Maize (*Zea mays* L.) to Different levels of Nitrogen and Sulfur Fertilizers in Chilga District, Amhara National Regional State, Ethiopia. International Journal of Recent Scientific Research, 6(8): 5689-5698.
37. Matusso, J.M.M. and M. Materusse, 2016. Growth and yield response of maize (*Zea mays* L.) to different nitrogen levels in acid soils. Academic Research Journal of Agricultural Science and Research, 4(2): 35-44.
38. Zeidan, M.S., A. Amany and M.F. El-Kramany, 2006. Effect of N-fertilizer and plant density on yield and quality of maize in sandy soil. Research Journal Agriculture Biology Science, 2(4): 156-161.
39. Merkebu, G. and B. Ketema, 2013. Yield Related Traits and Yield of Maize (*Zea mays* L.) as affected by Green Manuring and Nitrogen Levels at Mizan Teferi, South-west Ethiopia. International Journal of Agronomy and Plant Production, 4(7): 1462-1467.
40. Ahmad, S., A. Khan, M. Kamran, I. Ahmad and S. Ali, 2018. Response of Maize Cultivars to Various Nitrogen Levels. European Journal of Experimental Biology, 8: 1-2.
41. Yusuf, M.J., U.T. Musa and A.O. Ifeoluwa, 2019. Evaluation of Maize Varieties under Varying Fertilizer Application Rates in Owode-Egba Area of OGUN State Nigeria. Journal of Agriculture and Veterinary Science, 12(2): 25-32.