**SCHOOL OF GRADUATE STUDIES**

# EFFECT OF PLANTING DATES ON GROWTH AND YIELD OF MAIZE (*Zea mays* L.) VARIETIES AT EZHA DISTRICT, GURAGE ZONE, CENTRAL ETHIOPIA

**MSC THESIS**

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# Effect of Planting Dates on Growth and Yield of Maize (*Zea mays* L.) Varieties at Ezha District, Gurage Zone, Central Ethiopia

**A Thesis Submitted to the School of Graduate Studies, in Partial Fulfillment of the Requirements for the Degree of Master of Agronomy in Department of plant science**

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**May, 2024**
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# APPROVAL SHEET

## WOLKITE UNIVERSITY

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As Thesis Research Advisor, we hereby certify that we have read and evaluated this thesis prepared under our guidance by Dino Nasir Mohammed entitled **"Effect of Planting Dates on Growth and Yield of Maize (*Zea mays* L.) Varieties at Ezha District, Gurage Zone, Central Ethiopia"** and we recommend that it be submitted as fulfilling the requirement for the award of MSC, degree in plant science.

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As members of the board of examiners of the MSc science Thesis open defense examination, we certify that we have read and evaluated the thesis prepared by **Dino Nasir Mohammed** and examined the candidate. We recommend that the thesis be accepted as fulfilling the thesis requirements for the degree of Master of Science in Agriculture (Agronomy).

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# DEDICATION

I dedicate this thesis to my lovely family for their concern, prayer, patience, and encouragement in the success of my life.

# STATEMENT OF THE AUTHOR

By my signature below, I declare and affirm that this thesis work is my own work. I have followed all ethical principles of scholarship in the preparation, data collection, data analysis, and completion of this thesis. All scholarly matter that is included in the thesis has been given recognition through citation. I affirm that I have cited and referenced all sources used in this document. Every serious effort has been made to avoid any plagiarism in the preparation of this thesis.

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# BIOGRAPHICAL SKECH

The author, Dino Nasir Mohamed, was born at Muda near Koter Gedera kebele 13 km distance from Agena town on April 07, 1996 G.C in Ezha District, Gurage Zone, Central Ethiopia Region, from his father, Mr. Nasir Mohamed, and his mother, Miss Yabechi Sebani. He attended elementary school (grade 1-8) at Koter Gedera primary school, secondary school (grade 9-10) at Koter Gedera secondary school, and preparatory school (grade 11-12) at Agena town. Graduated from Wolaita Sodo University in 2012 G.C with a BSc degree in plant science. He worked as an expert in the Ezha woreda Agriculture Office from 2013–2015 G.C. and as the head of the Environmental Protection and Forest Office and Agriculture Office until he joined the postgraduate Programme. In December 2022 G.C., he joined the postgraduate program at Wolkite University, plant Science department, to pursue his studies for the degree of Master of Science in Agronomy.

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ANOVA | Analysis of Variance |
| ATA | Agricultural Transformation Agency |
| BRC | Bako Research Center |
| CEC | Cationic Exchange Capacity |
| CIMMYT | International Centre for Maize and WheatImprovement |
| CSA | Central Statistical Agency |
| FAOSTAT | Statistical data base of the Food and Agriculture of the United Nations |
| GLM | General Linear Model |
| HI | Harvest Index |
| LSD | Least Significant Difference |
| NPSB | Nitrogen, Phosphorus, Sulfur and Boron |
| OC | Organic Carbon |
| PHSE | Pioneer Hybrid Seed Ethiopia |
| RCBD | Random Complete Block Design |
| SAS | Statistical Analysis System |
| TN | Total nitrogen |

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# *ABSTRACT*

*Planting dates is a critical factor in maize production decision-making, with implications for crop management, variety selection, and adaptation to changing environmental conditions. Afield experiment was conducted to study the effect of planting date on growth and yield of maize varieties. The experiment was conducted in Ezha district during the 2023 main cropping season. The treatments consisted of factorial combinations of four maize varieties (BH540, BH661, Shone, and Limu) and four planting dates (9-April, 19-April, 29-April, and 9-May) laid out in a Randomized Complete Block Design (RCBD) with three replications. The experiment's findings demonstrated that planting dates and varieties had a significant impact on most parameters examined. However, varieties had no effect on the number of days to anthesis and silking. The statistical analysis result revealed that, Limu variety interacted with the planting date of 9-April, resulted, the longest days to anthesis silking interval (11.67), the largest number of ears per plant (1.40), the highest thousand kernel weight (410), the highest above-ground dry biomass (13.93 kg ha$^{-1}$), and the highest grain yield (6.71 t ha$^{-1}$) of maize. Similarly, the planting date 9-May interacted with the same variety, resulted the longest days to anthesis silking interval (11.67). The variety Limu resulted in the highest days to maturity (170), ear length (16.63 cm), ear diameter (16.08 cm), and harvest index (43.92). Similarly, Variety BH661 resulted in the highest ear height (101.45), longest days to emergence (9.08 days), longest days to anthesis (95.58 days), and longest days to silking (103.17); beside, the highest plant height (238.97cm), and the highest number of rows per ear (16.40) recorded from variety shone. Conversely, the planting date of 9-April yielded the longest days to maturity (161.75), the highest number of kernels per row (35.56 cm), the highest ear height (84.93 cm), the longest ear length (17.61 cm), the longest ear diameter (17.74 cm), and the highest harvest index (42.05%). Likewise, the planting date of 9-May recorded the longest day to emergence (9.5), the longest day to anthesis (98.67), and the longest days to silking (107.83). Thus, based on the result, early planting on April 9 resulted in the highest grain yield (6.7 t ha$^{-1}$) from the Limu variety, whereas the lowest grain yield (1.65 t ha$^{-1}$) was recorded from the BH540 late planted on May 9. Therefore, variety Limu with early planting date (April 9) was recommended for maize production in the study area. However, the experiment was done only at one location and one season; therefore, it would have to be replicated across locations and seasons to get the best conclusive result and a sound full recommendation for a specific area in order to assure the findings of the current study.*

**Keywords:** Cultivar, Growth, Maize, Planting date and Yield

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# 1. INTRODUCTION

Maize (Zea mays L.) is one of the most versatile crops having wider adaptability under varied agro-climatic conditions and successful cultivation in diverse seasons and ecologies for various purposes (FAOSTAT, 2021). Globally, maize is known as "Queen" of cereals because it has the highest genetic yield potential among the cereals (Anonymous, 2021). It is a significant and strategic cereal crop which is crucial to Ethiopian farmers' livelihoods and food security (Balemi *et al*., 2020). Maize provides a cheaper calorie source compared to the other cereals and now makes up the largest share in calorie intake and production in the country (Tsedeke *et al*., 2015; Jaleta *et al*., 2018). Because of its adaptability, maize is growing in different agro-ecologies, soil types, temperature regimes, and socio economic conditions Tsedeke *et al*. (2017); Balemi *et al*. (2020), and it has the potential to feed more than 100 million people nationwide (Dagne et al., 2019). Being one of the most significant crops grown in Ethiopia, both the acreage and production of maize have dramatically increased over the previous few decades.

The CSA estimated that production increased from 2.39 million tons in 2004 to 10.54 million tons in the 2020/2021 producing season (CSA. 2022). Due to the availability of several maize cultivars developed that are adapted for each circumstance, it is produced in Ethiopia in diverse agro ecologies ranging from an elevation of 1000 to 2400 masl and from high moisture to moisture stress zones (ESA, 2014).These agro-ecologies differ in altitude, annual rainfall, temperature, relative humidity, and latitude (Marenya *et al*., 2022). Genotype and environment interaction is the primary factor determining productivity and appropriate variety selection for a sowing time is worthwhile besides soil health, favorable temperature regimes and irrigation (Liaqat *et al*., 2018).

In comparison to its yield potential, maize's present national average yield is still low at 4.1 t $ha^{-1}$ (CSA, 2022). Ethiopia ranks second in Sub-Saharan Africa for maize production, after South Africa (Balemi *et al*., 2020). Gurage zone maize production coverage area of 47343 hectare with production of 276,886.5 ton or 5.8 ton per hectare. In the study area of Ezha District, maize is produced in most of mid altitude with an area coverage of (280 ha), output (1,388 tone) and productivity (4.9 t $ha^{-1}$), (Gurage Zone Administration Agricultural Office, 2022). Being a major cereal grown in the area, maize isthe staple diet and important source of income for many farmers. (Workneh Bekele., 2021).

One of the key factors affecting maize yields in each growth location is the planting date, which must be updated frequently to account for new cultivars and a climate that is prone to vary across a variety of time scales. The best time to sow corn depends on the climate and the region (Djaman *et al.*, 2022). When selecting a hybrid or cultivar of maize for relative maturity, maize growers take into consideration these factors (Baum *et al*., 2018)

The frequency and severity of droughts have been rising as a result of unusually little and sporadic rainfall (Gebrehiwot and Maathuis, 2011). As a result, Ethiopia is commonly depicted as being in a state of drought. Choosing an appropriate planting date is one of the crucial factors that significantly affect crop performance in rain fed agriculture. When the rainy season in many parts of Africa, including Ethiopia starts with a few light showers and is subsequently followed by dry spells, this might prevent crops from emerging or cause immature crops to desiccate (Begizew *et al*., 2018). To mitigate such effects, planting times must be adjusted.

Environmental factors such as temperature, radiation and water vary in a random manner around their seasonal mean trends, resulting in uncertainties in crop production during the main crop ping season (Tsimba et al. 2013) The biggest challenge is to determine the ideal time for planting either early or late season hybrids, especially when planting window is shortened by weather or management challenges. Because of differences in maturity and length of growing seasons, the ideal planting dates for maize hybrids vary among locations and seasonally within locations. Maximize yields and profitability it is however essential that the maize hybrid with the right maturity be selected for planting given the planting window available to the farmer (Tsimba *et al*., 2013).

Accordingly, a difference in planting time is associated to many meteorological factors (rainfall, temperature, and photoperiod). The interaction between the environment and the variety of maize is essential to its production (Otung, 2014). According to Baum *et al*. (2019), the best time to plant maize depends on its location and hybrid's relative maturity date. A yield reduction can be seen when maize is planted before or after the optimal planting window (Zhou *et al*., 2016). The best time of year to plant maize typically refers to the average meteorological conditions, and it does not apply every year (Baum *et al*., 2019).

Previous studies on effect of planting date on maize indicated that planting date significantly affects maize phenology (days to tasseling, silking, maturity) growth and as crop yield (Baum *et al*., 2019). According to Parker *et al*. (2016), planting maize too early could result in less-than-ideal soil and weather conditions, while planting it too late could subject plants to a shorter growing season, colder temperatures, and less solar radiation. According to (Delano and Modi., 2017) study the weather conditions at the time of planting have a profound influence on the potential profitability of maize especially under rain-fed cultivation which is common practice by small holder farmers. Hence, planting date is one of the most important management practices that influence the resultant crop yield through seedling establishment and development. Planting date has direct influence on day and night temperature, light intensity, photoperiod and soil moisture which affect crop growth duration and harvesting period. However, optimal planting dates varies across region and differences in planting dates expose crop to different stress factors (Delano and Modi. 2017).

The impacts of climate change on agriculture are extremely complex and diverse (Siebert and Ewert, 2014) affecting crop yields (Herrero et al., 2010). Rainfall patterns and other weather conditions associated with different planting dates have a modifying effect on length of the growing season, maize development and harvesting period (Beiragi et al., 2011). Variations in temperature and precipitation could affect agro-climatic conditions, changing growing seasons, planting and harvesting dates, water availability, and pest occurrence are some of its direct effects on agricultural systems (Saul, 2015). Soil and climatic conditions of district are highly favorable for maize production yet its average yield is very low. The reasons for low yield are non-availability of high yielding hybrids, and in-sufficient availability of water at proper time, improper sowing date and lack of modern production technology (Begizew *et al*., 2018). Among the various factors of improved hybrids and proper sowing dates play key role in boosting production of maize (Patel *et al*., 2017). Hybrid and sowing date play vital role in successful maize husbandry. According to Djaman *et al*. (2022) noted that, yield can be increased to a greater extent provided high yielding hybrids are identified and planted at optimum sowing dates.

Growth region and specific planting dates are therefore among one of the major determinants factors for maize yields and require regular updates to keep track with new cultivars and a climate that is subject to change on a range of time scales (Baum *et al*., 2019). Farmers in Ezha district of the Gurage zone grow a variety of improved maize cultivars with varying maturity dates. However, in the district, there is lack of information regarding the impact of planting dates on the crop's growth and yield of maize varieties with varying maturity group.

**General objective**

- To study the effect of planting dates on growth and yield of maize hybrid varieties

**Specific objectives**

- To investigate the effect of early and late planting on growth, yield components and yield of maize varieties
- To Investigate the optimum planting dates for maize varieties for optimum maize production

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# 2. LITRETURE REVIEW

## 2.1. Maize Production in Ethiopia

Maize is grows widely in Ethiopia in various agro-ecological zones. It grows in altitudes ranging+ from 500–2400 m above sea level (masl). In Ethiopia, maize has grown over the past few decades from being a simple garden crop to a profitable cereal crop. Since the mid-1990s, maize has led Ethiopia's primary cereal crops in terms of both production and yield, making it the largest and most productive crop (Kebede *et al*., 2020). Maize ranks second after teff in area coverage but ranks first in terms of production and can be grown on a different soil types and temperature regimes in the country (Balemi *et al*., 2020). The current national average yield of maize is 4.21 t ha-1 (CSA, 2021), which is still low compared to its yield potential. Ethiopia is the second highest maize producer in Sub-Saharan Africa next to Nigeria (Assefa, *et al*., 2020). Ethiopia's maize production increased from 939 thousand ton in 1970 to 8500 thousand ton in 2019, growing at an annual rate of 7.64% (FOA, 2020).

## 2.2. Agro- ecological Requirement of Maize

Maize grows well in a wide range of environments, but the interaction between the environments and genotype is critical to its production (Otung, 2014). These agro ecologies differ in altitude, annual rainfall, temperature, relative humidity, and latitude. The sub-humid agro-ecosystem of Ethiopia is the major maize producing belt in the country where the highest maize grain yield (11 tons $ha^{-1}$) was recorded in the farmers' field by using improved maize technologies for the first time in the history of Ethiopian agriculture in 1993 when Sasakawa Global (SG) 2000 started to operate in the country (Wakene *et al*., 2007).The factors determining the growth and final yield of maize (*Zea mays* L.) are climate, soil, fertilizer and crop management. The diverse agro-ecological environments where maize is cultivated (e.g. from wet to dry; from low to mid-altitude to highland) have led to the distinction of various rain fed maize mega-environments defined on the basis of growing season maximum temperature and rainfall (Erenstein *et al*., 2022).The optimal temperature range for maize growth during the summer season is around 25–33°C during the day and 17–23°C at night. Additionally, the optimal temperature for achieving maximum grain yield is approximately 25°C. These temperature conditions promote better growth and development of maize crops, ensuring favorable yields (Waqas *et al*., 2021). Significant differences among different cultivars for growth degree day (GDD) explain that different cultivars have varying maturity periods. Environmental factors, especially temperature during the period of seed development and maturation, might have affected yield and yield components and also influence plant growth and development (Mehdi, 2012). A good planting date is one of the crucial factors that strongly influence crop production inrain-fed agriculture. Particularly in many parts of Africa, where the rainy season starts with some light showers followed by dry spells that can cause poor crop emergence or desiccatea young crop.

## 2.3. Economic Important Maize in Ethiopia

The most widely produced food in the world, maize or corn ranks third in terms of cereal crop importance behind rice and wheat in terms of global consumption (FAO, 2020). Maize plays a significant role in Ethiopian diets and produces more of the country's total yearly output than teff, sorghum, and wheat combined by more than 50% (FAOSTAT, 2021). Maize for industrial use has helped meet rising demand. Currently, very little maize is used as feed, but this is changing as well to support the rapidly expanding poultry industry and urbanization (Abate *et al*., 2015). Maize is used as human food (62 percent of total household cereal consumption), a source of cash income (about 54 percent), fuel (about 25 percent), livestock feed, and for industrial purposes (Lemi Yadesa and Debela Diro, 2023).

In Ethiopia, maize ranks second in terms of area coverage and first in terms of total production among cereal crops. In Ethiopia, it is not only used in the food and poultry industries, but it is also a source of income in most towns, particularly at the fresh grain stage. Maize is a staple food and one of the main sources of calories in Ethiopia. Farmers eat maize by making bread, injera, thick porridge, boiled maize, roasted maize, and regional beer, among other foods (Lemi Yadesa and Debela Diro, 2023).The utilization dimension of maize for food security thereby merits increased support to promote healthier diets. Given the varied maize food uses, there is a growing interest in nutritionally enriched maize, specialty maize, and improvement of end use quality traits suitable for the processing industry and associated niche markets (Erenstein *et al*., 2022.).

The popularity of maize in Ethiopia is partly because of its high value as a food crop as well as the growing demand for the stover as animal fodder and source of fuel for rural families. Approximately 88 % of maize produced in Ethiopia is consumed as food, both as green and dry grain. Maize for industrial use has also supported growing demand. (Mitiku *et al*, 2022). Very little maize is currently used as feed but this is changing in order to support a rapidly growing urbanization and poultry industry.

Maize grain is a key ingredient in animal feed, and this added demand has driven up prices of maize grain and made it less affordable for poor consumers in several regions of the world. Production shortfalls in global maize supplies and increasing input prices have grave consequences for developing countries. Along with prices of other commodities, especially wheat, maize price have increased by 43% since 2008 and are projected to increase in the future in response to increasing demand and constraints on expanding supplies. Such increases will impose great hardship on the poor, as the food price surges of 2008 and early 2011 have made abundantly clear (Bekele, *et al*., 2011).

## 2.4. Factors Affecting Maize Production in Ethiopia

Numerous abiotic, biotic, and socioeconomic limitations may be to suspect for the low productivity of maize in several maize-growing low and middle-income countries, compared to the global average of nearly 5 tons $ha^{-1}$ (Lemi Yadesa and Debela Diro, 2023). The most important agronomic practices for the production of maize include field preparation, fertilizer application, proper seed rate, proper spacing, sowing at the proper time, appropriate weed management, and timely harvesting. All these are critical in the production of maize. Bulti Merga and Jema Haji Mohammed, (2019) study factors impeding effective crop production are improved seeds, initial capital for investment, and loss of crop land, labor, pesticides, invasive alien species, farm storage techniques, methods of small scale irrigation, and religious and cultural challenges.

Maize production is highly specific to each production region of Ethiopia with different factors playing a major role in yield. It has been predicted that due to climate change and extreme weather events maize yield will decrease significantly if agricultural practices are not adapted and matched to the changing climatic conditions (Adisa *et al* 2019). The differences in planting dates led to variation in canopy stature. On average, early planted and mid planted maize performed similarly having taller plants, greater leaf number and leaf area index relative to late planting maize thus producing large canopy earlier in their planting seasons which optimally utilize solar radiation for photosynthesis. The lower plant growth observed under late planting across days after planting might have been due to limited water availability for plant use under extreme weather condition which reduced photosynthetic rate, CO2 assimilation and fixation (Delano and Modi, 2017).

Although maize varieties are released for specific agro-ecology, it was observed that some farmers sometimes grow maize varieties that are not recommended for their area for various reasons, including lack of timely supply of the desired suitable varieties (Tesfaye *et al*., 2019). The identified factors that affect maize production were education of farmer Korgitet, (2019), fertilizer use Fufa and Hassan, (2006), land-labor ratio, use of fertilizer, use of pesticide, manure and household size Urgessa Tessma, (2015), and age of farmer. Taddesse Getaw, (2011) and farm size (Abate Lema, 2020).

Providing agricultural technology may not guarantee its success in closing the maize yield gap unless it is successfully implemented by maize growers like Assefa, *et al*. (2022). It is known that Ethiopia has sufficient agricultural input resources, but the majority of the population is still at severe risk of poverty. Thus the country still imports different cereal crops for food purpose. The farmers believed that large quantity of yield is obtained expanding land size and the farming is characterized by the low production per hector Taddesse Getaw (2011); Korgitet (2019). Consequently, the annual income from farming, especially maize is too low which is not sufficient for households to change their live standard.

## 2.5. Released Maize Varieties in Ethiopia

In Ethiopia, maize is produced under diverse agro-ecologies ranging from an elevation of 1000 to 2400 masl and from high moisture to moisture stressed areas due to the availability of different maize cultivars developed to be tailored for each condition (ESA, 2014 High yielding varieties are of primary importance for potential yield positively. Yield can be increased to a greater extent through high yielding varieties and appropriate time of planting, with advanced agronomic practices (Buriro et al., 2015).

The productivity of existing varieties is below potential. The low yield because of mainly not only a lack of improved varieties but also attributed to improper use of technology packages. Over the last four decades, more than 40 improved varieties of maize have been developed and released in Ethiopia 39% of the total maize area in Ethiopia is now planted with improved varieties(Zeng, 2013). At plot-level, the yield advantage of improved maize is 48–63% over local maize types. Additional input costs associated with the improved varieties such as seeds, pesticides, and herbicides imply a 23–29% increase in the cost of production (Zeng, 2013). Although maize varieties are released for specific agro-ecology, it was observed that some farmers sometimes grow maize varieties that are not recommended for their area for various reasons, including lack of timely supply of the desired suitable varieties (Tesfaye *et al*., 2019). More appropriate planting dates were also reported to be dependent on the type of maize variety grown (Beiragi et al., 2011).

## 2.6. Effect of Planting Date on Phenology of Maize

Maize phenology, such as days to tasseling, silking, maturity, and crop yield, is also affected by planting date (Dahmardeh and Dahmardeh, 2010; Shrestha *et al*., 2016, 2018; Lizaso *et al*., 2018; Baum *et al*., 2019). The influence of temperature on grain yield is related to its effect on the number of kernels per ear (Hatfield, 2016). Growing temperatures and planting dates affect phenology and grain yields of maize varieties and farmers have to choose suitable varieties that fit into different planting dates and growing temperatures (Tesfaye, et al., 2020). Temperature and light are the major factors regulating the phonological response of crops, including maize (Hatfield and Prueger, 2015). Crop development is usually accelerated under higher temperatures (Harrison et al., 2011).

According to Balemi *et al*., (2020) stated that days to maturity was also significantly influenced by the interaction effect of growing temperature and planting time. Under warm temperature, at Uke, late planting (June 6) resulted in longer days to maturity while under cool weather at Holeta, early planting (May 23) resulted in longer days to maturity. Thus, there is no clear trend of planting date effect on days to maturity since the influence of planting date on days to maturity varied with growing temperatures of the locations. Days to reach various phonological phases reduced with late sowing (Balemi *et al*., 2020). Very early planting increases the probability of poor planting conditions due to cold, wet soils, resulting in a negative impact on plant emergence and very late planting is associated with reduction in growing season length and accumulation of radiation (Baum *et al* ., 2019)

The silking and maturity dates were statistically significantly delayed as a result of planting date delays, which also resulted in shorter vegetative and reproductive intervals. The average amount of time from emergence to silking dropped from 67 to 54 days between early (April) and late (June) planting. Because of temperature variations, the number of days up to silking decreased more in the southern locations and less in the northern ones.

The typical length of the growing season for the mid-April PD was 130 days. The growing season lengths for the plantings in early May, mid-May, early June, and late June were, respectively, 123, 120, 112, and 103 days (Baum *et al* .2019).

A shorter ASI is desirable in maize cultivation as it maximizes the efficiency of pollination, reducing the risk of incomplete kernel development and yield loss due to poor pollination. Breeders often aim to develop maize varieties with shorter ASI to enhance yield stability and consistency across different growing Conditions. The highest anthesis silking interval suggests less synchrony between male and female flowering, whereas a shorter ASI indicates greater synchrony between female and male flowering. Kamara *et al*. (2006) reported that the anthesis silking interval was shorter among hybrids, with less emphasis on the planting date, particularly in modern maize varieties.

According to Dos Santos *et al*. (2019) also reported delayed seed emergence of up to two weeks under lower temperature compared to high temperature. They also reported that under extreme low or high soil temperatures percentage seed emergence may even highly decline. Unlike our observation, where we could not see difference in days to emergence between varieties, Kharazmshahi *et al*. (2015) reported significant effect of maize varieties on days to emergence.

Delays in planting time and low soil temperatures reduced days to seed emergence (Dos, *et al*., 2019) as well as maize grain yields (Baum *et al*., 2019). Due to the difference in maturity and length of growing seasons, the ideal planting dates for hybrid maize vary among locations that highly contrast in growing temperatures and even seasonally with locations due to varying weather (Tsimba *et al*., 2013). Planting under different environmental conditions influences the phonological stages in maize. The results of crop phenology showed clearer responses to differences in rainfall distribution and temperatures received at each planting date and season. The accumulated heat units for tasseling and silking were higher under warm temperature and sufficient availability water for plant uses (early and mid-planting) while it was shortened in late planting (Delano and Modi, 2017). .

## 2.7. Effect of Planting Date on Growth of Maize

Plant growth refers to irreversible increase in organ or whole plant size (length, area, and weight. Differences in planting dates might be due to the different climatic conditions, which are based on high temperatures during the plant's life cycle (Mehdi, 2012).

According to Ali *et al* .(2015) study plant height of maize sown on 16th July (232 cm) while minimum plant height was noted in maize sown on 30th July (185 cm). The possible reason could be that the early July sown crop had longer growth period to avail while end of July sown crop had shorter period for growth and therefore, taller and shorter plants were recorded in early and late sowing dates, respectively. Plant height was reduced by delayed sowing. Abdel-Rahman et al. (2001) found that maize plant height was affected by the sowing date, but in their trials taller plants were obtained in the plots sown earliest and dwarf plant height was measure in late sowing dates.

Choosing an appropriate planting date is one of the crucial factors that significantly affect crop performance in rain fed agriculture. Late planting of crop decreased its growth and development because less amount of solar radiation can be captured by crop during emergence to silking stage (Balemi *et al*., 2020). Likewise, if any crops bare exposed to colder temperature as well as low solar radiation environment during grain filling stage then very low dry matter accumulation occurs as result of late planting date. During middle of grain filling stage, higher amount of non-structural carbohydrates are accumulated in stem as result of delaying planting date. These consequences concluded that photosynthetic processes as well as kernel establishment are adversely affected by exposure to low temperature and radiation environment caused by late planting Shrestha *et al*., (2018).

## 2.8. Effect of Planting Date on Maize Yield and Yield Component

Two important techniques utilized globally for crop adaptation and mitigation to manage for unfavorable growth factors are planting date and hybrid maturity. The production potential of maize in each environment is determined by the hybrid maturity and planting date (PD) choices made. These two variables, along with the current weather, determine how long the crop can gather radiation during the growing season, which is positively connected with grain yield (Baum *et al*, .2019)

The seed yield is the function of combined effect of all the yield components under the effect of a particular set of environmental conditions. The seed yield increased little by little with the delay in planting date; the lowest seed yield was obtained at an early planting date, and with the delayed planting date, the seed yield decreased. The delay in planting gradually decreased the yield because of the decrease in temperature at the end of the season (Mehdi, 2012). This, however, may reduce grain yield through limiting the amount of total solar radiation received by the plant during each developmental stage and, in particular, at the grain filling stage (white and Reynolds, 2003; Harrison et al., 2011).

The optimum planting date achieves high yields in the central U.S. Corn Belt falls within the time frame of mid-April through early-May for corn (Zea mays). It is common for planting to be delayed past the optimum time frame due to the soil being too wet or cold. Planting date delays reduced grain yield significantly across maturities (Baum *et al*., 2019) Planting is delayed, growers must decide to continue to use a well-adapted, long-season hybrid maturity or switch to a shorter-season hybrid maturity. Yield highest within the optimum planting time frame and decreased the more the planting date was delayed. Similarly, as planting time delayed, the silking date was also delayed, shortening the length of grain fill. Earlier planting dates allowed accumulating more radiation and heat units throughout the growing season. The effect of relative hybrid maturity had little effect on yield across all planting dates (Baum, *et al*., 2019).

Killi and Altanbay (2005) observed that seed weight was significantly affected by the planting dates. The plants planted during the early part of the year (February-April) passed through lower temperatures during early phases and completed their life cycle more slowly, therefore having higher seed weight. Sowing during the later section of the year, July-August had higher temperatures during the early phases and completed their life cycle more rapidly, therefore having lower seed weight. Thousand grains weight was significantly affected by maize hybrids and sowing dates. The interaction of maize hybrids and sowing dates was found significant for thousand grains weight (Shahzad *et al*., 2015).

## 2.9. Response of maize hybrids to planting date

Sowing to the difference in maturity and length of growing seasons, the ideal planting dates for hybrid maize vary among locations that highly contrast in growing temperatures and even seasonally with locations due to varying weather (Tsimba *et al*., 2013). More appropriate planting date was also reported to be dependent on type of maize varieties grown (Beiragi *et al*., 2011).

Grain yield of full-season hybrids have a slightly higher relative yield compared with short-season hybrids at April to early May planting date, whereas short-season hybrids have a grain yield advantage when planted later. Planting in mid-May can significantly diminish Iowa maize grain yields. Grain yield variability is explained mostly by planting date with minor effect from relative maturity (Baum *et al*., 2019). In agreement with Shrestha et al., 2018 stated that, the longer maturity maize hybrids were more sensitive to late planting date than the short maturity hybrids. The reason for differential response to maize planting dates could be attributed to variation in the maturity periods Yield can be increased to a greater extent provided high yielding hybrids are identified and planted at optimum sowing dates. Planting dates are currently in late April or early May (Li *et al.*, 2000). The low moisture content in the soil before or during the planting season area encounters these soil water stress conditions, planting date have to be delayed. Then, the grain-filling period of full-season hybrids would be more affected by the unfavorable environmental conditions during reproductive growth stage than that of short or mid-season hybrids. Short-season hybrids would place reproductive stage under more favorable environmental conditions than their long-season counterparts as (Fulai Ke & Xinglin Ma., 2021)

For optimization of yield, planting at the appropriate time is very critical as delay in planting date can lead to a linear decrease in grain yields .Early planting in the spring is optimum and more efficient than delayed planting as through early planting germination occur when days are longer whereas delaying planting date results in a decrease in maize grain yields (Anapalli et al., 2005). Farmer’s choice on improved varieties is one of the most crucial factors affecting the productivity of a crop. High yielding varieties are of primary importance for potential yield positively. Yield can be increased to a greater extent through high yielding varieties and appropriate time of planting, with advanced agronomic practices (Buriro et al., 2015).

Mehdi, (2012) study showed that maize cultivars produced different seed weights; as the results the cultivars which remained for a longer duration in the field produced higher seed weight as compared to the cultivars which remained for a shorter period of time. The differences in seed weight might be due to the environmental conditions, mostly observed during the plant's life cycle. Early planting often yields higher grain yields in many areas .Previous studies have demonstrated the major impact of planting date on grain yield (Shrestha et al., 2018; Lizaso et al., 2018, and Baum et al., 2019 and Ke et al., 2021).. This may be explained by the longer growing season and the more ideal temperature during the critical time for grain formation, which allowed for improved development and yield.

# 3. MATERIALS AND METHODS

## 3.1. Description of the Study Area

The study was conducted in Gurage zone, Ezha district, at *Agujtereh* Keble during the Main cropping season in 2023. The experimental site represents mid-altitude agro-ecology. The study site 189 kilometers from Addis Abeba and 32 kilometers from Wolkite, Administrative zone. The district was located at 8o 12' 29" N latitude and 37o 53' 74" E longitude, with an altitude of 1890 m.a.s.l. The minimum and maximum temperatures are 21°C and 27°C, respectively; with an average annual rainfall of 1500–2300 mm. clay loam soil was the predominant soil type in the study area (Ezha woreda Agriculture and Natural Resource Office, 2023).

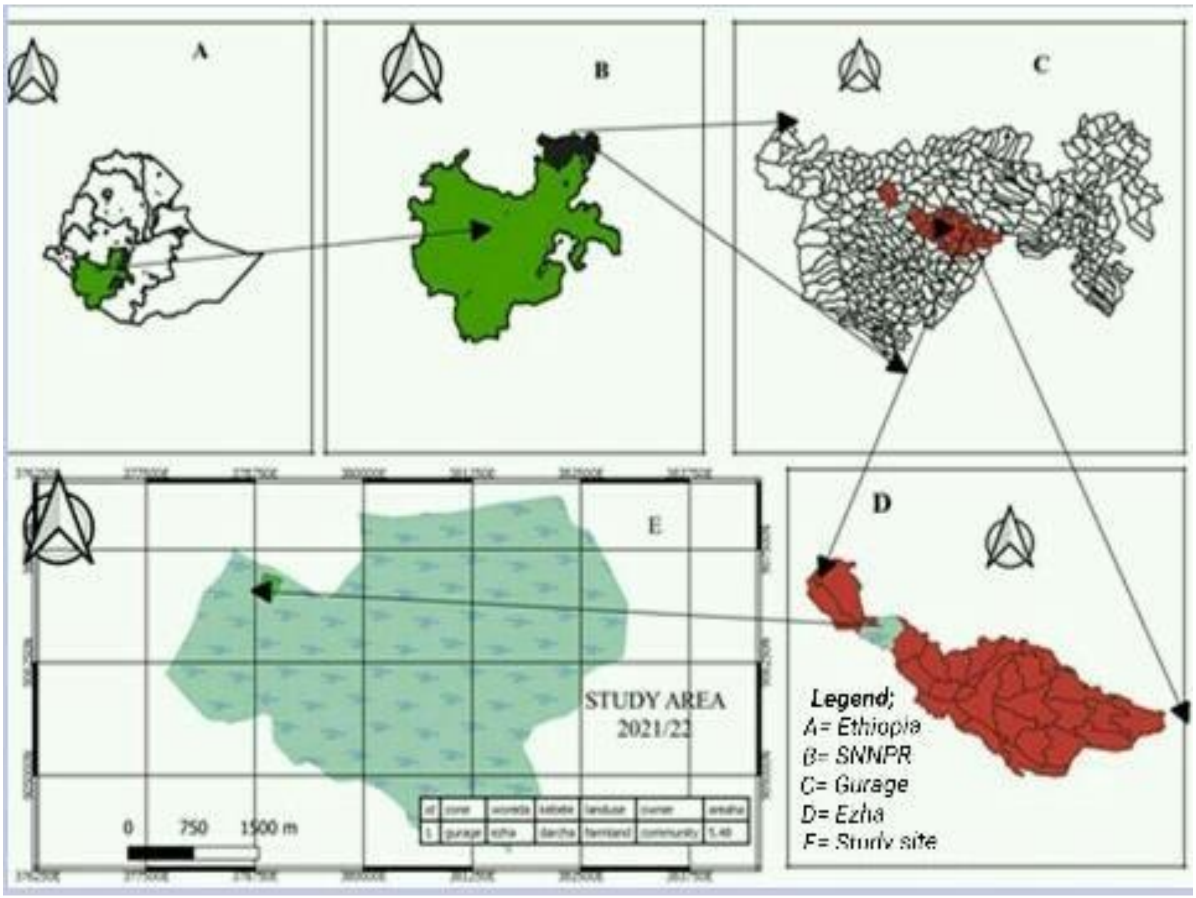


Figure 1. Map of the study site in *Agujtereh* Keble, Ezha district, Gurahge Zone, Central Ethiopia

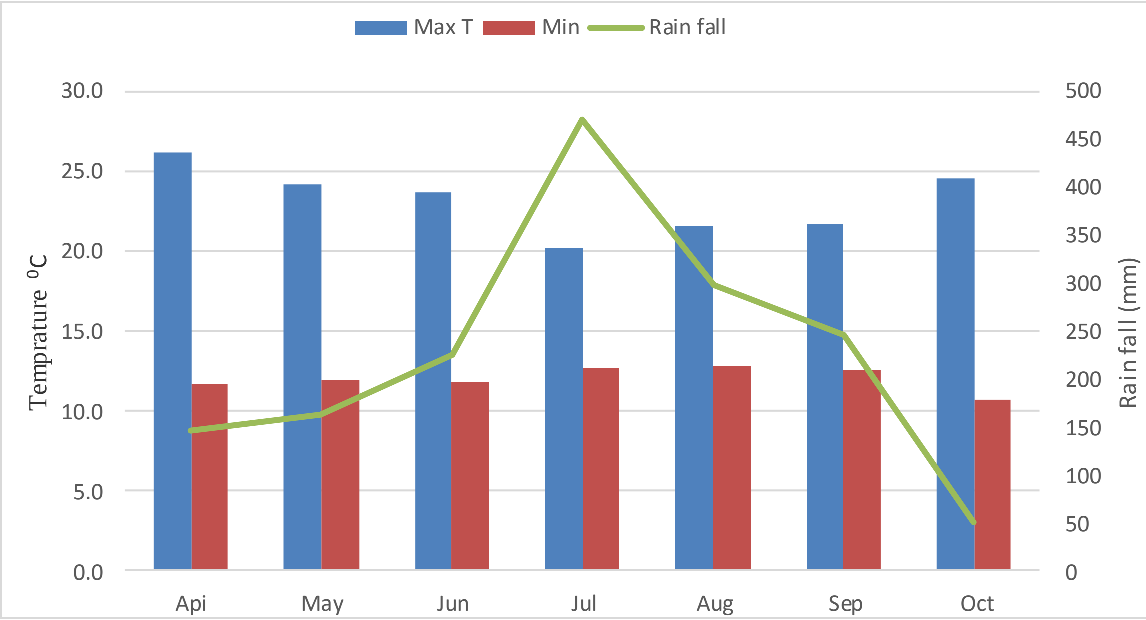


Figure 2. Temperature and rain fall conditions of experimental site during 2023 cropping season

## 3.2. Experimental Materials

For the experiment, four hybrid maize varieties with varying maturities were used: Limu and Shone from the Pioneer Seed Company, and BH540 and BH661 from the Bako Research Center. Limu and Shone and BH661were late in maturing (165–180 days), while BH540 was a medium maturation period (145 days) (Crop Variety Register., 2016). Additional description of the hybrid maize varieties used is presented in Table1.

Table 1. Description of maize varieties

| Name of Variety | Year of release | Rainfall (mm) | Altitude(m) | Maturity | Yield (qt ha-1) | | Breeder |
|---|---|---|---|---|---|---|---|
| | | | | | Farmer | Research station | |
| BH540 | 1995 | 1000-1200 | 1600-2200 | 145(Medium) | 50-65 | 80-90 | EIAR |
| BH 661 | 2011 | 1000-1500 | 1600-2400 | 160(Late) | 65-80 | 90-120 | EIAR |
| Shone | 2008 | 800-1200 | 1000-1800 | 165(late) | 65-80 | 70-110 | EIAR |
| Lemu | 2012 | 1000-1900 | 1200-2000 | 180 (Late) | 65-80 | 80-100 | PHSE |

Medium 120-150 and late 160-180 days (Balemi et al., 2020). BRC; Bako Research Center and PHSE; Pioneer Hybrid seed Ethiopia; EIAR, Ethiopian Institute of Agricultural Research.
Source: Crop Variety Register (2016)

## 3.3. Treatments and Experimental Design

The treatments consisted of four planting date (9-April, 19- April, 29- April and 9-May ) based on the farmer sowing time and the rain fall distribution and three maize varieties

(BH-540, BH-661, Shone and Limu) which were laid out in 4*4 factorial arrangements, 16 treatment combinations in Randomized Complete Block Design (RCBD) with three replications. The space between blocks and plots was 1m and 0.5 m, respectively and the space between rows and plants was 0.75m and 0.3 m, respectively. The gross plot size was 4.5 x 3 meters (13.5 m2), which could accommodate 6 rows with 10 plants per row in each plot. The data were collected from the central 4 rows after the border rows and plants were removed. Therefore, the net plot size was 3 x 2.4 meters (7.2 m2). The total area of the experimental field was 56 by 16.5 meters (924 m2).

## 3.4. Experimental Procedure and Management

The land was prepared by tractor. This included disc ploughing and cultivation to incorporate previous stover and to prepare the soil for the sowing. Each plot was consist of 6m rows with 3 m long separated by 0.75m. Rows and planting was made manually and maize seeds were planted with 0.75m inter-row and 0.30 m intra row spacing (44,444 plants $ha^{-1}$). Two seeds were planted per hill and were later thinned to one plant per hill before first round urea application after emergence. Full dose ofthe recommended blended NPSB (150) was applied during sowing and arecommended dose of 100 kg urea (46% N) was applied in three equal split at planting, 35 day after planting and flag leaf stage (Detebo *et al*., 2021). All the remaining agronomic practices were done uniformly to all experimental plots.

## 3.5. Data collected

The data was measured on phenology, growth, yield and yield components based on plot and plant base was made from the net plot area of each experimental plot as follows:

**Days to Emergency (DE):** It was recorded as the number of days from planting to when 50% of the seedling emerged in each plot.

**Days to Anthesis (DA)**: It was measured by counting the number of days from planting to the date when 50% of the plants in a plot shed pollen.

**Days to Slking (DS)**: It was measured by counting the number of days from planting to the date when 50% of the plants in a plot had emerged silks.

**Anthesis silking interval (ASI)**: It was computed as the difference between DS and DA.

**Days to physiological Maturity (DPM):** It was recorded as the number of days from planting to the formation of a black layer at the point of attachment of the kernel with the cob by 75% of the maize plants in the net plot.

**Plant height (PH):-** It was measured (in cm) from the base of the plant to the height of the first tassel branch and taken from five randomly selected plants from the central rows of each plot after flowering (measured two week after pollen shed).

**Ear height (EH)**:- It was measured (in cm) from the base of the plant to the node bearing the upper ear after flowering and taken from five randomly selected plants from the central rows of each plot after flowering (measured two weeks after pollen shed).

**Number of ears per plant (EPP):** It was determined by dividing the total number of ears harvested from the central rows of each plot by number of plants in the plot at harvest. An ear was counted if it had at least one fully developed grain.

**Number of rows per ear (RPE**):- It was recorded as the average number of kernel rows per ears from the five randomly sampled ears harvested from the central three rows of each plot.

**Number of kernels per row (KPR):** It was recorded as the average number of kernels per row from the 5 randomly sampled ears harvested from the central three rows of each plot.

**Ear length (EL) (mm)**: It was measured as length of the ear from the base to tip, an average of five ears was used.

**Ear diameter (ED) (mm)**: It was measured using Vernier caliper from five randomly selected ears from all harvested ears of each plot (net plot). It was measured at the mid-way along the ear length as average of the five randomly selected ears.

**Field weight (FWT)**: It was recorded as the weigh in kg of five representative cobs were selected, dehusked ears (cobs) in the plot (from net plot area) at harvesting.

**Moisture percentage (MOIST)**:- It was determine grain moisture content (%), five representative cobs were selected during harvesting, dehusked and shelled. The moisture content of the grains was then measured with grain moisture meter mini (Draminski, Kett Electric Laboratory) in the field.

**Thousand Kernels weight (TKW)**: It was determined by counting 1000 seeds from a bulk of each experimental plot and weighed in grams after the moisture was adjusted to 12.5%.

**Above-ground dry biomass yield (t ha$^{-1}$):**-It was determined after harvest on the basis of the plant samples from which the grain yield per plot was taken. This was done after the harvested Stover was dried by sun for about 10 days. It was measured plants harvested from the net plot area(7.2m2), using field balance (Salter Model-235),

**Grain yield (t ha$^{-1}$)**:- was determined on field weight basis (ears weighted in kg) from the net plot area, adjusted to 12.5% moisture content, and 80% shelling percentage was assumed for estimating the grain yield and converted to t ha$^{-1}$. It was determine grain moisture content (%), five representative cobs were selected and grains removed from their cobs. The moisture content of the grains was measured with grain moisture meter mini (Draminski, Kett Electric Laboratory) using the following formula (Badu-Apra et al., 2021).

**Grain yield** (t/ha) = [Fresh ear weight (kg/plot) × 10 × (100 − MC) × 0.8)/ ((100 − adjustedMC) × Plot Area]

**Harvest index:** was determined as the ratio of grain yield to total above ground biomass and multiplied by 100% in Kilo gram from each plot (Huehn, 1993).

## 3.6. Soil Sampling and Analysis

A composite soil sample was collected from 20 spots on the experimental site in a diagonal pattern before planting, a depth of 0–30 cm across the experimental field using a soil auger. Then, the samples were air-dried at room temperature in soil laboratory conditions, crushed with a mortar and pestle, and sieved to pass through a 2 mm mesh. Soil pH, Cation Exchange Capacity (CEC) (Cmol (+) kg-1), total nitrogen, organic carbon and soil texture were analyzed at the Wolkite sample testing and soil fertility improvement center.

The soil pH was determined by a 1:2.5 soil-to-water ratio using a glass electrode attached to a digital pH meter (FAO, 2021). Soil textural class was determined by using the Bouyoucos hydrometer method (Bouyoucos, 1962). Cation exchangeable capacity was determined titrimetric ally by distillation of ammonia that was displaced by Sodium. Total nitrogen was determined according to the modified Kjeldahl method with sulfuric acid by Dewis and Freitas (1984) Organic carbon was determined by the wet digestion method through the chromic acid digestion method, as described by (Walkley and Black, 1934).

## 3.7. Statistical Data Analysis

The collected data were subjected to in Microsoft Excel and subjected to the analysis of variance (ANOVA) by using the GLM OF SAS (Statistical Analysis Software) version 9.3 all significant pairs of torments were compared using the least significant difference LSD test at 5 % level of significance (Gomez and Gomez, 1984).

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# 4. RESULT AND DISCUSSION

## 4.1. Physical and chemical Properties of Soil in Experimental Site

Table 2 displays the physical and chemical properties of the soil in the experimental field prior to planting. According to the soil physical analysis of the soil texture was clay loam soil, which is appropriate for producing maize because of its good ability to retain nutrients and available water. The soil particle of experimental field composition was 28% clay, 36% silt, and 36% sand. The result demonstrate that the soil pH of experimental site was 5.7, which indicates that it is moderately acidic. According to Marx et al. (1996) classification soil as strongly acidic (below 5.1), moderately acidic (5.2-6.0), slightly acidic (6.1-6.5), neutral (6.6-7.3), moderately alkaline (7.3-8.4), and strongly alkaline (above 8.5) based on the pH content. The normal soil pH for maize production is known to be between 5 and 8 (Martin, 1993), the current pH result of the sites indicate suitability for maize production

The research site had a high level of organic carbon (3.65).According to Tekalign et al. (1991) demonstrated that greater than three percent categorized high level of Soil organic carbon. The OM content rating criteria, Dagne (2016), classify soils as high if they have more than 5.20% rated content so Soils with more than 5.20% organic matter fall into this category. High organic matter content is beneficial for soil fertility, water retention, and overall soil health. As a result, the research area's organic matter level was high (6.39%). According to the research site demonstrated that the research site's was high (0.31%) level of total nitrogen content. The authors Tekalign et al. (1991) further categorized soil total nitrogen availability high the categories (>0.25%).

According to Landon and Manual (1991), top soil having a CEC greater than 40 meq/100g of soil is rated as very high. Thus, the soil of the site had a very high (44 meq/100g soil) CEC. This shows that the soil has the capacity to hold nutrient cations and supply to the crop.

Table 2. Physiochemical properties of soil of the experimental site before sowing

| Soil properties | Results | Rating | Reference |
|---|---|---|---|
| Soil particle size | | | |
| Clay (%) | 28 | | |
| Silt (%) | 36 | | |
| Sand (%) | 36 | | |
| Textural class | Clay loam | | |
| Soil pH (1:2 H2O) | 5.8 | Moderately acidic | Marx *et al*., (1996) |
| Organic carbon (%) | 3.65 | High | Tekalign *et al.*, (1991) |
| Organic matter (%) | 6.29 | High | Dagne, (2016) |
| Total Nitrogen (%) | 0.31 | High | Tekalign *et al.*, (1991) |
| CEC (meq/100g soil) | 44 | Very high | Landon (1991) |

## 4.2. Phenological Parameter

### 4.2.1. Day to 50 % Emergence (DE)

The analysis of variance showed that days to 50% emergence (DE) was significantly ($p<0.01$) affected by planting date and variety; however, variety by planting date interaction had no effect on DE ($p>0.05$) (Appendix Table 1).

The longest days (9.08 days) to emergence was observed from variety BH661 and Shone and was statistically at par with Limu (9.0 days) variety. However, the earliest days to emergence was observed by BH-540 variety (7.33 day) (Table 3). Such observed variations in days to emergence might be the genetic variations existing among maize varieties included in this study. In agreement, Balemi *et al*. (2020) also reported variation between maize varieties on days to emergence. Another study by Liaqat *et al.* (2018) also indicated that seed sizes, rate of water diffusion in seeds, activation of enzymes with in seeds and seed vigor of varieties have different genetic makeup, which creates variation in emergence duration of different varieties (Balemi *et al*., 2020).

The longest days to emergence recorded when maize was planted on April 29 (9.5 days), which was statistically similar to planting on May 9 (9.08 days) (see Table 3). Conversely, the shortest emergence period (7.8 days) was observed when planting occurred on April 9 and April 19, with a significant difference noted among these results. These variations may be attributed to differences in environmental conditions such as light, moisture, and temperature during the growing season. Likewise, Balemi *et al*. (2020) reported that seed germination and seedling emergence were delayed if soil temperatures are low and these findings support our observation in the current study.

Table 3. Main effects of varieties and planting date on day to 50% emergence of maize

| Treatments<br>Varieties | Days to emergence |
|---|---|
| BH-540 | 7.08[b] |
| BH-661 | 9.08a |
| Shone | 9.08[a] |
| Lemu | 9.0[a] |
| LSD (5%) | 0.84 |
| Planting date | |
| 9-Apr | 7.8b |
| 19-Apr | 7.8[b] |
| 29-Apr | 9.5[a] |
| 9-May | 9.08[a] |
| LSD (5%) | 0.84 |
| CV (%) | 15.62 |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

#### 4.2.2. Days to 50% Anthesis (DA)

The analysis of variance indicated a significant effect of planting date on DA ($P<0.01$). However, neither the variety nor the interaction between variety and planting date had a significant effect on the same parameter ($P > 0.05$) (Appendix Table 1).

Table 4 displays the impact of planting date on days to anthesis (DA). It reveals that the shortest DA (91.50 days) occurred in plots planted on April 9, which was statistically comparable to plots planted on April 19. Conversely, the longest DA was observed in plots planted on May 9 (98.67 days), with planting on April 29 resulting in the next longest duration.

Table 4. Effects of planting date on days to 50 % anthesis

| Planting date | Days to anthesis |
|---|---|
| 9-Apr | 91.58[c] |
| 19-Apr | 91.50[c] |
| 29-Apr | 96.08[b] |
| 9-May | 98.67[a] |
| LSD (5%) | 2.34 |
| CV (%) | 3.04 |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

The longest duration to anthesis (98.6 days) was observed in plots planted on May 9, while the shortest duration (91.5 days) was statistically comparable to plots planted on April 9.

Temperature fluctuations in the study area may have contributed to the variation in days to anthesis. Liaqat et al. (2018) suggested that late sowing can lead to a decrease in days to silking due to subsequent changes in climate during the growing season. Conversely, early planting may result in more days to tasseling and silking because the length of days decreases, promoting crop maturity and initiating the reproductive phase of development.

#### 4.2.3. Day to 50% Silking (DS)

The analysis of variance indicated a significant effect of planting date on DS (P<0.01). However, neither the variety nor the interaction between variety and planting date had a significant effect on the same parameter (P > 0.05) (Appendix Table 1).

Table 5. Effects of planting date on days to 50 % silking of maize

| Planting Date | Days to silking |
|---|---|
| 9-Apr | 100.17[c] |
| 19-Apr | 99.67[c] |
| 29-Apr | 103[b] |
| 9-May | 107.83[a] |
| LSD (5%) | 2.81 |
| CV (%) | 3.2 |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

The longest duration to reach 50% silking (107.83 days) was observed in plots planted on May 9, followed by those planted on April 29. In contrast, the shortest duration to anthesis (99.67 days) was observed in plots planted early on April 19, which was statistically comparable to plots planted on April 9 (100.17 days). According to weather data condition of metrological station of Expermtal field temperature decrease April to Augest but rain fall distribution was increase April to Augest at end of maturity decrease. Thus, early planting optimum weather conditions but late planting date temperature and rainfall variations during the growing season in the study area may have also contributed to the differences in days to silking. According to Delano and Modi. (2017) noted that maize planted lately to flower earlier because of deficit in accumulated heat units as compared to plants from early and mid-planting dates. The accumulated heat units for tasseling and silking were higher under warm temperature and sufficient availability water for plant uses (early and mid-planting) while it was shortened in late planting. Conversely, early planting required more days to reach tasseling and silking due to decreasing day length, which promoted crop maturity and initiated the reproductive phase of development.

### 4.2.4. Days to Anthesis Silking Interval (ASI)

The analysis of variance showed that the interaction between varieties and planting dates, as well as the main effect of planting date, significantly influenced ASI (P<0.01). However, the main effect of varieties did not have a significant impact on maize (P>0.05) (Appendix Table 1).

Table 6.Interaction effects of varieties and planting date on days to anthesis silking interval of maize

| Planting date | Varieties | | | |
|---|---|---|---|---|
| | BH-540 | BH-661 | SHONE | LIMU |
| 9-Apr | 8.00[bc] | 9.33[b] | 8.67[b] | 8.33[bc] |
| 19-Apr | 8.33[bc] | 8.67[b] | 8.33[bc] | 7.33[bcd] |
| 29-Apr | 5.67[cd] | 6.33[bc] | 9.33[b] | 6.33[bc] |
| 9-May | 11.33[a] | 6.00[cd] | 7.67[ab] | 11.67[a] |
| CV (%) | 18.34 | | | |
| LSD (5%) | 1.26 | | | |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

The BH-540 hybrid planted on April 29 exhibited the shortest ASI (5.67 days) statically similar with hybrid BH-661(6.00days) with planting date on May 9 (Table 6), conversely, the longest ASI (11.67 days) was observed from Limu and Bh540 varieties planted on May 9.Acording to the study this variation due to weather condition of the growing season. A study by Lizaso *et al*. (2019) noted lack of water and poor nutrition during critical periods can affect grain yield variability, including the ASI .The shortest ASI in maize indicates a high degree of synchrony between male and female flowering, with pollen shed and silk emergence occurring simultaneously or in close succession. A shorter ASI is desirable in maize cultivation as it maximizes the efficiency of pollination, reducing the risk of incomplete kernel development and yield loss due to poor pollination. The highest anthesis silking interval suggests less synchrony between male and female flowering, whereas a shorter ASI indicates greater synchrony between female and male flowering. Kamara *et al*. (2006) reported that the anthesis silking interval was shorter among hybrids, with less emphasis on the planting date, particularly in modern maize varieties.

### 4.2.5. Days to physiological maturity

The analysis of variance revealed that the days to physiological maturity were significantly affected by the main effects of varieties and planting date ($p<0.01$). However, the interaction effect of varieties with planting date did not show a significant influence on the days to physiological maturity ($p>0.05$) (Appendix Table 1).

The variety Limu exhibited the longest time to reach physiological maturity, at 170 days, whereas the shortest duration (135.92 days) was recorded for variety BH-540 (Table 7). The significant differences among the varieties for physiological maturity may be attributed to their genetic variations. Shrestha *et al*. (2018) noted that longer-maturing maize varieties tend to be more sensitive to late planting dates compared to early-maturing hybrids. The variation in the days to attain physiological maturity among the maize varieties observed in this study could also be attributed to inherent genetic factors, as suggested by Bawa *et al*. (2021). These genetic factors may include differences in maturity length, growth rate, and developmental pathways among the maize varieties. Breeders often select and develop varieties with specific maturity characteristics to suit different growing conditions and market preferences. Genetic diversity plays a crucial role in determining the adaptability and performance of maize varieties across various environments and management practices. Planting dates had a significant impact on the days to maturity of maize varieties (Table 7).

The longest period to reach physiological maturity (161.75 days) was observed with the early planting date of April 9, while the shortest period (146.92 days) was recorded with the late planting date of May 9. These findings suggest that early planting resulted in delayed maturity compared to late planting, likely due to the availability of moisture and optimal planting conditions associated with the later dates. Our findings are consistent with those of Balemi et al. (2020), who observed that the days to reach various phonological stages decreased with late sowing, aligning with our observations of decreased days to maturity under lower temperatures as planting progressed. This strategy allows the crop to avoid potential moisture limitations toward the end of the season, which are often associated with late planting. These results emphasize the influence of temperature and planting timing on the maturity of maize varieties and highlight the importance of considering environmental factors in crop management strategies.

Table 7. Main effects of varieties and planting date on days to physiological maturity of maize

| Varieties | Days to physiological maturity |
|---|---|
| BH-540 | 135.92[c] |
| BH-661 | 153[b] |
| SHONE | 156.92[b] |
| LIMU | 170[a] |
| CV | 3.10 |
| LSD (5%) | 3.97 |
| Planting date | |
| 9-Apr | 161.75[a] |
| 19-Apr | 156.50[b] |
| 29-Apr | 150.67[c] |
| 9-May | 146.92[c] |
| CV | 3.10 |
| LSD (5%) | 3.97 |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

## 4.3. Growth parameter

### 4.3.1. Plant height (PH)

The analysis of variance indicated that both the main effects of varieties and planting date, as well as interaction effect, varieties by planting date was significantly influenced plant height (PH) of maize ($p<0.01$) (Appendix Table 2).

In the current study, maize variety Shone displayed the tallest plant height (238.97 cm) when planted on April 19, which was statistically comparable to the planting dates of April 9 for BH-661 hybrids. Conversely, the shortest plant height was observed in hybrid BH540 (153.30 cm) when planted on May 9, which was statistically similar to the plant heights of BH540 planted on April 29 and Shone planted on May 9, (Table 8). According to Djaman et al. (2022) also reported that, significant effect of planting dates on the plant height of maize varieties. This suggests that the timing of planting plays a crucial role in determining the ultimate height of maize plants, with variations observed depending on the specific planting dates used. Shrestha et al. (2018) stated that, late planting of crop decreased its growth and development because less amount of solar radiation was captured by crop during emergence to silking.

Table 8.Interaction effects of varieties and planting date on plant height of maize

| Planting date | Varieties | | | |
|---|---|---|---|---|
| | BH-540 | BH-661 | SHONE | LIMU |
| 9-Apr | 210.53[bc] | 236.37[a] | 212.70[bc] | 225.43[ab] |
| 19-Apr | 218.87[abc] | 231.37[ab] | 238.97[a] | 198.30[cd] |
| 29-Apr | 153.67[f] | 198.9[c] | 164.83[ef] | 168.83[ef] |
| 9-May | 153.30[f] | 170.73[ef] | 153.33[f] | 177.67[de] |
| CV | 6.47 | | | |
| LSD (5%) | 20.99 | | | |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

### 4.3.2. Ear height (EH) (cm)

The analysis of variance revealed that ear height was significantly influenced by the main effects of varieties and planting date ($p<0.01$), while the interaction effect of varieties by planting date did not show a significant influence (Appendix Table 2).

The highest EH (101.45 cm) was observed for variety BH-661, while the lowest ear height (84.78 cm) was recorded for variety BH540, while statistically similar with varieties Limu and Shone (Table 9). The significant differences among the varieties for EH might be attributed to their genetic baground of the varieties as each variety possesses distinct morphological traits and growth characteristics. Variations in maize hybrids for growth parameters recorded in the current study is in agreement with previous studies on maize hybrids in their study (Tesfaye Balemi et al., 2020). Similarly, existence of hybrids variability to maturity and growth characters have also been reported (Dagne Wegary et al., 2014)

The study revealed that early planting on April 9 resulted in the longest ear height (84.93 cm), which was statistically comparable to planting on April 19 (84.48 cm). Conversely, the shortest ear height (68.6 cm) was recorded for planting on May 9, which was statistically similar to planting on April 29 (74.47 cm) (Table 9). Late planting dates were associated with shorter ear heights, possibly due to adverse weather conditions, increased pest and disease pressure, and reduced solar radiation during the growing season. Shrestha *et al*. (2018) observed that late planting decreased maize growth and development due to reduced solar radiation capture. Compared to late-planted crops, early-planted crops have more days for vegetative development because they proceed into the reproductive stage when temperatures lower and the vegetative phase is shorter (Liaqat *et al.*, 2018). Overall, early planting generally promotes taller ear heights in maize due to a longer growing season, optimal environmental conditions, reduced resource competition, and genetic factors. Late planting, on the other hand, often results in shorter ear heights due to a shortened growing season, less favorable environmental conditions, increased resource competition and potential genetic differences in variety response.

Table 9. Main effects of varieties and planting date on ear height of maize

| Varieties | Ear height |
|---|---|
| BH-540 | 84.78[b] |
| BH-661 | 101.45[a] |
| SHONE | 85.29[b] |
| LIMU | 86.14[b] |
| CV | 13.13 |
| LSD (5%) | 9.79 |
| Planting date | |
| 9-Apr | 84.93[a] |
| 19-Apr | 84.48 [a] |
| 29-Apr | 74.47[b] |
| 9-May | 68.6 [b] |
| CV | 13.13 |
| LSD (5%) | 9.24 |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

## 4.4. Yield and yield parameter

### 4.4.1. Number of ears per plant (EPP)

The analysis of variance revealed a significant interaction effect ($p\leq 0.05$) between variety and planting date, as well as a significant ($p\leq 0.01$) effect of planting date on the number of ears per plant. However, variety did not affect number of ears per plant significantly ($P > 0.05$) (Appendix Table 3).Different maize varieties may have varying responses to planting dates in terms of ear production. Some varieties may exhibit consistent ear production regardless of planting date, while others may show a stronger association between planting date and ear number.

Early planting on April 9 resulted in the highest number of ears per plant (EPP) for both Shone and Limu hybrids, with a value of 1.4. Conversely, the lowest EPP was recorded for BH540 planted on April 9, as well as for all varieties planted on April 29 and May 9 (Table

10). These results suggest that early planting generally promotes higher ear production per plant, while late planting dates are associated with lower EPP regardless of variety differences. Early planting generally promotes higher EPP in maize due to a longer growing season, more favorable environmental conditions, and potentially less competition among plants. Late planting, on the other hand, tends to result in lower EPP due to a shortened growing season and less favorable growing conditions. However, the specific response may vary depending on the maize variety and environmental factors present during the growing season.

Table 10. Interaction effects of varieties and planting date on number ear of per plant of maize

| Planting date | Varieties | | | |
|---|---|---|---|---|
| | BH-540 | BH-661 | SHONE | LIMU |
| 9-Apr | 1.00[d] | 1.27[bc] | 1.40 [a] | 1.40 [a] |
| 19-Apr | 1.20 [cd] | 1.33[ab] | 1.33[ab] | 1.00 [d] |
| 29-Apr | 1.00 [d] | 1.00 [d] | 1.00[d] | 1.00 [d] |
| 9-May | 1.00 [d] | 1.00 [d] | 1.00 [d] | 1.00[d] |
| CV | 12.81 | | | |
| LSD (5%) | 0.12 | | | |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance*

### 4.4.2. Number of rows per ear (RPE)

The ANOVA results indicated that planting date, variety, and their interaction had a significant effect on the number of rows per ear (RPE) (refer to Appendix Table 3).

The highest RPE (16.40) was recorded for Shone varieties planted on April 9 and April 19, respectively. Conversely, the Shone variety exhibited the lowest RPE (11.47) with later dates. In agreement with these findings, Shrestha *et al*. (2018) also reported the effect of planting time on RPE of maize varieties. They observed that late planting reduced RPE in varieties. Rows per ear were higher in early sowing, which could be due to better plant growth and healthy reproductive parts. The difference in rows per ear of varieties could be due to their hybrid status as well as the variety's performance in environment Lashkari *et al*. (2011). Healthy grains were produced by early sowings, which may be due to maximum days to complete grain size and weight in early sowing. Seed filling duration was also greater in early sown for assimilate storage (Giunta *et al*., 2009; Shah et al., 2012). Farmers can adjust their planting schedules to minimize the impact of such factors on RPE development and overall crop productivity.

Table11. Interaction effects of varieties and planting date on number of row per ear (RPE) of maize

| Planting date | Varieties | | | |
|---|---|---|---|---|
| | BH-540 | BH-661 | SHONE | LIMU |
| 9-Apr | 12.80[def] | 13.47[de] | 16.40 [a] | 15.47[ab] |
| 19-Apr | 13.20[def] | 13.47[de] | 16.40 [a] | 13.60[cde] |
| 29-Apr | 12.40[def] | 13.07[def] | 15.33[abc] | 14.13[bcd] |
| 9-May | 12.07[ef] | 12.40[def] | 11.47 [f] | 13.47[de] |
| CV (%) | 7.85 | | | |
| LSD (5%) | 1.78 | | | |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

### 4.4.3. Number of kernels per row (KPR)

The analysis of variance revealed that both the main effects of varieties and planting date had a highly significant (P≤ 0.01) impact on the KPR of maize. However, the interaction effect of planting date and varieties was not significant (P>0.05) in influencing the KPR (Appendix Table 2).

The highest number of row per ear was observed in the Limu variety (33.49), which was not significantly different from the number of row per ear of BH661 (30.52). Conversely, the least number of kernel rows per ear (26.38) was recorded for the BH540 variety, which was statistically comparable to the Shone variety (26.7). This variability in number of row per ear among maize varieties is consistent with earlier studies, as observed by Mekuannet Belay (2020). These differences in number of row per ear among varieties can be attributed to variations in ear length, rows per ear, grains per row, and grain size, as noted by Ali *et al*. (2015). The difference in the number of kernels per row number of row per ear among maize varieties reflects varietal characteristics and genetic traits influencing grain development. Some varieties may naturally produce more kernels per row than others due to genetic factors such as ear size, kernel arrangement, and grain filling capacity.

The highest number of kernels per row (35.56) was recorded for maize planted on April 9, while the lowest number of kernels per row (20.1) was observed for maize planted on May 9 (Table 12). This trend suggests that early planting dates tend to result in higher kernels per row compared to later planting dates. The number of grains per ear was also higher in early-sown maize, gradually decreasing as planting was delayed. According to Ali *et al.*, (2015) noted that early-sown crops benefitted from optimum conditions for a longer duration, allowing for maximum fertilization and grain formation. This likely contributed to the production of healthier grains, with early-sown crops having more time to complete grain size and weight development. Furthermore, early-sown maize experienced a longer seed filling duration, allowing for greater assimilate storage. This supports the notion that early planting provides maize plants with more time to accumulate resources and complete key developmental processes. Shrestha *et al*. (2018) similarly found that delaying planting dates adversely affected the number of kernels per cob and flower distribution, as well as significantly influencing kernel number per row and ovule number per row. This highlights the importance of planting timing in maximizing kernel development and overall maize yield.

Overall, early planting dates generally favor higher KPR in maize due to a longer growing season, more favorable environmental conditions, and potentially reduced competition among plants. Late planting dates may result in lower KPR due to a shortened growing season and less favorable growing conditions (Liaqat *et al.,* 2018). However, the specific response of KPR to planting dates may vary depending on the maize variety and weather conditions present during the growing season.

Table12. Main effects of varieties and planting date on number of kernel per row of maize

| Varieties | Kernel per row |
|---|---|
| BH-540 | 26.38[b] |
| BH-661 | 30.52[a] |
| SHONE | 26.7[b] |
| LIMU | 33.49[a] |
| CV (%) | 14.3[6] |
| LSD (5%) | 3.5 |
| Planting date | |
| 9-Apr | 35.56 [a] |
| 19-Apr | 31.72[b] |
| 29-Apr | 29.72 [b] |
| 9-May | 20.1 [c] |
| CV (%) | 14.36 |
| LSD (5%) | 3.5 |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

#### 4.4.4. Ear length (EL) (cm)

The analysis of variance revealed that ear length (EL) was significantly influenced by the main effects of planting dates and varieties ($p \leq 0.01$). However, the interaction effect between planting dates and varieties did not have a significant effect on ear length (refer to Appendix Table 2).

Maize hybrid Limu recorded the longest EL (16.63 cm), which was comparable to that of Shone (16.6 cm). In contrast, BH540 and BH661 resulted in significantly shorter EL compared to the pioneer hybrids (Limu and Shone) (see Table 13).The presence of genetic variations among the hybrids likely contributes to the observed differences in ear length. Variability in EL among maize hybrids has been reported in Ethiopia for varieties adapted to both mid-altitude and low-land environments (Tasisa Temesgen and Teshome Kebena, 2019; Mekuannet Belay, 2020).

The longest ear length (17.74 cm) was observed in plots planted on April 9 and was statistically comparable to those planted on April 19 while the shortest ear length recorded for the late planting date of May 9(see Table 13). However, there was a significant difference in ear length between early and late planting dates. This suggests a decrease in ear length associated with late planting dates. This finding aligns with the observation made by Maryam *et al*. (2011), who also reported a reduction in cob length with late planting of maize varieties. Differences in cob length among varieties may be attributed to their inherent genetic characteristics, leaf area, and growth potential, as noted by Buriro et al. (2015).

Table 13**.** Main effects of varieties and planting date on ear length of maize

| Varieties | Ear length |
|---|---|
| BH-540 | 15.01[b] |
| BH-661 | 14.92[b] |
| SHONE | 16.6 [a] |
| LIMU | 16.63 [a] |
| CV (%) | 10.83 |
| LSD (5%) | 1.43 |
| Planting date | |
| 9-Apr | 17.74 [a] |
| 19-Apr | 16.63[a] |
| 29-Apr | 15.13 [b] |
| 9-May | 13.67 [c] |
| CV (%) | 10.83 |
| LSD (5%) | 1.43 |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

### 4.4.5. Ear diameter (ED) (cm)

The ANOVA revealed that ear diameter was significantly influenced by varieties ($p<0.05$) and highly significantly influenced by planting date ($p<0.01$). However, the interaction effect between varieties and planting date did not have a significant impact on ear diameter (Appendix Table 2).

Ear diameter varied among the maize varieties, ranging from 14.92 cm for BH661 to 16.63 cm for Limu. The widest ear diameter (16.63 cm) was observed for Limu, which was statistically comparable to Shone varieties. Conversely, the narrowest ear diameter (14.92 cm) was recorded for BH661, which was statistically comparable to BH540 (Table 14). These differences in ear diameter suggest the presence of genetic variation among the maize varieties. This finding aligns with previous studies by Tasisa Temesgen (2019), who reported significant differences among maize varieties for both ear length and diameter, highlighting the influence of growth factors and genetic variation on ear morphology.

Table 14 .Main effects of varieties and planting date on ear diameter of maize

| Varieties | Ear diameter |
|---|---|
| BH-540 | 15.01[b] |
| BH-661 | 14.92 [b] |
| SHONE | 16.60 [a] |
| LIMU | 16.63 [a] |
| CV (%) | 10.39 |
| LSD (5%) | 1.43 |
| Planting date | |
| 9-Apr | 17.74 [a] |
| 19-Apr | 16.63 [a] |
| 29-Apr | 15.13 [b] |
| 9-May | 13.67 [c] |
| CV (%) | 10.39 |
| LSD (5%) | 1.43 |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

The widest ear diameter (17.74 cm) was recorded for April 9 planting, which was statistically comparable to the April 19 planting. Conversely, the narrowest ear diameter (13.67 cm) was observed for the May 9 planting. These findings indicate that planting date also plays a significant role in influencing ear diameter, with earlier planting generally resulting in wider ear diameters compared to later planting dates. These observations are supported by previous research conducted by Mousavi et al. (2020) and Andayani et al.

(2020), which also reported significant effects of environmental factors on ear diameter and other ear characteristics in maize.

### 4.4.6. Thousand kernel weight (TKW)

The analysis of variance revealed that both the main effects of varieties and planting date and interaction effect of planting date by variety had a significant effect ($P \leq 0.01$) on thousand kernel weight (Appendix Table 3).

Thousand kernel weight (TKW) ranged from 410 grams to 253.33 grams across different varieties and planting dates. The highest TKW was observed for the Limu variety planted on April 9, while the lowest TKW was recorded for the Shone variety planted on May 9 (Table 15). The decrease in TKW observed with late planting dates may be attributed to weather condition and other growth-related factors that affect final kernel weight. According to Ethiopia metrological data of the study area the amount of rain fall was high during grain filling stage. Ali et al. (2015) reported significant differences among maize varieties on thousand kernel weights with the interaction between maize varieties and planting dates. They noted that delayed sowing of maize resulted in decreased grain number and thousand kernel weight. This suggests that planting date plays a crucial role in determining TKW, with earlier planting result in higher TKW compared to later planting dates. Generally, the interaction between maize varieties and planting dates plays a crucial role in determining TKW, with genetic factors, environmental conditions, and management practices were contributing to the variations in TKW. Understanding these interactions is essential for optimizing maize production strategies and maximizing grain yield and quality (Liaqat *et al.*, 2018).

Table 15. Interaction effects of varieties and planting date on Thousand Kernel weight (TKW) of maize

| Planting date | | Varieties | | |
|---|---|---|---|---|
| | BH-540 | BH-661 | SHONE | LIMU |
| 9-Apr | $370.00^{ab}$ | $256.67^{g}$ | $383.33^{ab}$ | $410.00^{a}$ |
| 19-Apr | $323.33^{cdef}$ | $303.33^{efg}$ | $340.00^{bcdef}$ | $360.00^{abc}$ |
| 29-Apr | $316.67^{edf}$ | $293.33^{gf}$ | $353.33^{bcde}$ | $290.00^{gf}$ |
| 9-May | $323.33^{cdef}$ | $300.00^{gf}$ | $253.33^{g}$ | $263.33^{g}$ |
| CV (%) | 9.46 | | | |
| LSD (5%) | 50.65 | | | |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

### 4.4.7. Above-ground dry biomass yield (t $ha^{-1}$)

Aboveground biomass was highly significantly ($p \leq 0.01$) affected by planting date, variety and their interaction (Appendix Table 4).

The results of the study indicate that Variety Limu, planted on April 9, exhibited the highest above-ground dry biomass (13.93 kg $ha^{-1}$). This was statistically comparable to the performance of Variety BH661, also planted on the same date, which achieved a biomass score of 13.41 kg $ha^{-1}$. Conversely, the lowest above-ground dry biomass score was recorded for Variety BH540, planted on the last date of planting, at 5.33 kg $ha^{-1}$ (Table 16). Overall, the findings suggest that early planting, irrespective of variety, tended to result in higher above ground biomass while late planting led to reduce above ground biomass. This trend is likely influenced by several factors, including environmental conditions, growth duration, and stress factors experienced by the maize plants during their development. Early planting allows for a longer growing season and optimal conditions for grain filling, contributing to higher above ground biomass. Conversely, late planting may expose the plants to stressors such as water and nutrient limitations, leading to reduce above ground biomass. In agreement with this, Ke *et al*. (2021) resulted in significant effect of planting date and variety on above ground biomass of maize.

Table 16. Interaction effects of varieties and planting date on above ground dry biomass (AGDB) of maize

| Varieties<br>Planting date | BH-540 | BH-661 | SHONE | LIMU |
|---|---|---|---|---|
| 9-Apr | $12.16^{bcd}$ | $13.41^{ab}$ | $12.61^{ab}$ | $13.93^{a}$ |
| 19-Apr | $11.35^{cd}$ | $12.42^{abc}$ | $12.10^{bcd}$ | $12.27^{bc}$ |
| 29-Apr | $7.07^{f}$ | $9.37^{e}$ | $11.25^{cd}$ | $10.63^{de}$ |
| 9-May | $5.33^{g}$ | $9.28^{e}$ | $7.04^{f}$ | $9.39^{e}$ |
| CV (%) | 8.66 | | | |
| LSD (5%) | 1.53 | | | |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

The study consistently found that early planting dates tended to increase biomass production for most maize types. However, adverse weather conditions, pest and disease infestations had a significant negative impact on plant height, the number of kernels per plant, the number of ears per plant, ear length, and overall vegetative growth of the crop. These factors contributed to lower above-ground dry biomass across late planting dates.

The decrease in above-ground dry biomass observed in varieties planted during late dates aligns with findings from Ali *et al*. (2015), who also noted a reduction in aboveground biomass across various maturity groups of maize varieties when planting was delayed from early to late dates. This suggests that while early planting dates generally favor higher biomass production, late planting dates can lead to decreased biomass due to a combination of environmental stressors and reduced growth duration. Understanding these dynamics is crucial for optimizing planting strategies and mitigating the impact of adverse conditions on maize production.

According to Tsimba *et al*. (2013), observed that a decrease in biomass with later planting dates, particularly in maize varieties with longer maturity period. When taken as a whole, these studies demonstrate the intricate relationships that exist between environmental conditions, planting dates, and the growth and development of maize. This emphasizes the significance of timely planting and management techniques for maximizing output and reducing yield losses

#### 4.4.8. Grain yield (t $ha^{-1}$)

The analysis of variance revealed that both the main effects of planting dates and variety as well as the interaction effects had significant ($p \leq 0.01$) effect on grain yield of (Appendix Table 4).

Table 17. Interaction effects of varieties and planting date on grain yield of maize

| Planting date | Varieties | | | |
|---|---|---|---|---|
| | BH-540 | BH-661 | SHONE | LIMU |
| 9-Apr | $4.37^{de}$ | $4.16^{ef}$ | $5.56^{bc}$ | $6.71^{a}$ |
| 19-Apr | $4.20^{ef}$ | $4.88^{cde}$ | $5.25^{bcd}$ | $5.88^{ab}$ |
| 29-Apr | $2.92^{gh}$ | $3.33^{fg}$ | $4.96^{cde}$ | $4.61^{de}$ |
| 9-May | $1.65^{i}$ | $3.08^{g}$ | $2.15^{hi}$ | $3.07^{g}$ |
| CV (%) | 12.86 | | | |
| LSD (5%) | 0.89 | | | |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance*

This indicates that maize variety yield is significantly affected by planting dates. Limu variety planted on April 9 achieved the highest grain yield of 6.71 t $ha^{-1}$, which was statistically comparable to the grain yield of Limu variety planted on April 19 (5.58 t $ha^{-1}$) (refer to Table 17). The results consistently demonstrated an increase in grain yield with earlier planting dates across most maize varieties. This finding is supported by Lizaso *et al*. (2018), who suggested that the reduction in grain yield observed in late plantings could be attributed to poor assimilate partitioning to the grain, resulting in lower kernel weight and kernel number per ear. Early planting, which led to higher yields, may be associated with sufficient moisture during grain filling, as well as favorable temperatures and reduced pest and disease pressure.

In agreement with our findings, Balemi *et al*. (2020) also reported higher grain yields for early planting of maize compared to late planting, emphasizing that delayed planting may expose the plants to terminal drought during the grain-filling stage. They recommended early or at least mid-planting for better maize seed yields and quality, which aligns with our results.

According to Dahmardeh (2012)stated that early planting generally enhances grain yield due to the longer growth period and optimal temperatures during grain formation, the impact of planting date on yield can vary based on the specific environment and varieties involved. Understanding these variations is crucial for optimizing planting strategies and maximizing maize productivity in target regions (Mehdi. 2012)

#### 4.4.9. Harvest index

Harvest index is the ratio of grain yield to total dry biomass and is a measure of physiological efficiency and ability of crop for converting the total dry matter into economic yield. The results of the experiment indicate that the harvest index (HI) was significantly ($\leq 0.01$) influenced by both varieties and planting date. However, there was no significant interaction effect between varieties and planting date on HI (Appendix Table 4). This suggests that the individual effects of varieties and planting date play key roles in determining the harvest index, but there is no significant combined effect of these factors on this parameter.

The highest harvest index (43.24%) was recorded from the Limu variety and it was statically par with varieties shone (40.48%). Conversely, the lowest harvest index (34.83 %) was obtained from variety BH661and was statically par with variety BH540 (36.09%) (Table 18).  These variations in HI among maize varieties suggest genetic differences influencing this trait. In line with Kebede *et al*., (2020) demonstrated variations in maize varieties for HI. Each variety possesses unique genetic traits that influence various agronomic characteristics, including HI. Traits such as plant architecture, growth habit, reproductive efficiency, and allocation of resources to grain production can differ between varieties, leading to variations in harvest index. Environmental factors, such as temperature, moisture availability, and soil fertility, can also interact with genetic differences to influence harvest index.

The highest harvest index (HI) of 42.02 was observed for the planting date on April 19, which was statistically comparable to both April 29 and April 9 planting dates. Conversely, the lowest HI of 31.73 was recorded for the May 9 planting date, likely due to environmental factors. Late planting of maize significantly impacts both vegetative growth and the grain-filling phase. In agreement, Baum et al. (2019) noted a decrease in harvest index associated with late planting, attributed to reduce grain filling. Early planting promotes healthier plants with higher grain yield per plant. Late planting results in decreased grain weight and biomass, affecting the varieties' harvest index, which reflects their ability to convert dry matter into grains (Liaqat et al., 2018). Studies by Tsimba et al. (2013) found that late planting disproportionately affects grain formation, leading to a decrease in harvest index compared to total biomass production.

Table 18. Main effects of varieties and planting date on harvest index (HI) of maize

| Varieties | Harvest index |
|---|---|
| BH-540 | 36.09$^{bc}$ |
| BH-661 | 34.83 $^{b}$ |
| SHONE | 40.48$^{ab}$ |
| LIMU | 43.24$^{a}$ |
| CV (%) | 13.98 |
| LSD (5%) | 4.43 |
| Planting date | |
| 9-Apr | 39.95 $^{a}$ |
| 19-Apr | 42.02$^{a}$ |
| 29-Apr | 40.94$^{a}$ |
| 9-May | 31.73$^{b}$ |
| CV (%) | 13.73 |
| LSD (5%) | 4.43 |

*LSD (0.05) = Least significant difference at 5% level; CV (%) =Coefficient of variation. Means in the columns followed by the same letter are not significantly different at 5% level of significance.*

# 5. CONCLUSION AND RECOMENDATION

The interaction between the planting date and the variety of maize is essential to its production. A yield reduction can be seen when maize is planted before or after the optimal planting window. Almost majority of parameters were significantly and highly significantly influenced by the interaction of both factors. Days to anthesis silking interval, and number of row per ear, plant height, thousand kernel weight, above ground dry biomass and grain yield were highly significantly ($p<0.01$) affected due to the interaction of both factors while, number of ear per plant, significantly ($p<5\%$) affected by the interaction of both factors but, days to emergence, days to anthesis, days to silking days to physiological maturity, ear length, ear diameter, and harvest index was not significantly affected by the interaction of varieties and planting date.

The experiment's findings demonstrated that planting dates and varieties had a significant impact on all parameter examined in the maize test; however, varieties had no effect on the number of days to emergency, anthesis, and silking. Consequently, their interaction affected the lemu variety with a planting date of April 09, which had the longest days to anthesis silking interval (11.67), highest number of ears per plant (1.40), thousand kernel weight (410), above-ground dry biomass (13.93 kg $ha^{-1}$), and grain yield (6.71t $ha^{-1}$). However, the anthesis silking interval (11.67) determined using May 9 as the planting date. The highest days to maturity (170), ear length (16.63cm), ear diameter (16.08 cm), and harvest index (43.92) was recorded verities Limu. Conversely, the planting date of April 09 yielded the highest days to maturity (161.75), number of kernels per row (35.56 cm), ear height (84.93 cm), ear length (17.61cm), ear diameter (17.74 cm), and harvest index (42.02). Likewise, the planting date of May 09 the longest days to emergence (9.5), longest days to anthesis (98.67), and longest days to silking (107.83). Variety BH661 has the highest ear height (101.45), longest days to emergence (9.08), longest days to anthesis (95.58), and longest days to silking (103.17). Conversely, the longest days to emergence (9.08), the highest plant height (238.97), and the highest number of rows per ear (16.40) recorded from variety shone. The study findings indicate that planting date significantly influenced various growth and yield parameters in maize varieties. Early planting on April 9th resulted in the tallest plant height across all hybrids, while late planting on May 9th led to the shortest plant height. Additionally, early planting dates of April 9th and April 19th produced maize with the longest ear length and diameter compared to later planting dates.

Furthermore, the first two planting dates yielded the highest dry biomass, indicating better overall vegetative growth. Harvest index was highest in Limu and Shone hybrids, with April 9th, April 19th, and April 29th planting dates resulting in the maximum harvest index. Therefore April 9th planting yielded the highest grain yield of 6.7 t $ha^{-1}$ in the Limu variety, while May 9th planting resulted in the lowest grain yield of 1.65 t $ha^{-1}$ in the BH540 variety. As a result of their interaction impact, which produced the maximum productivity in the study area, variety Lemu with a planting date of April 09 might therefore be advised for an early planting date based on the study results. However, the results of the present study need to be validated and proven in the same agro-ecologies and seasons with further experiments.

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# 7. APPENDIX

## 7.1. LIST OF TABLES IN THE APPENDIX

Appendix Table 1. Mean squares of analysis of variance for phonological parameter maize affected by varieties and planting date

| Sources of variation | Mean squares | | | | | |
|---|---|---|---|---|---|---|
| | DF | DE | DA | DS | ASI | DPM |
| Replication | 2 | 4.00 | 5.14 | 24.02 | 7.65 | 91.27 |
| Planting date | 3 | 8.85** | 149.47** | 168.22** | 10.92** | 510.36** |
| Variety | 3 | 11.43** | 9.13ns | 4.05ns | 2.14ns | 2370.03** |
| Variety x planting date | 9 | 0.08ns | 8.23ns | 17.98ns | 10.38** | 4.97ns |
| Error | 30 | 1.02 | 8.26 | 11.39 | 2.27 | 22.71 |
| CV (%) | 0 | 11.81 | 3.04 | 3.2 | 18.34 | 3.10 |

*DF= degree of freedom; ns= non-significant; *= significant at 5% level of significance; **= significant at 1% level of significance; DE= days of emergency::DA= Days to 50% anthesis; DS= Days to 50% silking; PH= Plant height DASI= Days to anthesis silking interval and DPM= Days to physiological maturity*

Appendix Table 2. Mean squares of analysis of variance for growth parameter and yield component of maize affected by varieties and planting date

| Sources of variation | Mean squares | | | | | |
|---|---|---|---|---|---|---|
| | DF | PH | EH | EL | ED | KPR |
| Replication | 2 | 331.12 | 56.42 | 3.19 | 3.19 | 3.21 |
| Planting date | 3 | 11750.99** | 4154.45** | 37.83** | 37.83** | 519.27** |
| Variety | 3 | 1346.27** | 776.04** | 10.96** | 10.96* | 137.26** |
| Variety x planting date | 9 | 538.87** | 114.02ns | 1.39ns | 1.39ns | 28.67ns |
| Error | 30 | 158.50 | 137.81 | 2.93 | 4.54 | 17.67 |
| CV (%) | | 6.47 | 13.13 | 10.83 | 10.39 | 14.35 |

*DF= degree of freedom; ns= non-significant; *= significant at 5% level of significance; **= significant at 1% level of significance; PH= Plant height: EH= ear height: EL= ear length: ED =ear diameter: KPR=Number of kernel per row*

Appendix Table 3. Mean squares of analysis of variance for yield components of maize affected by varieties and planting date

| Sources of variation | Mean squares | | | |
|---|---|---|---|---|
| | DF | EPP | RPE | TKW |
| Replication | 2 | 0.01 | 1.16 | 2893.75 |
| Planting date | 3 | 0.24** | 10.94** | 10497.22** |
| Variety | 3 | 0.04ns | 12.77** | 5791.67** |
| Variety x planting date | 9 | 0.05* | 3.17* | 5132.41** |
| Error | 30 | 0.02 | 1.16 | 922.64 |
| CV (%) | | 12.81 | 7.85 | 9.46 |

*DF= degree of freedom; ns= non-significant; *= significant at 5% level of significance; **= significant at 1% level of significance; EPP= Number of ear per plant; RPE= Number of row per ear; TKW= thousand kernel weight*

Appendix Table 4. Mean squares of analysis of variance for yield and yield components of maize affected by varieties and planting date

| Sources of variation | Means squares | | | |
|---|---|---|---|---|
| | DF | AGDB | GY | HI |
| Replication | 2 | 0.92 | 0.13 | 7.33 |
| Planting date | 3 | 68.24** | 18.89** | 264.91** |
| Variety | 3 | 15.35** | 7.23** | 181.98** |
| Variety x planting date | 9 | 2.94** | 0.99** | 39.51ns |
| Error | 30 | 0.84 | 0.29 | 28.27 |
| CV (%) | | 8.66 | 12.86 | 13.73 |

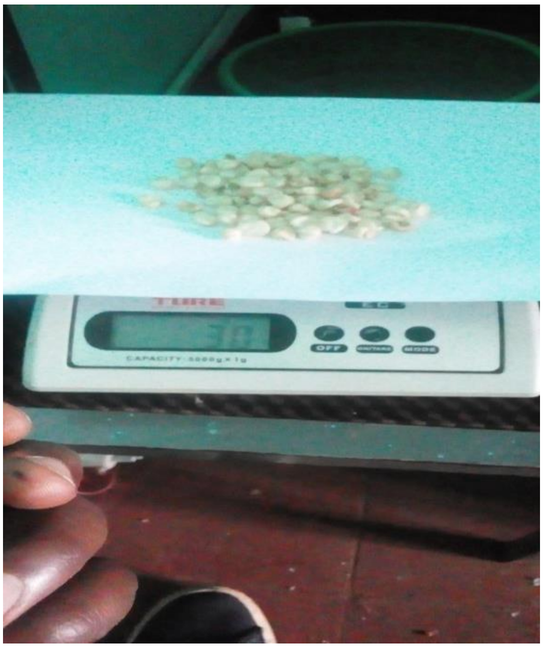
*DF= degree of freedom; ns= non-significant; *= significant at 5% level of significance; **= highly significant at 1% level of significance; AGDBM= above ground dry biomass; GY= grain yield; HI= Harvest index*

Appendix Table 5.Temperature $^{0}$C and rain fall (mm) conditions of experimental site cropping season

| Monthly | April | May | June | July | August | September | October |
|---|---|---|---|---|---|---|---|
| Max T | 26.1 | 24.2 | 23.6 | 20.2 | 21.5 | 21.7 | 24.5 |
| Min T | 11.7 | 11.9 | 11.8 | 12.7 | 12.8 | 12.5 | 10.7 |
| Rain fall | 145 | 162 | 225.5 | 470.5 | 297.5 | 246.5 | 50.5 |

## 7.2. List of Figure in the Appendix

**Appendix Figure 1.Photo in Expermtal Site**




26.1%
GMM mini