American-Eurasian Journal of Agronomy 16 (2): 18-29, 2023
ISSN 1995-896X

DOI: 10.5829/idosi.aeja.2023.18.29

Growth, Yield, Yield Component and Economic Analysis of Maize (*Zea mays* L.) as Affected by Nitrogen Fertilizer Time Applicationin Western Oromia, Ethiopia

[1]Megersa Debele and [2]Tolera Abera

[1]Oromia Agricultural Research Institute (OARI),
Bako Agricultural Research Center, P.O.Box.03, West Shewa, 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

Abstract: The findings of this study serve as a foundation for further investigation and development that will lead to recommendations for nitrogen application rates, timing and varieties for sustainable maize production. At the Bako Agricultural Research Center in Western Ethiopia, a field experiment was carried out on hybrid maize varieties during the 2020 growing season to ascertain the effects of nitrogen fertilizer rates and timing on yield and yield components of maize varieties. The experiment used two varieties of maize (BH-546 and BH-547) and four stages of nitrogen application (1/2 dose at sowing stage + 1/2 dose at Knee height stage; 1/2 dose at sowing stage + 1/2 dose at tasseling stage; 1/3 dose at sowing stage + 1/3 dose at knee height stage + 1/3 dose at tasseling stage; and 1/2 dose at knee height stage + 1/2 dose at tasseling stage). Three replications were used in the randomized complete block design of the experiment. The mean ear diameter, ear length, number of kernels per ear and thousand seed weight of maize varied significantly between the varieties. The effects of nitrogen rate application on days to 90% physiological maturity, plant height, grain yield and harvest index of maize cultivars were extremely significant. The timing of the nitrogen treatment had a big impact on the average leaf area, dry biomass and harvest index of maize. The leaf area of maize was significantly impacted by the interactions between nitrogen rates and variety. On average dry biomass of maize, the interplay between nitrogen rates and nitrogen application time had a substantial impact. Lower grain yield (3898.46 kg ha^{-1}) and significantly greater grain yield (8998 kg ha^{-1}) were observed when controls (110 kg N ha^{-1}) and controls (N applied 1/2 dosage at knee height + 1/2 dose at tasseling of maize) were used as the fertilizer rates. With regard to growth, yield and yield component, grain yield demonstrated great significance. The largest monetary gain was 88821 Birr per hectare.

Key words: Maize · Nitrogen Application · Nitrogen Use Efficiency · Nitrogen Rate

INTRODUCTION

The most frequently cultivated cereal in the world and the main source of food in many developing nations is maize (*Zea mays* L.) [1]. after rice and wheat, maize is the third-largest cereal crop produced globally [2]. Due to its cross-pollination, maize has a wide range of morphological variety and geographic adaptation. 1,134 million tons of maize grains were produced in the 2018 production season on 197 million hectares of land, according to FAO [3] Maize is cultivated under a variety of agroclimatic conditions and is crucial to Ethiopia's food security [4]. In terms of productivity and area cultivated, maize is Ethiopia's most significant grain crop. Eight million tons of corns were produced from two million hectares by around 80% of all farmers. One of the most significant cereals grown in Ethiopia is maize. It comes in first for overall production and second for coverage of the area after tef. Regarding calorie intake, maize is the most significant steady crop in Ethiopian rural families. It provides 16.7% of the national per capita calorie consumption, making it the cheapest source of calories

Corresponding Author: Megersa Debele, Seed Research and Technology Multiplication, Bako Agricultural Research Center, Oromia Agricultural Research Institute, P.O. Box: 03, Bako, West Showa, Oromia, Ethiopia.

[5]. In Ethiopia, maize is grown primarily for food, both as green cobs and grain [6]. 75% of the maize produced is consumed by agricultural households, who grow it mostly for subsistence [4]. One of the top producers of maize in Africa is Ethiopia [7]. Grain crops span a total of around 12, 979,459.91 hectares of land and of that total, cereals made up 81.19% (10,232,582.23 hectares). 2, 526,212.35 hectares, or 21.40 percent, were devoted to maize, which produced 10, 5570,935.92 tons of grain [4]. Even though there is a lot of land planted in maize, the average yield in the country is only about 4.17 t ha^{-1} [4]. This yield is significantly lower than the global average, which is roughly 5.2 t ha^{-1} [3]. Even though there are numerous biotic and abiotic factors that might cause these large yield disparities, low productivity is mostly caused by depleted soil fertility and ineffective fertilizer management [8].Compared to other nutrients, nitrogen fertilizer is more in demand. A lack of nitrogen during the tasseling and silking stages may have a substantial impact on crop failure. The amount of nitrogen to be applied to the maize plant, however, depends on the variety of maize, the kind of soil, the crop's nutrient state, the location and the yield [9].

Nitrogen is extremely soluble as compared to other nutrients and it can be lost by leaching, denitrification, volatilization, erosion and other processes [10].Significant amounts of N can also be immobilized in organic forms that are not easily accessible to crops. Utilizing the yield potential of maize requires the adoption of better cultivars and the best application of nitrogen fertilizer [11]. Due to increased grain output, profit was increased at greater nitrogen application rates [12]. Due to growing seasons and split nitrogen applications, grain production, days to flowering, plant height, ear height, number of rows and kernels per row, ear length and thousand grain weight were all considerably impacted [13].One of the main abiotic variables limiting the crop's yield and productivity is the rate at which nitrogen is applied. Another important area of study to improve nitrogen use efficiency and boost maize yield is the timing of nitrogen treatment at the proper crop growth stage. When compared to nitrogen delivery at planting time, delayed nitrogen application after crop establishment considerably raised the harvest index [14]. Nitrogen losses are significantly decreased by applying nitrogen in two separate applications when the crop has a good foundation [15]. Farmers in the study area apply nitrogen twice, half at planting and half at knee height. However, other studies show that nitrogen use efficiency, even at modest rates applied two to three times, significantly increases nitrogen absorption in good rainy seasons [16]. Utilizing the right amount of nitrogen at the right time will increase maize productivity. Therefore, this project was started to evaluate the recommended nitrogen rates, timing of nitrogen treatments and effectiveness of nitrogen use on improved maize varieties (BH-546 and BH-547) in the study area. This study's goal is to increase maize output and analyze its economics in Western Oromia, Ethiopia, by applying nitrogen at the right time and at the right rate.

MATERIALS AND METHODS

The experiment was carried out in the Bako Agricultural Research Center in western Oromia Regional National State's East Wollega Zone during the main cropping season of 2020. Nekemte town is located in Gobu Sayo district, about 8 kilometers from Bako town and is about 250 kilometers from Addis Abeba, the nation's capital. At 1650 meters above sea level, Bako is located. The centroid was roughly at latitude 090 6' North and longitude 370 09' East. With annual maximum, lowest and average temperatures of 23.7 and 13.5ºC, respectively, the region has a warm, humid environment. The region experiences an average annual rainfall of 1237 mm, mostly from May to October, with the wettest months being June and August. According to Jones' assessment [17], the area's major soil type is nitisol, which has a characteristic reddish brown color with a pH that ranges from very strongly acidic to very acidic.

Experimental Materials: The treatments were carried out using the BH- 546 and BH-547) kinds of medium maturing hybrid maize. The Bako National Maize Research Center recently announced the new kinds, which may be planted anywhere between 1000 and 2000 meters above sea level and require an even distribution of 1000 to 1500 millimeters of yearly rainfall during their growing seasons. On the research station and farmer fields, the yield potential for each variety was 85-115 and 65-75 kg ha-1, respectively. The nitrogen fertilizers were applied in accordance with the treatment plans and were 82.5, 110 kg N ha-1 from urea (46% N).

Treatments and Experimental Design: The treatments included three variables: two different maize varieties (BH-547 and BH-546), two nitrogen application rates (82.5 and 110 kg N ha-1) and four different nitrogen application timings (i.e., half at planting + half at knee height, half at planting + half at tasseling, half at planting + half at knee height, half at planting + half at tasseling).

The treatments were set up in RCBD as two-by-two-by-four factorial combinations with three replications. With two non-fertilizer applications as control, there were a total of 18 treatments. The overall plot was made up of six rows that were each 3 meters long and 4.5 meters wide, with one row on each side serving as the plot's border, Thus, the center four rows were chosen as the net plot size (3m x 3m = 9m^2) and for data collecting.

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 (TSP) 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 is 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 2020. All other management practices were given as per the recommendations.

Soil Sampling and Analysis: A representative soil sample was collected and composite using auger from a surface layer of 0-20cm from the whole experimental field prior to planting. The collected soil samples were air dried ground and sieved using a 0.2 mm mesh sieve size for analysis of selected soil physicochemical properties, *i.e.* total N, soil pH, available phosphorus, cation exchange capacity (CEC), organic matter and texture. The selected soil physico chemical properties were analyzed at Bako Agricultural Research Center Soil Laboratory section.

Soil pH was determined potentiometrically using pH meter with combined glass electrode in a 1:2.5 soil to water supernatant suspension [18]. 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 [19]. 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 Jackson [20]. Available soil phosphorus was extracted by the Bray II procedure [21] 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 [22] where the standard paste is distilled to estimate the ammonium liberated by titration with acid. Particle size distribution was done by hydrometer method.

Data to Be Collected

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 height of each plant.

Leaf Area: Was determined from 5 randomly selected plants per treatment by measuring the length and width of three middle leaves with a measuring tape and then calculated using the formula: Leaf Length x Leaf width x 0.75 [23].

Ear Length: Was measured from the point where the ear attaches to the stem to the tip of the ear.

Ear Diameter: was measured circumference of cob by caliper.

Number of Rows per Ear: was counted from rows on ear of five plants.

Number of Kernels per Ear: Was computed as the average number of kernels of five randomly taken ears from the central net plot areas.

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 using the formula:

$$\text{Yeild at standard moiture content (12.5\%)} = FW\left(\frac{100-A}{100-D}\right)$$

where FW= unshelled field weight of maize; A= actual moisture content of the grain; M= standard moisture content of maize (12.5 %) and 0.81= correction factor (shelling percentage of maize). The adjusted grain yield per plot of maize at 12.5% moisture level was converted to $kgha^{-1}$ and used for the analysis.

Harvest Index: Was calculated as the ratio of grain yield to total aboveground biomass yield

Statistical Analysis: All collected data parameters were subjected to analysis of variance using of SAS GLM version 9.1 [24]. Whenever the effects of the treatments were found to be significant, the means were compared using Least Significance Difference (LSD) test at 5% level of significance [25].

Economic Analysis: The economic analyses, partial budget was carried out using the procedures described by CIMMYT [26]. The average yield was adjusted downward by 10% to reflect the farmer's field yield as described by CIMMYT [26]. The current price of grain and stalk yield of maize were valued at an average open market price at Bako town which were 10 ETB kg^{-1} and 0.5 ETB kg^{-1}, respectively. The price of NPS and urea fertilizer were 15.15 and 15.27 ETB kg^{-1}. The costs of Labor for fertilizer application per treatment was recorded and used for this analysis. The other cost inputs and production practices such as labor cost for land preparation, planting, weeding, harvesting and threshing were considered the same for all treatments or plots.

RESULTS AND DISCUSSION

The data collected were analyzed and significant tests were performed for each treatment at 5% probability level and result are presented and discussed below.

According to physicochemical properties of the soil are indicated Table 1. The soil had a moderate total nitrogen content of 0.24 % [27]. The soil has organic matter of 3.91% which was considered as medium [28]. The soil available P content of experimental sites was 9.5 ppm and low [27]. The soil textural class of the experimental site was clay with a proportion of 19% sand, 69% clay and 12% silt. The soil reaction (pH) of the experimental site was 4.81 showing moderate acidity. The average CEC of the soil was 22Cmol (+) /kg, which is rated as medium. 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.

Days to Physiological Maturity: The main effect of nitrogen application level significantly (P0.01) altered the mean days to physiological maturity of maize (Table 3), although the interaction of varieties, time and nitrogen application level was not significant for days to maturity of maize. The application of 110 kg N ha-1 resulted in the Long number of days to reach maturity (135 days), whereas the application of 82.5 kg N ha-1 resulted in the Short number of days (130 days).Compared to maize that had nitrogen fertilizer applied, untreated treatment required shorter days to reach physiological maturity (Table 2). The average number of days until maize is fully mature was increased when the N rate was enhanced. This might be as a result of the nitrogen fertilizer application delaying the senescence of the leaves, maintaining leaf photosynthesis during the active crop development stage and extending vegetative growth. Similar findings were made by Zerhun and Hayilu [29], who discovered that high nitrogen usage in plants results in continuous development and a delayed maturation stage. According to Shresth *et al.* [9], nitrogen rates and the increasing N rate application had an impact on the number of days until physiological maturity. It can be

Table 1: Some physicochemical properties soil of the experimental site of maize at BARC in 2020

Soil property	Amount	Rating
Particle size distribution (%)		
Sand (%)	19	
Silt (%)	12	
Clay (%)	69	
Textural Class	Clay	
pH (H_2O) 1:2.5	4.81 (acidic)	
Total N (%)	0.24	Moderate
Available phosphorus mg/kg soil(%)	9.5	Low
Organic carbon (%)	2.54	Moderate
Organic Matter (%)	3.97	Medium
CEC%	22	Medium

Table 2: Interaction effects of varieties and nitrogen rates on mean leaf area of maize at BARC in 2020 cropping season

Treatment	Nitrogen rates (kg ha^{-1})	
Varieties	82.5	110
BH-547	6874b	7244ab
BH-546	7315a	7092ab
LSD (5%)	402.061	
CV (%)	6.8	

Number followed by the same letter on column was non-significantly different at 5 % probability levels

Table 3: Main Effects of varieties, N-rates and time of N application on men Physiological Maturity, plant height and dry biomass of maize at Bako in 2020 cropping season

Varieties	Physiological maturity	Plant height (cm)	Dry biomass (kg ha^{-1})
BH-546	135^{a}	271	20578.7
BH-547	135^{a}	272	20555.6
LSD (5%)	Ns	NS	NS
Nitrogen rates (Kg N ha^{-1})			
82.5	130.7^{b}	270^{b}	20093
110	135.4^{a}	273^{a}	21042
LSD (5%)	0.4295	1.7485	NS
Time of nitrogen application			
1/2 sowing +1/2 Knee height	133	272	20740.7^{ab}
1/2 sowing +1/2 Tasseling	133	271	18981.5^{b}
1/3sowing +1/3 Knee height 1/3 tasseling	133	272	21481.5^{a}
1/2 knee height +1/2 Tasseling	133	271	21064.8^{a}
LSD (5%)	Ns	Ns	2053.884
CV (%)	0.6	1.091221	10.4
Control mean	127^{B}	262.65^{B}	10277.78^{B}
Treated mean	135^{A}	271.32^{A}	21597.22^{A}
LSD (5%)	1.4843	1.5396	1049.3
CV (%)	0.33	0.16	1.87

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

because the plant was left green for a longer time, resulting in a lengthier maturation phase. Additionally, according to Akbar *et al*. [30], maize maturity days rose as fertilizer rate increased.

Plant Height: The study's statistical analysis revealed substantial differences between nitrogen rates for plant height. Table 3 shows the impact of nitrogen level on the average plant height of maize. The level's interaction effect, the effects of cultivars, timing of nitrogen delivery and mean plant height were not significant. The longer plant height (272 cm) was obtained by applying 110 kg ha^{-1} of nitrogen, whereas the lesser plant height (270 cm) was attained by applying 82.5 kg ha^{-1} of nitrogen. When compared to no fertilizer plots, nitrogen fertilizer applied plots had the longest plant height (Table 4). The continuance of vegetative growth of the plants with higher N availability to the plant was evidenced by the rise in plant height with increased nitrogen application. The highest plant height (256.1 cm) was attained when nitrogen was applied at a rate of 92 kg ha-1, whereas the lowest value (240.1 cm) was observed when nitrogen was not applied. A longer period of vegetative development may possibly have contributed to the increase in plant height. According to Tolera *et al*. [31], nitrogen fertilizer application rates had a substantial impact on the mean plant height of maize. Matusso, [32] plant height increased with increased nitrogen level.

Leaf Area: The mean leaf area of maize was highly significantly affected due to main effect time of nitrogen application and interaction varieties with nitrogen rates (Table 2). Because nitrogen was applied at different times, the amount of leaf area per plant of maize significantly increased. On the leaf area of maize, the interaction between varieties and nitrogen rates varied dramatically.

The BH-546 variety produced the highest leaf area plant^{-1} (7315), while the BH-547 variety produced the lowest leaf area plant^{-1} (6874), both with an application of 82.5 kg N ha-1 (Table 3). The timing of nitrogen fertilizer application has a substantial impact on mean leaf area. The application of nitrogen time half dose at sowing half dosage at knee height of maize produced the maximum leaf area plant^{-1} of 7363 cm^{2}, whereas the application of

Table 4: Interaction effect of nitrogen rates and applications timing on mean dry biomass of maize in BARC 2020 cropping season

	Time of nitrogen application			
Nitrogen rates kg ha^{-1}	AT1	AT2	AT3	AT4
82.5	20926abc	19815cd	19630cd	20000bcd
110	20556abcd	18148d	22500ab	22963a
LSD (5%)	2342.721			
CV (%)	9.7			

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

nitrogen time 1/3 dose at sowing +1/3 dose at knee height +1/3 dose at tasseling of maize produced the minimum leaf area plant-1 of 6669 cm2.Similarly, Niaz *et al*. [33] and Rizwan *et al*. [34] observed that greater amount and split nitrogen application boosted LA and grain production. Mean leaf area and leaf area index of maize varieties were strongly impacted by the interaction of maize varieties by nitrogen rates. The leaf area and leaf area index of maize cultivars planted with half and full amounts of the recommended nitrogen were higher than those planted without nitrogen. Higher mean leaf area measured between 5803 and 7262 cm^2.

Similar to this, [35] observed that the leaf area index of sorghum increased after the application of a high fertilizer dose. Similar to this, Haghighi *et al.* [36] found an increase in LAI on maize as a result of higher N fertilizer application rates. Jasemi *et al.* [37] also noted that maize LAI was higher on nitrogen-treated plants, which was most likely a result of enhanced leaf output and leaf area duration. Assefa Keyro and Zenebe Mekonn [38] observed that the amount and timing of nitrogen application had a substantial impact on leaf area index.

Dry Biomass Yield: Table 4 shows how the impacts of the interactions between various nitrogen application rates and the time of application on maize's dry biomass yield were significant. On the dry biomass of maize varieties, the interaction effect of nitrogen levels and application timing was shown to be considerably effected (Table 4), whereas the main effect of nitrogen rates and variety was non-significant (Table 3). Maximum dry biomass is 22963 kg per hectare. Compared to another treatment combination, obtained by applying 110 kg N ha-1 with a 1/3 dose at planting, a 1/3 dose at knee height and a 1/3 dose at tasseling. The administration of 110 kg N ha-1 with half dose at sowing and half dose at tasseling of the time of nitrogen treatment resulted in the lowest dry biomass measurement of 18,148 kg ha-1 (Table 4). Similarly, Zerhun Abebe and Hayilu Feyissa [29] reported that the interaction of nitrogen rates and time of application also showed significant effects on biomass yield of maize. Amanullah *et al.* [23] found that biomass yield at various growth stages increased significantly with increase in N rate. According to Mariga *et al.* [39], maize biomass output significantly increased when N was applied up to tassel initiation stage, which may be related to increases in mean single leaf area, leaf area per plant and plant heights at higher than at lower N rates.

Ear Diameter: The analysis of variance showed highly significant (P<0.01) due to main effect of varieties (Table 5). The highest ear diameter (5.277 cm) was recorded from BH-547 varieties, while the lowest ear diameter (3.873) was recorded from BH-546 varieties of maize (Table 5). The lowest ear diameter was recorded from none fertilizer plots as compared to fertilized plots (Table 5). Similarly, Amali and Namo [40] indicated that ear width was significant difference between two varieties of maize.

Ear Length: Main effect of varieties was showed significantly effected on ear length of maize (Table 5). The longest ear length (16.9 cm) was recorded from BH-546 varieties, while the shortest ear length (15.54 cm) was recorded from BH-546 varieties of maize (Table 5). The untreated with N plot was producing lower ear diameter as compared with fertilized plots (Table 5). Yusuf *et al.* [41] found that cob length was significantly different on maize varieties. Ear length was different among varieties [42].

Number of Rows per Ear: The average number of grain rows ear^{-1}is presented in (Table 5). All main effect and interaction were non-significantly affected mean number of grain rows ear^{-1}. Similarly, Sharifi and Namvar [43] reported that N rates and their application time had no significant effect on the number of grain rows ear^{-1}. Also, the same author [44] showed that the application of N fertilizer rate was non-significant on number of rows per ear. It seems that environmental factors have a low influence on the number of grain rows and this trait is significantly affected by genetic factors compared with other sources.

Table 5: Main effects of varieties, nitrogen rate and time of N application on ear diameter, ear length, number of kernels per ear of maize at BARC in 2020 cropping season

Varieties	Ear diameter	Ear length	Number Row per ear	Number kernel per ear
BH-546	4.75^{b}	16.93^{a}	14	563 ^{a}
BH-547	5.26^{a}	15.54^{b}	14	529^{b}
LSD (5%)	0.1063	0.3335	NS	27.04
Nitrogen rates Kg (N ha^{-1})				
82.5	5	16.09	14	555
110	5	16.38	14	548
LSD (5%)	NS	NS	NS	NS
Time of nitrogen application				
1/2 sowing +1/2 Knee height	5.06	16.25	14	548
1/2 sowing +1/2 Tasseling	4.96	16.18	14	572
1/3sowing +1/3 Knee height 1/3 tasseling	4.97	16.08	14	550
1/2 knee height +1/2 Tasseling	5.03	16.43	14	535
LSD (5%)	NS	NS	NS	NS
CV (%)	3.6	3.5	5.5	8.9
Control mean	3.89^{B}	12.80^{B}	14	504
Treated mean	4.99^{A}	16.78^{A}	15	550
LSD (5%)	0.3637	2.71	NS	NS
CV (%)	2.332437	5.222	6.063	5.312

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

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 2020 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})			
82.5	8217^{b}	41.14^{b}	330.6
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 (%)	4.062609	3.128	3.044

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

Number of Kernel per Ear: Mean number of kernels ear^{-1} was significantly different due to varieties but non-significant effect to nitrogen rates and time of N application and the interaction between varieties, nitrogen levels and time of N application (Table 5). The highest number of kernels ear^{-1} (564) was recorded from BH-546 variety, while the lowest number of kernels ear^{-1} 529 was recorded from the BH-547 varieties of maize (Table 5). Number of kernels per ear was no significantly different between control plots and treated plots (Table 5) [41].Found that mean number of grains cob^{-1} was significantly different due to varieties and higher number of kernels ear^{-1}.Number of grain ear-1 was significance affected by nitrogen levels and maize cultivar high number of grains ear^{-1} was recorded in the plots treated [45].

Grain Yield: On average grain yield for maize varieties, the main influence of N rates had a substantial impact (Table 6). A nitrogen application of 110 kg ha-1 resulted in a significantly greater grain yield of maize (8998 kg ha-1), whereas an application of 82.5 kg ha-1 resulted in a significantly lower grain yield (8217 kg ha-1) (Table 6).

When compared to control plots, fertilizer-treated plots provided the highest mean grain yield of maize (Table 6). It was statistically insignificant for nitrogen rate and application time to interact. Higher nitrogen levels may increase mean grain output because there is less competition for nutrients, which allows plants to accumulate more biomass and have a greater capacity to convert more photosynthesis into grain yield. This result was in agreement with Begizew Golla *et al.*[46] who found 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}[47] founded that nitrogen is the principal factor in controlling the growth and development of the crop. The grain yield significantly influenced by nitrogen rate application [29]. Desta Habtamu [48] also, indicated that grain yield was significantly increased with the application of N fertilizer.

Increased application of N fertilizer and accompanied linear increase in grain yield of maize also reported by Kena Kelbesa [49] reported that maize grain yield was linearly influenced by nitrogen levels applied.

Thousand Seed Weight: It is an important yield determining component and reported to be a genetic trait that is influenced least by environmental factors. Mean thousand seed weight of maize was significantly (P<0.01) affected by the varieties (Table 6). The interaction between varieties, nitrogen levels and time of N application 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 8). Likewise, Ahmad *et al.* [45] 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.

Effects of Nitrogen Rate and Time of Application on Nitrogen Use Efficiency of Maize Varieties: Nitrogen use efficiency is different definitions and perspectives exist for NUE and its components. Moll *et al.* [50] defined NUE as the ratio of grain yield per unit of available N (Ns) in the soil, including the present residual soil N and fertilizer N. But not all available plant N comes from N fertilizer and applied N fertilizer can be immobilized making this definition insufficient and imprecise. Agronomic efficiency definite as the ratio of fertilized grain yield minus control grain yield per unit of fertilizer applied

Nitrogen Use Efficiency (NUE): Nitrogen use efficiency, measures the amount of grain produced per applied unit of nitrogen. The efficiency of nitrogen use by different cultivars of maize was shown in Table 7. The BH-546 variety recorded the highest nitrogen use efficiency (91.53), whereas the BH-547 variety reported the lowest nitrogen use efficiency (NUE) of 89.6. Increased nitrogen rates resulted in a decline in nitrogen-use efficiency (NUE).

The higher nitrogen use efficiency (99.493) was recorded from nitrogen rate 82.5kgNha^{-1}, while the lower nitrogen use efficiency 81.64 was obtained from 110kg Nha^{-}1 N- rate. This result contrast with Azeez and Adetunji [51] indicated that Nitrogen-use efficiency was increased with increase in N rate. Shamme *et al.*[52] found that irrespective of genotype, the nitrogen use efficiency was maximum with N ha^{-1} and with every increase in N rate it decreased. Among the test genotypes, BH-546 variety exhibited maximum NUE (134.6) followed by BH-547 (90.7) N ha^{-1}. The Nitrogen Use Efficiency (NUE) was affected by time of nitrogen application. Split N application was also found to enhance the agronomic nutrient use efficiency (NUE). The higher nitrogen use efficiency 97.64429 obtained from 1/3 does at planting + 1/3 does at knee height1/3 does at tasseling of N time application, while the lowest nitrogen use efficiency (NUE) 81.56933 was obtained from 1/2 does at knee height +1/2 does at tasseling. Agree with finding of Tadesse Tilahun *et al.*[53] indicated that the medium maturing variety had the highest NUE when the nitrogen was applied in split of 1/3 at planting and 2/3 at knee height. In the case of the late maturing variety, the highest NUE was observed when the nitrogen was split applied 1/4 at planting and 3/4 at knee height.

Agronomic Efficiency (NAE): Agronomic efficiency of maize varieties is indicated in Table 7. Agronomic efficiency of maize varieties was varied among varieties. The highest mean Agronomic efficiency 50.08 was obtained from BH-547 of maize variety, while the Agronomic efficiency 48.31 was obtained from BH-546 of maize variety. Agronomic efficiency with every increase in N application rate, the Agronomic efficiency showed diminishing trend similar to that of N uptake efficiency and N recovery efficiency. The maximum Agronomic efficiency 52.03 was obtained with 110 kg N ha-[1]while lower Agronomic efficiency 46.36 was obtained from 82.5kg Nha^{-1}. This result agrees with finding of Zerhun Abebe and HayiluFeyissa [29], Shamme *et al.* [52] and Tadesse Tilahun *et al.* [53]. Agronomic Nitrogen Use Efficiency (ANUE) was affected by nitrogen levels.

Table 7: Effects of nitrogen rate and time of application on nitrogen use efficiency and Agronomic efficiency of maize varieties

Varieties	Nitrogen use efficiency(kg kg^{-1})	Agronomic efficiency(kg kg^{-1})
BH-546	89.66	48.31
BH-547	91.42	50.08
Nitrogen rates (Kg N/ha^{-1})		
82.5	99.28	52.03
110	81.80	46.36
Time of nitrogen application		
1/2 sowing +1/2 Knee height	91.59	50.24
1/2 sowing +1/2 Tasseling	88.09	46.74
1/3sowing +1/3 Knee height 1/3 tasseling	89.01	47.67
1/2 knee height +1/2 Tasseling	93.47	52.13

Table 8: Partial budget analysis of nitrogen rates and time of applications on maize at BARC in 2020 cropping season

N- Rates (kg ha^{-1})	Time of N Application	Grain yield (kg ha^{-1})	Adjusted Grain yield (kg ha^{-1})	Stalk biomass (kg ha^{-1})	Gross grain field benefit (EB ha^{-1})	Gross stalk benefit (EB ha^{-1})	Total field benefit (EB ha^{-1})	TCV (EB ha^{-1})	Net benefit (EB ha^{-1})	Value to cost ratio	MRR (%)
0	0	3898	3509	6380	35086	3190	38276	0	38276		
82.5	1/2 at S 1/2 at k	8499	7649	12427	76489	6214	82703	3525	79178	22.46	1160
82.5	1/2 at S1/2 at T	8319	7487	11296	74872	5648	80520	3600	76920D	21.37	
82.5	1/2 at k1/2 at T	8193	7373	11437	73733	5719	79452	3675	75777D	20.62	
110	1/2 at S1/2 at k	8960	8064	11596	80640	5798	86438	4225	82213	19.46	434
110	1/2 at S1/2 at T	8288	7459	9860	74591	4930	79521	4300	75221D	17.49	
82.5	1/3 at S1/3 at k 1/3 at T	7858	7072	12142	70720	6071	76791	4350	72441D	16.65	
110	1/2 at k 1/2 at T	9641	8677	12859	86766	6430	93196	4375	88821	20.3	4405
110	1/3 at S 1/3 at k1/3 at T	9106	8195	13857	81954	6929	88883	4975	83908D	16.87	

D=dominance, maize grain and stalk price =10 ETB kg^{-1} and 0.5 ETB kg^{-1}, Price of NPS and N fertilizer= 14.5 and 13.5 ETB kg^{-1} 1/2 at S 1/2 at k = 1/2 at sowing + 1/2 at knee height, 1/2 at S1/2 at T = 1/2 at sowing + 1/2 at Tasseling, 1/2 at k1/2 at T = at knee height + 1/3 at Tasseling, 1/3 at S1/3 at k 1/3 at T =1/3 at sowing + 1/3 at knee height +1/3 at Tasseling

Effects of Nitrogen Rate and Nitrogen Application Time on Economic Feasibility of Maize Production: Partial budget analysis of the combination of nitrogen levels and time of N application was presented in Table 8. The highest net benefit of EB 88821 ha^{-1} with higher marginal rate return of 4405% with value to cost ratio of EB 20.30 per unit of investment was obtained from application of 110 kg N ha^{-1} with two split application of 1/2 dose at knee height + 1/2 dose at tasseling for maize production followed by net benefit of EB 82213and marginal rate of return of 434% with value to cost ratio of EB 19.46 per unit of investment from combination 110 kg N $ha^{-1}$and time of N application (1/2 dose at sowing + 1/2 dose at knee height). However, the lowest net benefit of EB 38275Birr ha^{-1} was obtained from without fertilizer treated (control treatment). Similarly, Tana and Moges [54] reported that higher net benefit was obtained from higher N rate application. Begizew Golla *et al.*[46] also reported that the highest net return EB 46592ha^{-1} was obtained from application of 115 kg N ha^{-1} followed by 92 kg N ha^{-1}. Likewise, Bakala Anbessa [55] reported that application of 150 kg NPSB + 110.8N kg ha^{-1} had the highest net benefit of EB 32321 ha^{-1}. Therefore, as this result the combination 110 kg N ha^{-1} nitrogen rate with two split application (1/2 dose at knee height + 1/2 dose at tasseling) was profitable and recommended for farmers in Bako district area and others similar agro-ecological condition.

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, 110kg N ha^{-1} fertilizer rates with two times application 1/2 does at knee height + 1/2 does at tasseling gave higher net benefit of EB 88821 ha^{-1}) with acceptable marginal rate of return 4405% is economically feasible for study area and recommended for wider use in study area and similar agro ecology. The definite recommendation may not be drawn from this research result, as the present result came from single experiment involving one location. So that future study at different location for more than one cropping season should be conducted the economically feasible nitrogen rates, time of nitrogen application and varieties should be considered to give reliable recommendation for sustainable maize production.

ACKNOWLEDGMENTS

The authors express their genuine acknowledgment to the Bako Agricultural Research Center for all the necessary facilities they provide for the accomplishment of this study.

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.).Cercetări Agronomiceîn Moldova, 1(153): 77-82.
3. FAO, 2019. World Food and Agriculture Organization and World food and agriculture Statistical pocketbook, pp: 254.
4. CSA, 2021. Area and production of major crops. Agricultural Sample Survey 2020/21 (2013E.C).V1 V1 Statistical Bulletin. 589 Addis Ababa, Ethiopia.
5. Rashid, S.h., G. Kindie and L. Solomon, 2010. Maize Value Chain Potential in Ethiopia: Constraints and opportunities for enhancing the system. International Food Policy Research Institute, pp: 64.
6. Mandefro Nigussie, D. Tanner and S. Twumasi-Afriyie, 2001. Enhancing the contribution of maize to food securityin Ethiopia in, in Proceedings of the Second National Maize Workshop of Ethiopia, pp: 12-16, Addis Ababa, Ethiopia.
7. FAO, 2013. World Food and Agriculture Organization and World food and agriculture Statistical pocketbook.
8. 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.
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. Khazaei, F., M.A. Alikhani, L. Yari and A. Khandan, 2015. Study the correlation, regression and path coefficient analysis in maize (*Zea mays* var. saccharata) under different levels of plant density and nitrogen rate. Journal of Agricultural and Biological Science, 5(6): 14-19.
11. Sharma, R., P. Adhikari, J. Shrestha and B.P. Acharya, 2019. Response of maize (*Zea mays* L.) hybrids to different levels of nitrogen. Archives of Agriculture and Environmental Science, 4(3): 295-299.
12. Abbas, G., Z. Fatima, M. Hussain, S. Hussain, N. Sarwar, M. Ahmed and S. Ahmad, 2020. Nitrogen rate and hybrid selection matters productivity of maize-maize cropping system under irrigated arid environment of Southern Punjab, Pakistan. International Journal of Plant Production, pp: 1-12.
13. Adhikari, P., B.R. Baral and J. Shrestha, 2016. Maize response to time of nitrogen application and planting seasons. Journal of Maize Research and Development, 2(1): 83-93.
14. Niaz, A., M. Yaseen, M. Arshad and R. Ahmad, 2015. Response of maize yield, quality and nitrogen use efficiency indices to different rates and application timings. Journal of Animal and Plant Sciences, 25(4): 1022-1031.
15. Sawyer, J., 2008. Nitrogen application timing, forms and additives, American Society of Agricultural and Biological Engineers.
16. Limon-Ortega, A., N.A. Ruiz-Torres, G. Vazquez-Carrillo and A. Baez-Perez, 2016. Environment and nitrogen influence on rain fed maize yield and quality. Crop Science, 56(3): 1257-1264.
17. Jones, J.B., 2003. Agronomic Handbook: Management of crops, soils and their fertility. CRC Press LLC, Boca Raton, Florida, USA, pp: 482.
18. Van Reeuwijk, L.P., 1992. Procedure for soil analysis 2nd edition, Int. Soil Reference and Information Center (ISRIC), the Netherlands, pp: 37.
19. Diaz-Zorita, M., 1999. Soil organic carbon recovery by the Walkley-Black method in a typichapludoll. Communications in soil science and plant analysis, 30(5-6): 739-745.
20. Jackson, M.L., 1958. Nitrogen determinations for soil and plant tissue. Soil chemical analysis, pp: 183-204.
21. 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.
22. Chapman, H. D.,1965. Cation-exchange capacity. Methods of Soil Analysis: Part 2 Chemical and Microbiological Properties. 9, 891-901.
23. 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. Jornal of Botany, 41(2): 761-768.

24. SAS (Statistical Analysis system) Institute Inc, 2004.
25. 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.
26. CIMMYT, 1988. Farm Agronomic to farmer's recommendation. An Economic Training Manaual.Completely revised edition, D.F. Mexico.81.
27. Tekalign Mamo, 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.
28. Berhanu Debele, 1980. The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land use planning and regulatory department, Ministry of Agriculture. Addis Ababa, Ethiopia.
29. Zerhun Abebe and Hayilu Feyissa, 2017. Effects of nitrogen rates and time of application on yield of maize: rainfall variability influenced time of N application. International Journal of Agronomy.1-10
30. 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.
31. Tolera Abera, Tolessa Debele and Dagne Wegary, 2017. Effects of Varieties and Nitrogen Fertilizer on Yield and Yield Components of Maize on Farmers Field in Mid Altitude Areas of Western Ethiopia. International Journal of Agronomy, 1(1): 1-13.
32. 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.
33. Niaz, A., M. Yaseen, M. Arshad and R. Ahmad, 2015. Response of maize yield, quality and nitrogen use efficiency indices to different rates and application timings. Journal of Animal and Plant Sciences, 25(4): 1022-1031.
34. Rizwan, M., M. Maqsood, M. Rafiq, M. Saeed and Z. Ali, 2003. Maize (*Zea mays* L.) response to split application of nitrogen. Int. J. Agri. Biol., 5(1): 19-21.
35. Gebrelibanos Gebremariam and Dereje Assefa, 2015. Nitrogen Fertilization Effect on Grain Sorghum [*Sorghum bicolor* (L.) Moench] Yield, Yield Components and Witch weed (*Striga hermonthica* (Del.) Benth) Infestation in Northern Ethiopia. International Journal of Agricultural Research, 10(1): 14-23.
36. Haghighi, B.J., Z. Yarmahmodi and O. Alizadeh, 2010. Evaluation of the effects of biological fertilizer on physiological characteristics and yield and its components of corn under drought stress. American Journal of Agricultural Biological Science, 5: 189-193.
37. Jasemi, M., F. Darab and R. Naser, 2013. Effect of planting date and nitrogen fertilizer application on grain yield and yield components in maize. American-Eurasian Journal of Agricultural and Environmental Science, 13(1): 914-919.
38. Assefa Keyro and Zenebe Mekonn, 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.
39. Mariga, I.K., M. Jonga and O.A. Chivinge, 2000. The effect of timing of application of basal and topdressing fertilizers on maize (*Zea mays* L.) yield at two rates of basal fertilizer. Crop Research (Hisar). 20(3): 372-380.
40. Amali, P.E. and O.A.T. Namo, 2015. Effect of Time of Fertilizer Application on Growth and Yield of maize (Zea Mays L.) in Jos-Plateau Environment. Global Journal of Agricultural Sciences, 14(1): 1-9.
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. IOSR Journal of Agriculture and Veterinary Science, 12(2): 25-32.
42. Taye Tolessa, Natol Bekele and Yonas Shimalis, 2016. Evaluation of highland maize at BuleHora District of Southern Oromia, Southern Ethiopia. Afr. J. Agric. Res., 11(34): 3178-3181.
43. Sharifi, R.S. and A. Namvar, 2016. Effects of time and rate of nitrogen application on phenology and some agronomical traits of maize (*Zea mays* L.). Biologija, 62(1): 35-45.
44. Arif, M., I. Amin, M.T. Jan, I.Q.B.A.L. Munir, K.H.A.L.I.D. Nawab, N.U. Khan and K.B. Marwat, 2010. Effect of plant population and nitrogen levels and methods of application on ear characters and yield of maize. Pakistan. Journal of Botany, 42(3): 1959-1967.
45. 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.
46. Begizew Golla, Adugnaw Mintesnot and Merkeb Getachew, 2018. Impact of Nitrogen Rate and Intra Row Spacing on growth parameters and Yield of Maize at Bako, Western Ethiopia. Open J. Plant Sci., 3(1): 034-040.

47. 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.
48. Desta Habtamu, 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 Research, 6(8): 5689-5698.
49. Kena Kelbesa, 2015. Effect of Nitrogen Rates and Inter row Spacing on Growth, Yield and Yield Components of Maize (*Zea mays* L.) at Nejo, Western Ethiopia. Doctoral dissertation, Haramaya University, Haramaya.
50. Moll, R.H., E.J. Kamprath and W.A. Jackson, 1982. Analysis and interpretation of factors which contribute to efficiency of nitrogen utilization. Agronomy Journal, 74: 562-564.
51. Azeez, J.O. and M.T. Adetunji, 2007. Nitrogen-use Efficiency of Maize Genotypes under Weed Pressure in a Tropical Alfisol in Northern Nigeria. TROPICULTURA. 25(3): 174-179.
52. Shamme, S.K., C.V. Raghavaiah, T. Balemi and I. Hamza, 2016. Sorghum (*Sorghum bicolor* L.)Growth, productivity, nitrogen removal, N-use efficiencies and economics in relation to genotypes and nitrogen nutrition in Kellem-Wollega zone of Ethiopia, East Africa. Adv Crop Sci Tech., 4(3): 1-8.
53. Tadesse Tilahun, Alemayehu Assefa, Minale Liben and Zelalem Tadesse, 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.
54. Tana, T. and A. Moges, 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. Ph.D. dissertation, Haile Sellassie I University College of Agriculture.
55. Bakala Anbessa, 2018. Soil Characterization and Response of Maize (*Zea mays* L.) to Application of Blended Fertilizer Types and Rates in Asossa District, Western Ethiopia M.Sc Thesis. Hawassa University, pp: 117.