American Journal of BioScience
2024, Vol. 12, No. 4, pp. 118-126
https://doi.org/10.11648/j.ajbio.20241204.13

SciencePG
Science Publishing Group

Research Article

Response of Maize (*Zea may L.*) Cultivars to Urea Time Application on Phenology, Growth and Grain Yield at Bako, East Wollaga, Ethiopia

Megersa Debele*

Oromia Agricultural Research Institute, Bako Agricultural Research Center, Bako, Ethiopia

Abstract

The results of this research provide a basis for additional exploration and advancement, which will culminate in suggestions for the timing of split urea treatment and cultivars for sustainable maize production within the study region. During the 2019 and 2020 growing seasons, a field experiment was conducted at the Bako Agricultural Research Center to determine the response of hybrid maize cultivars to urea split application on phenology, growth, and grain production. In the experiment, six levels of urea split application were applied to two types of corn. T1 = 1/2 dose of urea at planting + 1/2 dose of urea at Knee height; T2 = 1/2 dose of urea at planting + 1/2 dose of urea at tasseling; T3 = 1/ 3 dose of urea at planting + 1/3 dose of urea at knee height + 1/3 dose of urea at tasseling; T4 = 2/3 dose of urea at knee height + 1/3 dose of urea at tasseling; T5 = 1/2 dose of urea at knee height + 1/2 dose of urea at tasseling; and T6 = 1/4 dose of urea at planting + 1/2 dose of urea at knee height + 1/4 dose of urea at tasseling. The experiment's randomized complete block design made use of three replications. The primary effects of the urea split time of application were found to have a substantial impact on plant height, 90% physiological maturity, grain production, total leaf area per plant, and leave area index. Three urea split applications 1/4 dosage at planting, 1/2 dose at knee height, and 1/4 dose at tasseling provided the maximum net benefit of EB 246,536.7 ha-1 and the best marginal rate return of 2822.26% for maize output. In conclusion, urea split application 1/4 doses at planting stage 1/2 dose at knee-height and 1/4 dose at tasseling stage is the best time of application in good rainy seasons and hence recommended for the end users. However, in the case of erratic and heavy rainy seasons, application at three times should be used to get maximum profit and acceptable MRR.

Keywords

Cultivar, Growth, Maize, Phenology, Split, Urea

1. Introduction

Globally, between 2000 and 2020, the production of primary crops rose by 52% [1]. Among cereals, maize (Zea mays L.) has the largest production potential and is the third most important crop in the world after wheat and rice [2]. The total area of maize (for dry grain) in the world is 197 M hectares, with significant portions being in Latin America, Asia, and sub-Saharan Africa (SSA) [3]. The past few decades have seen a dramatic growth in the production of maize worldwide, driven by growing demand as well as a confluence of yield increases, area expansion, and technical advancements. In

*Corresponding author: debelemegersa@gmail.com (Megersa Debele)

Received: 28 June 2024; **Accepted:** 22 July 2024; **Published:** 15 August 2024

terms of volume produced, maize leads all cereals and is expected to overtake all other crops as the most frequently farmed and sold crop in the ensuing ten years. In addition to its many non-food uses, this adaptable multipurpose crop is widely used as feed worldwide and is also significant as a food crop, particularly in sub-Saharan Africa and Latin America [4]. Maize is a more multipurpose and flexible crop than wheat and rice. It has a variety of uses as an industrial and energy crop, but its main usage in industrialized nations is as a crop for cattle feed. After rice and wheat, maize is the third most popular cereal ingested by humans [4]. Ethiopia's most significant cereal crop in terms of area covered and output level is maize. Eight million tons of corn was produced from two million hectares by around 80% of all farmers [5]. However, among the nations that produce the most maize in Africa is Ethiopia [1]. Grain crops cover a total land area of approximately 12,979,459.91 hectares, of which 81.19% is planted with cereals. A total of 2,526,212.35 hectares and 21.40% of cereal crops were planted to maize, which produced grain yields of 105,570,935.92 tons [5]. Depletion of soil fertility and inadequate nutrient management are two of the main causes of low productivity, however there are many other biotic and abiotic factors that can also lead to yield gaps [6]. One of the main things limiting maize productivity in Ethiopia's maize-growing regions is poor soil fertility [7]. The most crucial ingredient for the cultivation of maize is nitrogen fertilizer. Its use and demand are growing daily, and applying it at the right time is another low-cost way to stop nutrient leaching and keep plant demand and nutrient supply in sync [7]. One way to enhance crop utilization of nitrogen while lowering nutrient loss from leaching and volatilization is to apply nitrogen in splits. This can help increase the efficiency of nitrogen consumption in crops, such as maize. On the other hand, timely application of urea can enhances its recovery up to 58–70%, increasing crop output and grain quality [7]. Consequently, the goal of the study was to find out when to apply split urea to enhancement maize yield in the research area.

2. Material and Methods

The experiment was carried out in the Bako Agricultural Research Center for two years in 2019 and 2020. The center is situated in a subhumid region of Western Ethiopia, at an altitude of 1650 meters above sea level and a latitude of 9E60N and 37E90E. The mean minimum and maximum air temperatures there are 13.5 and 29.7∘C, respectively, each year. The region saw 1431 mm of annual rainfall in 2019 and 1067 mm in 2020, with May through August seeing the most precipitation. The Bako region has nitosol, or reddish-brown soil. The pH range of this soil is 4.5–5.6, making it acidic.

The treatments consisted of two factors, namely, two maize Cultivars (BH-546 and BH-547) and Six different Urea application times $T1$ = (1/2 dose of urea at planting,1/2 dose of urea at knee height and 0 dose at tasseling), $T2$ = (1/2 dose of urea at planting, 0 dose urea at knee-height and 1/2 dose of urea at tasseling), T3= (1/3 dose urea at planting, 1/3 dose urea at knee-high and 1/3 dose of urea at tasseling) T4= (0 dose of urea at planting, 1/2 dose urea at knee-height and 1/2 dose of urea at tasseling), $T5$ = (0 dose of urea at planting, 2/3 dose urea at knee-height and 1/3 dose of urea at tasseling) and T6= (1/4 dose of urea at planting, 1/2 dose urea at knee-height and 1/4 dose of urea at tasseling) that were arranged in 2x6 factorial combinations. Moreover, previous time of urea split applications 1/2 dose at planting and 1/2 dose at knee-height (referred as recommended). A total of 12 treatment combinations with previous recommended time of Urea application were laid out using a randomized complete block design (RCBD) with three replications. Application time of urea was done within the stated time ranges, but at the same date as per treatment arrangements. The experimental plots were plowed three times at different time intervals and leveled manually prior to field layout. Spacing for all experimental plots was 75 cm between rows and 30 cm between plants. Recommended NPSB (46 kg ha^{-1}) for all experimental plots was equally and uniformly applied at the time of maize planting. 92 kg of Urea $ha^{-1}$was applied as per treatment arrangements. Two maize Cultivar BH-56 and BH-546 were used for the execution of the treatments. The trial was planted on end of May in the 2019 and in 2020. Other agronomic managements rather than treatment variations were uniformly applied to all experimental plots. At the time of harvesting, the maize was harvested by excluding two border rows from each side. A net plot size for each plot was 3.75 m × 3 (11.25 m2).

2.1. Data to Be Collected

Days to 50% tassel and silk, days to 90% maturity, and other phonological parameters of maize were calculated as the number of days from the day of planting to the time at which 50% of each plot produced tassels, began to produce pollen, and formed a black layer at the point where the kernel attached to the corn cob, respectively. Plant height was assessed as the distance from the ground level to the location where the tassel appeared and started to branch out at the physiological maturity stage from randomly selected 10 plants per net plot. The leaf area index (LAI) was calculated as the ratio of total leaf area obtained from 10 plants per net plot (L x W x K) to the land area occupied by the plant ($0.75\,m \times 0.30\,m = 0.225\,m^2$), where L = leaf length, = leaf width, and K = correction factor 0.75 [8]. Tasseling date, Silking date, Total Leave area, Leave area index, Plant height, Physiological maturity, Grain yield and other important agronomic traits were collected. Maize grain yield was adjusted to standard moisture contents to 10% as described as follows: Adjusted yield = actual yield × 100 − M/100 –D, where M and D are measured and standard moisture contents, respectively. Costs that vary among treatments were also assessed. By evaluating the current local market pricing, the labor costs associated with applying urea and shelling were calculated. The price of daily labors (75 ETB per one person day based on government's current scale in the study area). Time elapsed during urea application for some plots of each treatment was recorded to calculate daily labor required for one hectare. One person per day was estimated based on eight working hours per day. But since every agronomic management strategy was implemented consistently and evenly to every experimental plot, additional non-varied costs were left out. Before calculating gross revenue, maize yields obtained from each experimental plot were adjusted down by 10%. Finally, gross revenue was calculated as total yield obtained multiplied by field price. The net benefit and the marginal rate of return (MRR) were also calculated as per standard manual [9].

2.2. Data Analysis

Analyses of variance (ANOVA) across seasons were carried out using Gen Stat 15th edition software, and the Duncan multiple range test at $P < 0.05$ was used for comparing treatment means.

3. Result and Discussion

The combined analysis's outcome showed that seasonal variations greatly impacted grain yield, days to 90% physiological maturity, days to 50% tasseling and days to 50% of the crop being silked (Table 1 and Figure 1). Even though main effects of Maize varieties did not show significant variation to all parameters, there were highly significant effects due to the various times of urea split applications. Moreover, the effect of urea time of application significantly affected 90% physiological maturity, Grain yield, Total leave area per plant, Leave area index and Plant height while this interaction due to maize varieties and Urea time of application significantly affected both days to 50% tasseling and days to 50% silking (Table 1). Therefore, separate analysis for each season was done since the seasonal rainfall variability considerably affected the response of treatments (Figure 1).

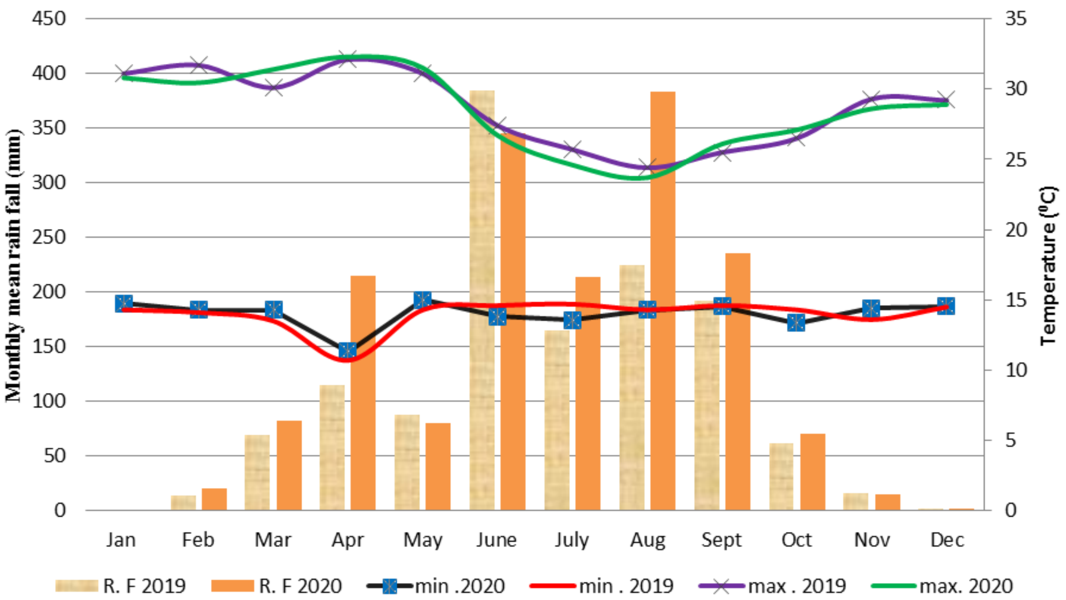

Figure 1. *Mean monthly rainfall and minimum and maximum temperature of Bako research site, 2019-2020.*

Table 1. *Analysis of variance for Phenology, Growth and yield of maize as influenced by Varieties, time of Urea application, and the interaction effects in 2019and 2020 at Bako, Western Ethiopia.*

Source of Variation	Degree of freedom	90% Physiological Maturity	Grain Yield	50% Tasseling date	50% silking dates	Total Leave Area	Leave Area Index	Plant height
Time of Application (TA)	5	<.001	<.001	0.221	0.998	<.001	<.001	<.001
Variety (VR)	1	0.481	0.883	0.385	0.729	0.112	0.088	0.093
Year (YR)	1	<.001	<.001	<.001	<.001	0.373	0.398	0.865
TA.VR	5	0.336	0.214	<.001	0.005	0.303	0.827	0.387
TA.YR	5	1.00	0.914	1	1	0.995	0.997	0.704

Source of Variation	Degree of freedom	90% Physiological Maturity	Grain Yield	50% Tasseling date	50% silking dates	Total Leave Area	Leave Area Index	Plant height
VR.YR	1	1.00	0.591	1	1	0.704	0.652	0.533
TA.VR.YR	5	1.00	0.91	1	1	0.975	0.998	0.305
Residual	46							
Total	71							

3.1. Effect of Urea Split Application on Days to 50% Tasseling

The major influence of season Variation had a substantial impact on the days to 50% tasseling of maize (Figure 1). The Main impact of variety and timing of urea split application did not significantly change the date of tasseling, but the combination of variety and urea split application had a significant effect (Table 1). As depicted in (Figure 2), The mean days of 50% tasseling were considerably impacted by the interaction effect of the varieties and the timing of urea split application.

The longest days to tasseling were obtained from interaction effect of V1T1 of treatment while the shortest days to 50 % tasseling recorded from interaction effect V1T4 and V2T5 (Figure 2). This conclusion was in line with study [10], which showed that the timing of urea application had a substantial impact on the number of days it took to tasseling. When urea was sprayed at the V12 stage, it took 64 days, whereas when it was sprayed at the V9 stage, it took 59 days. Also reported by [11] indicated that nitrogen fertilizer application at booting and silking stages caused significant increments in grain yield. According to Tas [12], Days to tasseling were found to be highly influenced by cropping year and variety.

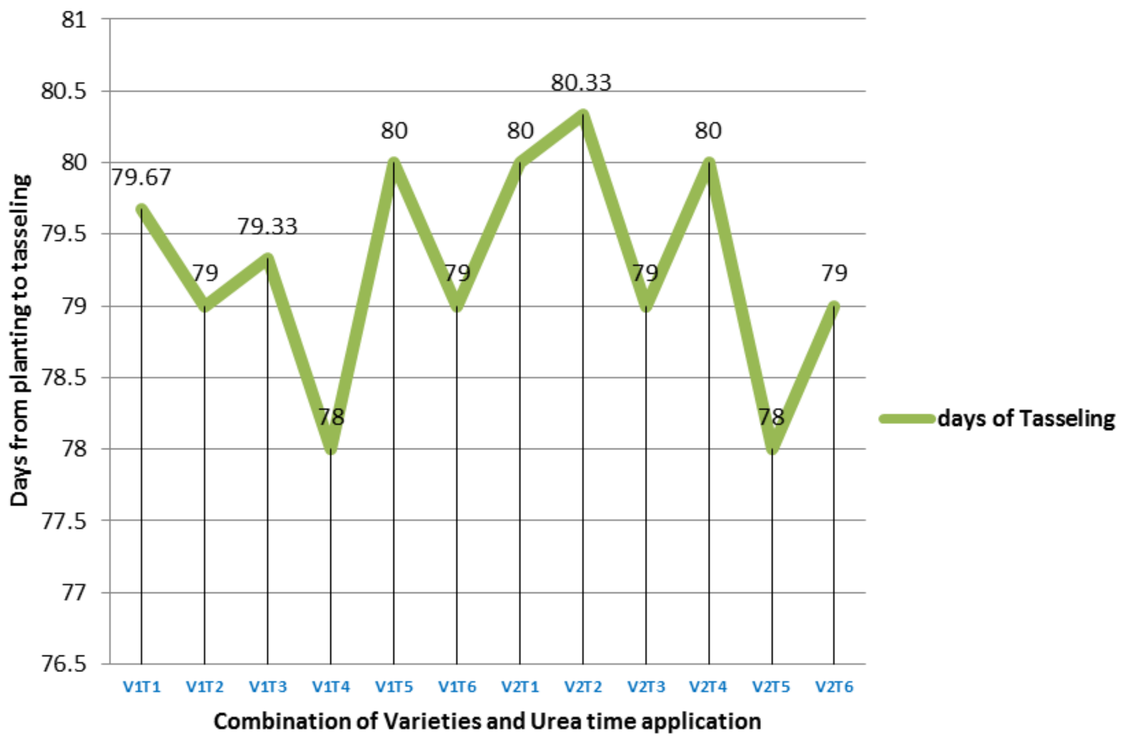

Figure 2. *Interaction effect of Urea time of Application and Maize varieties on Tasseling dates of 2019 and 2020.*

NB: -V1=BH-547, V2=BH-546, T1=1/2 at plantin+1/2 at knee-hieght, T2=1/2 at plantin+1/2 at tasseling, T3=1/3 at plantin+1/3 at knee-hieght+1/3 at tasseling, T4=2/3 at knee-height +1/3 at tasseling, T5=1/2 at knee-height + 1/2 at tasseling and T6=1/4 at planting+ 1/2 at knee-height + 1/4 at tasseling.

3.2. Effect of Urea Split Application on Days to 50% Silking

Application time of Urea was significantly varied across seasons (Table 1 and Figure 1).The days to 50% Silking of maize were significantly affected by the interaction effect of Varieties and Time of urea application while the main effect of time of urea application and Varieties were showed no significant effect on tasseling date (Table 1). Longest days to 50% silking (84.33) was observed from V1T3 and V2T4 of urea time application while the shortest days to 50% silking (82.3) obtained from interaction of V1T4 treatment (Figure 3). This result agree with Sharifi and Namvar [11] reported that nitrogen fertilizer application at booting and silking stages caused significant increments in grain yield. Khan *et al.* [13] reported that nitrogen time application influenced on phenology of maize.

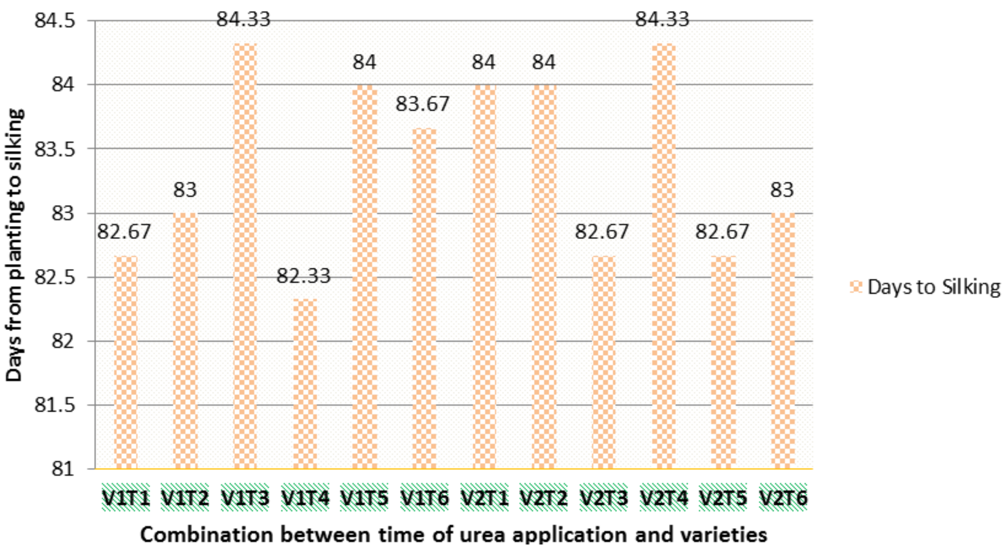

Figure 3. *Interaction effect of Urea time of Application and Maize varieties on Silking dates of 2019 and 2020 cropping season.*

NB: - V1=BH-547, V2=BH-546, T1=1/2 at plantin+1/2 at knee-hieght, T2=1/2 at plantin+1/2 at tasseling, T3=1/3 at plantin+1/3 at knee-hieght+1/3 at tasseling, T4=2/3 at knee-height +1/3 at tasseling, T5=1/2 at knee-height + 1/2 at tasseling and T6=1/4 at planting+ 1/2 at knee-height + 1/4 at tasseling.

3.3. Effect of Urea Split Application on Total Leaf Area

This study presents the impact of varying urea application timings on leaf area at different growth stages during two seasons Figure 4. The results showed that the timing of the urea split treatment had a substantial impact on leaf area at every sampling occasion during both seasons. On the other hand, nitrogen promoted growth, which in turn affects the growth and development of leaves. The main effect of time of nitrogen fertilizer application had highly significantly ($p<0.01$) influenced on Total leaf area of maize while no significantly affected by main effect of varieties and seasonal variation and their interaction effect (Table 1). As Showed in Figure 3, time of urea split application significantly affected the mean Total leave of maize. The maximum mean total leaf area 8360cm^2 was measured form time of urea split application T4, whereas minimum mean total leaf area 6454 cm^2 was recorded from Urea time application T2 (Figure 4). This result similar with Ogunboye *et al*. [14] reported that nitrogen split application at was significantly affect total leave area of maize.

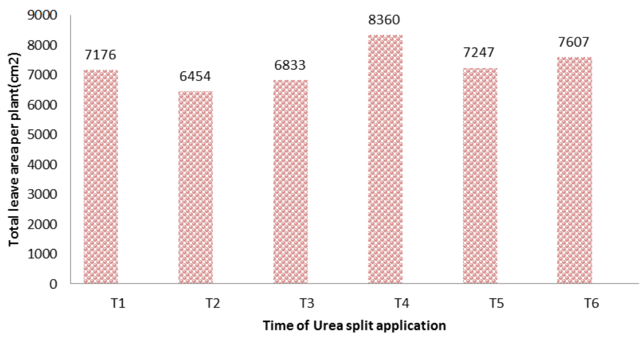

Figure 4. *Main effect of Urea split application on Total leave area in 2019 and 2020 cropping season.*

N.B:- T1= 1/2 at plantin+1/2 at knee-height, T2=1/2 at plantin+1/2 at tasseling, T3=1/3 at plantin+1/3 at knee-hieght+1/3 at tasseling, T4=2/3 at knee-height +1/3 at tasseling, T5=1/2 at knee-height + 1/2 at tasseling and T6=1/4 at planting+ 1/2 at knee-height + 1/4 at tasseling.

3.4. Effect of Urea Split Application on Leave Area Index

Leaf area index is major factor determining photosynthesis and dry matter accumulation (Moosavi *et al*., 2012). The main effect of urea split application had highly significant (P<0.01) influence on leaf area index of maize while the interaction effect of variety and time of urea split application was no significantly difference on leaf area index (Table 1). The highest leaf area index 3.87 was obtained from application of T4 in 2019 cropping season; while the lowest 2.96 was recorded from T4 in 2019 cropping year (Figure 5). In line with the agreement of this result, both Leave area and leave area index were significantly increased as the function of N time application and other reports were also similar [15, 16]. However, delayed application of N after crop establishment significantly increased LAI compared to N application at the time of planting [17].

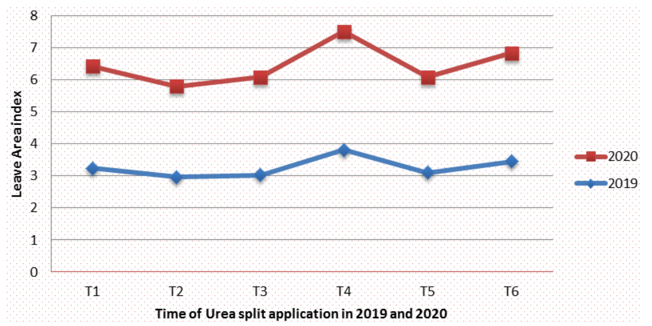

Figure 5. *Main effect of time Urea split application on leave area index in 2019 and 2020 cropping season.*

N.B:- T1= 1/2 at plantin+1/2 at knee-height, T2=1/2 at plantin+1/2 at tasseling, T3=1/3 at plantin+1/3 at knee-hieght+1/3 at tasseling, T4=2/3 at knee-height +1/3 at tasseling, T5=1/2 at knee-height + 1/2 at tasseling and T6=1/4 at planting+ 1/2 at knee-height + 1/4 at tasseling.

3.5. Effect of Urea Split Application on Days to 90% Physiological Maturity

The mean days to 90% physiological maturity of maize significantly (P<0.01) difference across year and affected by main effect of time of urea split application but their interaction was non-significant on days to 90 % maturity of maize (Table 1 and Figure 1). The maximum number of days to attain maturity (133.67 days) was recorded from T6 in 2020, while the minimum (129.17.33 days) was recorded from T4 in 2019 (Figure 6). 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 [15] found that the excessive use of nitrogen in the plants causes continued growth and results in late maturation period. Megersa *et al*. [16] reported that number of days to physiological maturity was affected by nitrogen time application.

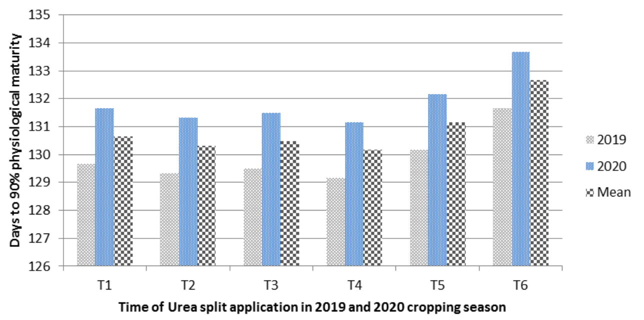

Figure 6. *Main impact of time of Urea split application on 90% of physiological maturity of maize production in 2019 and 2020 cropping season.*

N.B:- T1= 1/2 at plantin+1/2 at knee-height, T2=1/2 at plantin+1/2 at tasseling, T3=1/3 at plantin+1/3 at knee-hieght+1/3 at tasseling, T4=2/3 at knee-height +1/3 at tasseling, T5=1/2 at knee-height + 1/2 at tasseling and T6=1/4 at planting+ 1/2 at knee-height + 1/4 at tasseling.

3.6. Influence of Urea Split Application on Plant Height

The time of Urea fertilizer Split application had a Significant (P 0.001) effect on plant height, according to the combined analysis of variance (Table 1). The longest plant height (275.45 cm) was recorded form T6, whereas the shortest plant height (252.90 cm) was observed from T2 of urea split application (Figure 7). The results showed that applying urea split application (1/4 at planting+1/2 dose of urea at knee height and 1/4 dose of urea at tasseling) enhanced plant height (Figure 7). This indicated that applying nitrogen fertilizer in three stages, 1/4 at planting + 1/2 at knee height and 1/4 at tasseling was more beneficial than the other treatments in boosting plant height. This could be due to nitrogen application at the right moment, enhancing N availability to the plant. This result is consistent with that of Chala *et al*. [18] who found that the timing of nitrogen treatment substantially impacted maize plant height. Late nitrogen fertilization during crop flowering may be important to optimize maize agronomic performance [19]. Also Aleminew *et al.* [20] reported that urea split application showed highly significant differences plant height of crops.

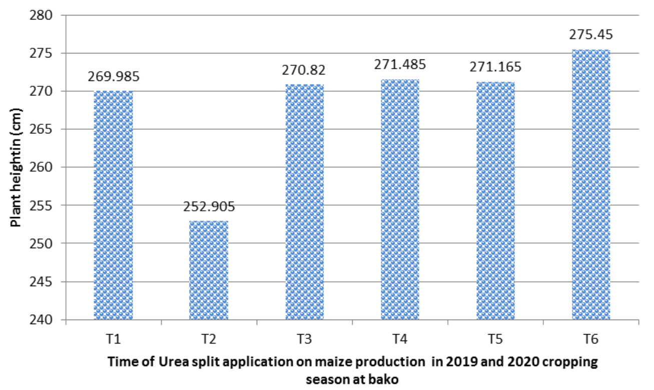

Figure 7. *Main effect of time of Urea split application on Plant height of maize production in 2019 and 2020 cropping season.*

N.B:- T1= 1/2 at plantin+1/2 at knee-height, T2=1/2 at plantin+1/2 at tasseling, T3=1/3 at plantin+1/3 at knee-hieght+1/3 at tasseling, T4=2/3 at knee-height +1/3 at tasseling, T5=1/2 at knee-height + 1/2 at tasseling and T6=1/4 at planting+ 1/2 at knee-height + 1/4 at tasseling.

3.7. Impact of Urea Split Application on Grain Yield

The responses of grain yield to time of Urea split application combined data are demonstrated in (Table 1). The grain yield was significant (P<0.001) differences between years and time of urea split application. Grain yield was better in the second year (2020).This is due to the Optimum rain fall received at urea application in 2020 than 2019 (Figure 1). This conductive environment helps for maize growth and development. Application time of urea was significantly varied across year on grain yeild (Table 1 and Figure 8). The minimal grain yield (7.80 t ha^{-1}) was acquired from 2019 in T2, while the maximum grain yield (9.53tha^{-1}) was obtained from T6 in the 2020 cropping season. (Figure 8). The analysis of variance also revealed that the main effect of time of urea split application and year were highly significantly influenced on grain yield (Table 1 and Figure 8). So, the maximum grain yield was obtained from three stages (T6) which applied 1/4 at planting + 1/2 at knee height time and 1/4 at tasseling time. While the least value was recorded from two stage (T2) which applied 1/2 at planting + 1/2 at near tasseling time (Figure 8). The result is in agreement with the result of Zerihun and Hayilu [15] who reported that yield and yield components of maize increase by appropriate time of nitrogen split application. Similarly, Chala *et al.* [18] reported that timing of nitrogen fertilizer application had a substantial (P 0.001) impact on grain yield and also applying nitrogen fertilizer 1/4 at planting and 3/4 at knee height, produced the maximum yield for late-maturing cultivars.

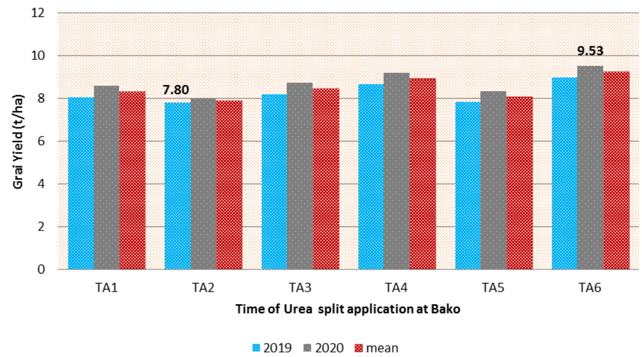

Figure 8. *Main impact of Urea split application on maize production in 2019 and 2020 cropping season.*

N.B:- T1= 1/2 at plantin+1/2 at knee-height, T2=1/2 at plantin+1/2 at tasseling, T3=1/3 at plantin+1/3 at knee-hieght+1/3 at tasseling, T4=2/3 at knee-height +1/3 at tasseling, T5=1/2 at knee-height + 1/2 at tasseling and T6=1/4 at planting+ 1/2 at knee-height + 1/4 at tasseling.

3.8. Urea Split Application on Economic Feasibility of Maize Production

Partial budget analysis of urea split application time was presented in Table 2. The highest net benefit of EB 201,536.7 ha^{-1} with higher marginal rate return of 2822.26 % with value to cost ratio of EB 5.13 per unit of investment was obtained from three urea split application of 1/4 dose at planting +1/2 dose at knee height + 1/4 dose at tasseling for maize production followed by net benefit of EB 193,974.3 and marginal rate of return of 455076% with value to cost ratio of EB 5.08 per unit of investment from time of Urea split application (2/3 dose at knee height+ 1/3 dose at tasseling). However, the lowest net benefit of EB 165610.8 Birr ha^{-1} was obtained from 1/2 dose at planting + 1/2 dose at tasseling of urea split application. Similarly, Tana and Moges [21] reported that higher net benefit was obtained from N application at vegetative stage of maize. Golla et al. [22] 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} at vegetative stage.

Table 2. Partial budget analysis of urea split application time of maize production at Bako in 2019 and 2020 cropping season.

Time of N Application	Grain yield (kg ha^{-1})	Adjusted Grain yield (kg ha^{-1})	Gross grain field benefit (EB ha^{-1})	TCV (EB ha^{-1})	Net benefit (EB ha^{-1})	Value to cost ratio	MRR (%)
T5	8099.83	7289.85	218695.5	47470	171225.5	4.60702549	
T4	8942.57	8048.31	241449.3	47475	193974.3	5.085819905	455076
T2	7897.62	7107.86	213235.8	47625	165610.8	4.477392126	
T1	8329.13	7496.21	224886.3	47850	177036.3	4.699818182	
T6	9269.88	8342.89	250286.7	48750	201536.7	5.134086154	2822.26
T3	8461.43	7615.28	228458.4	49050	179408.4	4.657663609	

D=dominance, maize grain price =30 ETB kg^{-1} at 2023 and daily Labor cost 75 ETB day^{-1}. T1= (1/2 at planting + 1/2 at knee height), T2 = (1/2 at Planting + 1/2 at Tasseling), T3 = (1/3 at sowing + 1/3 at knee height + 1/3 at Tasseling), T4=2/3 at knee height + 1/3 at tasseling stage), T5= (1/2 at knee height + 1/2 at Tasseling) and T6= (1/4 at planting + 1/2 at knee height + 1/4 at Tasseling stage of urea split application). The cost of gain maize 30

4. Conclusion

Among the cereals, maize has the best potential for production and is the third most significant crop grown worldwide, after rice and wheat. Even though its current productivity is higher than other major cereal crops, the yield is below its potential. Therefore, the general objective of the research was to investigate the appropriate time of urea split application to enhance the productivity of maize crops in the study area. The treatments consisted of two factors, namely, two maize varieties (BH-546 and BH-547)) and six different application times of urea (1/2 dose at planting + 1/2 dose at knee height, 1/2 at planting + 1/2 dose at tasseling, 1/3 at planting + 1/3 at knee height + 1/3 at tasseling, 2/3 at knee height +1/3 dose at tasseling, 1/2 at knee height + 1/2 tasseling and 1/4 dose at planting +1/2 dose at knee height +1/4 dose at tasseling). The experiment was laid in a randomized complete block design (RCBD) in 2 x 6 factorial arrangements with three replications. The results of the analysis indicated that Urea split application at different growth stage of maize proved an additional source for a higher rate of photosynthesis and transport of photo-assimilates during grain filling that resulted in a higher grain yield of maize. Moreover, the effect of urea time of application significantly affected 90% physiological maturity, Grain yield, Total leave area per plant, Leave area index and Plant height while this interaction due to maize varieties and Urea time of application significantly affected both days to 50% tasseling and days to 50% silking. Therefore, separate analysis for each season was done since the seasonal rainfall variability considerably affected the response of treatments. From this study urea split application 1/4 doses at planting stage 1/2 dose at knee-height and 1/4 dose at tasseling stage is the best time of application in good rainy seasons and hence recommended for the end users. However, in the case of erratic and heavy rainy seasons, application at three times should be used to get maximum profit and acceptable MRR.

Abbreviations

RCVD	Randomized Block Design
LAI	Leave Area Index
BH	Bako Hybrids
ANOV	Analyses of Variance
TVC	Total Variable Cost
MRR	Marginal rate of Return
FAO	Food and Agricultural Organization
CSA	Agricultural Central Survey
CIMMTY	International Maize and Wheat Improvement Center

Acknowledgments

The authors acknowledged Oromia Agricultural Research Institute for funding the activity and Bako Agricultural Research Centre for planning and budget allocation to execute the field experiment. Special thanks go to all the staff members of the Seed Research and Technology Multiplication Team for their assistance in data collection and field management.

Funding

The Oromia Agricultural Research Institute of Bako Agricultural Research Center coordinates this work as part of its regular research activities.

Data Availability Statement

The raw data are available from the corresponding author upon request.

Author Contributions

Megersa Debele is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

References

[1] (FAO). World Food and Agriculture Organization and World food and agriculture Statistical Pocketbook. 2021, 254.

[2] Zamir, M. S. I., Yasin G., Javeed, H. M. R., Ahmad, A. U. H., Tanveer, A., Yaseen, M. Effect of different sowing techniques and mulches on the growth and yield behavior of spring-planted maize (Zea mays L.). Cercetări Agronomice în Moldova. 2013,1(153), 77-82.

[3] FAOStat (Food and Agriculture Organization Corporate Statistical Database). Food and agriculture organization statistics data base, agricultural production indices. fao, rome, Italy. 2021.

[4] Erenstein, O., Jaleta, M., Sonder, K., Mottaleb, K. and Prasanna, B. M. Global maize production, consumption and trade: Trends and R&D implications. *Food Security*. 2022, *14*(5), 1295-1319.

[5] CSA. Agricultural sample survey 2020/2021. Volume I. Report on Area and Crop Production of Major Crops (Private Peasant Holdings Main season). Statistical Bulletin 586, Addis Ababa, Ethiopia. 2021.

[6] Kadigi, I. L., Richardson, J. W., Mutabazi, K. D., Philip, D., Mourice, S. K., Mbungu, W., Bizimana, J. C. and Sieber, S. The effect of nitrogen-fertilizer and optimal plant population on the profitability of maize plots in the Wami River sub-basin, Tanzania: A bio-economic simulation approach. *Agricultural systems*. 2020,*185*,102948.

[7] Abo, A. A., Mamo, M. A. and Handiso, Y. EInfluence of Nitrogen Fertilizer Rate and Its Time of Application on Productivity of Maize (Zea Mays L.) In Hadero Tunto District, Kambata Tambaro Zone Southern Ethiopia. *International Journal of Agricultural and Natural Sciences*. 2022, *15*(2), 149-162.

[8] Zhang, X., Zhang, K., Sun, Y., Zhao, Y., Zhuang, H., Ban, W., Chen, Y., Fu, E., Chen, S., Liu, J. and Hao, Y. Combining spectral and texture features of UAS-based multispectral images for maize leaf area index estimation. *Remote Sensing*. 2022, *14*(2), 331.

[9] CIMMYT. Economics Program, International Maize and Wheat Improvement Center, From agronomic data to farmer recommendations: an economics training manual. 1988) (No. 27). CIMMY.

[10] Amanullah, Yasir, M., Khalil, S. K., Jan, M. T. and Khan, A. Z. Phenology, growth, and grain yield of maize as influenced by foliar applied urea at different growth stages. Journal of plant nutrition. 2010 33(1), 71-79. https://doi.org/10.1080/01904160903391099

[11] Sharifi, R. S. and Namvar, A. Effects of time and rate of nitrogen application on phenology and some agronomical traits of maize (Zea mays L.). *Biologija*. 2016, *62*(1).

[12] Tas, T. Physiological and biochemical responses of hybrid maize (Zea mays L.) varieties grown under heat stress conditions. PeerJ. 2022. 10, 14141.

[13] Khan, A. Z., Jan, A., Shah, Z., Ahmad, B., Khalil, S. K., Ali, A., Ahmad, F. and Nawaz, AFoliar application of nitrogen at different growth stages influences the phenology, growth and yield of maize (Zea mays L.). Soil & Environment. (2013), 32(2).

[14] Ogunboye, O. I., Adekiya, A. O., S Ewulo, B. and Olayanju, A. Effects of split application of urea fertilizer on soil chemical properties, maize performance and profitability in southwest Nigeria. *The Open Agriculture Journal*. 2020, *14*(1).

[15] Zerihun, A. and F. Hayilu). Effects of nitrogen rates and time of application on yield of maize: rainfall variability influenced time of N application. International Journal of Agronomy. 2017, 1-10.

[16] Megersa, D., Tolera, A. and Tadesse, D. 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. ajps. 2019, 13(2), 33-41.

[17] Niaz, A., Yaseen, M., Arshad, M. and Ahmad, R. Response of maize yield, quality and nitrogen use efficiency indices to different rates and application timings. *JAPS: Journal of Animal & Plant Sciences*. 2015, *25*(4).

[18] Chala, M., Chalchissa, C. and Biratu, G. Determination of Appropriate Time of Nitrogen Fertilizer Application for Maize in the Central Highlands of Ethiopia. Results of Crop Improvement and Management Research for. 2022 https://jurnal.uns.ac.id/arj

[19] Lu J, Cheng D, Geng C, Zhang Z, Xiang Y, Hu T). Combining plant height, canopy coverage and vegetation index from UAV-based RGB images to estimate leaf nitrogen concentration of summer maize. Biosyst Eng. 2021, 202, 42–54. https://doi.org/10.1016/j.biosystemseng.2020.11.010

[20] Aleminew, A., Legas, A. and Misganaw, M. Yield response of bread wheat to timing of urea fertilizer application in eastern Amhara region. *Journal of Biology, Agriculture and Healthcare*. 2015, *5*(3), 180-184.

[21] Tana, T. and Moges, A. Effect of Nitrogen Fertilizer Rates and Plant Densities on Yield and Yield Related Traits of Maize (Zea maize L.) Under Irrigation in Southern Tigray, Ethiopia. PhD dissertation, Haile Sellassie I University College of Agriculture. 2015.

[22] Golla, B., Mintesnot, A. and Getachew, M.,. Impact of nitrogen rate and intra row spacing on growth parameters and yield of maize at Bako, Western Ethiopia. Open journal of plant science. 2018, 3(1), 30-40.