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Determination of Optimum Intra-Row Spacing for Maize Varieties (*Zea mays* L.) on its Yield and Yield Components in West Hararghe, Ethiopia

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Abstract

The western part of the Ethiopia is generally well suited for the current maize varieties with the largest adoption, in particular to west hararghe. However, agronomic management practices such as appropriate plant spacing and use of improved varieties are quite important for enhancing maize production. Hence, a field experiment was not conducted before 2023 cropping season at Gumbi bordodde district western hararghe to determine the effects of intra -row spacing on yield and yield components of maize varieties. The experiment consisted of the factorial combinations of two maize varieties ("BH-546",'M-6'' and "M-2") and five intra-row spacing (20, 25, 30, 35 cm and 40cm) with a total of 15 treatments in RCBD with three replications. The results of the study had shown that there were highly significant differences due to the main effects of varieties on days to 50% tasseling, 50% silking, and 90% maturity. There was also highly significant difference due to the main effects of both variety and intra-row spacing on ear length and number of grains per row while, leaf area index was highly significant on the main effect of varieties and significant on main effect of intra-row spacing. Avery highly significant interaction effect of variety and intra-row spacing on above ground dry biomass yield and grain yield and highly significant in hundred grain weight. Generally, higher grain yield and above ground dry biomass were obtained from BH-546 at 25 cm (10325.47kg·ha−1 and 34334.65kg·ha−1) respectively. The highest grain yield (10325.47kg·ha−1) was obtained at 25cm spacing in BH-546 while the lowest grain yield (3735.18 kgha−1) was obtained from 40cm spacing in 1. M2. The result of economic analysis showed that the maximum net benefit (ETB 278988.75 ha-1) was obtained at spacing of 25cm in BH-546. Therefore, based on economic analysis it can be conclude that optimum intra row spacing (25 cm) is promising for BH-546 maize variety production in main season of Gumbi bordodde district and similar agro ecologies. For better confirmation of the result, this one-year experiment needs to be repeated at multi-locations and in different seasons.

Keywords: BH-546; M-6; M-2; Intra-Row Spacing; Plant Density; Yield

Abbreviations: SI: Supplemental Irrigation; FTC: Farmers Training Center; GLM: General Linear Model; LSD: Least Significance Difference.

Introduction

Maize *Zea mays* L. belongs to the family of poaceae Gramineae and originated in Mexico and Central America and possesses 20 somatic chromosomes [1]. It is an annual cereal major staple crop grown in diverse agro-ecological zones, farming systems and vital for the livelihoods of many people [2]. Maize isthe cheapest source of calorie, providing 16.7% of per capita calorie intake nationally [3]. Maize is the most important cereal crop of the world after wheat and rice, growing everywhere in the rain-fed as well as in irrigated areas [4]. It is the first in total production (975,587,619 MT) and productivity (5.5-ton ha^{-1}) in the world and about 6.6 t ha^{-1} in developed countries [5]. Maize has expanded rapidly and transformed production systems in Africa as a popular and widely cultivated food crop since its introduction to the continent around 1500 A.D and arrived in Ethiopia slightly later, around the late 17th century [6]. Within the country, maize is the largest cereal commodity in terms of total production and yield and second in terms of acreage next to teff. Currently maize grows in all parts of the country [7]. It is mainly grown in the four big regions of the country: Oromia, Amara, SNNPR, and Tigray, contribute to almost eighty percent of the maize produced. The western part of the country is generally well suited for the current maize varieties with the largest adoption. Specifically, the agro-ecology spanning Amara, Benishangul Gumuz, Eastern Gambela, Western Oromia, and Western SNNPR are well suited for production intensification, by using current varieties of improved seed, applying proper agronomy practices and increasing accessibility to improved farm implements and equipment [8]. Within the country the national average yield is about 4.09-ton ha^{-1} [9]. While significant gains have been made in maize production over the past decade, there still remains large potential to increase its productivity. Despite its earliest introduction to the country and agro-ecological suitability of the country compared to other African countries, maize productivity in Ethiopia is generally low [10].

According to Kebede D [11], compared to the 1960s, the share of maize cultivated land production and consumption among cereals increased more than double to nearly 30% in the 2000s; however, as compared to the developed countries its productivity is still low. Mismanagement of plant population, poor soil fertility, improper agronomic practices, water logging, drought, wind, disease, soil acidity, pest, lack of improved seed and weed competitions are among the key factors contributing to the present low productivity of maize in Ethiopia.

Maize yield is more affected by variations in plant population density than other members of the grass family due to its inability for tillering to adjust variation in plant stand, monoecious floral organization and the presence of a short flowering period [12,13]. Variations in plant density or spacing promote changes in leaf dimensions, plant height, leaf area, ear size, ear length, number of seeds and seed weight. Narrow and short leaves and small leaf area were promoted by the increase of plant density [14]. For each production system, there is a population that optimizes the use of available resources, allowing the expression of maximum attainable grain yield in that particular environment. There is no single recommendation for all conditions because the ideal plant number per unit area will depend upon several factors such as water availability, soil fertility, and nature of the variety and maturity group [13]. Maize populations above and below the optimum level might waste plant nutrients and often result in lower total grain yields. Yield increases with increase in plant density up to a certain maximum level for a maize genotype grown under a set of particular management conditions Plensicar M, et al. [15,16] suggested that in a dense population most plants remain barren, ear size remains smaller and crops become susceptible to lodging, disease and pest while plant population at sub-optimum level results in lower yield per unit land area. Trenton FS, et al. [16] reported that the maximum biological yield was found at higher planting density.

Iptas, et al. [17] indicated that plant densities had no significant effects on leaf percentage, but stem length increased as plant densities increased [18]. Seed row spacing is an agronomical management strategy used by producers to optimize the husbandry of the soil and plant ecosystem from sowing to harvest with the goal of bolstering the production of crops. Crop spacing influences canopy architecture, which is a distinguishing characteristic that affects the utilization of light, water, and nutrients [19]. Optimum plant density for maximum grain yield per unit area may differ from hybrid to hybrid because of significant interactions between hybrids and densities [20]. Despite the importance of maize and its many uses, there are several factors affecting its productivity, among them, mismanagement of plant density and drought is considered to be the most important factor that can highly affect crop performance and yield. Hence, there is a need to improve crop management practices like intra-row spacing and soil moisture status via supplemental irrigation of maize for getting higher maize yield [21]. Supplemental irrigation aims to overcome the effects of drought periods as soil moisture drops and halts crop growth and development. Different variety of Maize is very sensitive to drought at different growth stages from germination to maturity Cengiz, et al. In the development growth stages of maize drought affect cell division and cell proliferation Cengiz, et al. while in the reproductive stage drought affecting tassel, embryo endosperm development, ear, pollination, fertilization grail filling and resulting the loss of crop yield. While most of sub-Saharan Africa maize production is based on rainfed systems Beyenesh et al. there is a need to find out alternative soil moisture conservation strategies to mitigate drought effects. In these regards mulching, tied ridges, terracing, bunding, supplementary irrigation method is some of the methods with high soil water conservation potential. Supplemental irrigation (SI) is for unlocking rainfed yield potential and water productivity in rainfed areas having perennial water sources in the study area Beyenesh, et al. In Ethiopia, the national spacing recommendation for maize is 30cm x 75cm (44,444 plants/ha).

This spacing has been used, without taking into account the numerous factors such as the existences of soil and climatic differences [22]. In the study area, the production of maize under supplemental irrigation takes on a special significance; because there is high demand for consumption during off/rainy season as long as water is available for irrigation. Due to this reason, farmers produce maize under irrigation with varied intra-row spacing and yet, this awareness is mainly limited to some improved varieties as a result, plant population per hectare varies among farmers due to miss using proper intra-row spacing. Some of the farmers said that the national recommended intra-row spacing is that it does not give higher yield. Moreover, they think as use of higher plant population may result in more yields that was visually observed.

Objectives of the study were: to evaluate the effects of intra-row spacing and varieties on yield and yield components of maize in the study area.

To evaluate the interaction effects of intra-row spacing and varieties on yield and yield components of maize in the study area.

To evaluate the economic return of intra-row spacing on yield of maize in the study area.

Materials and Methods

Description of the Study Area

The experiment was conducted at Hargiti Kebele Farmers Training Center (FTC) in 2022 main cropping season. The experimental site was found in Gumbi Bordode woreda, Western Hararghe, Oromia Regional State, Ethiopia. The site is located 39 km away from Bordode City and 61 km from Chiro Town, capital of West Hararghe Zone. The experimental site was situated at Latitude of $10^{o}038'66``$ N and longitude of $67^{o}42'$E at altitude of 1098 meter above sea level (m.a.s.l). The area receives annual rain fall of 900-1200 mm with mean minimum and maximum temperatures of 11^{o}C and 31^{o}C, respectively. The site has a slope of 1-3% and has sandy loam soil texture Source from Unpublished Gumbi Bordode woreda Agricultural Office, 2022. Maize is one of the major cereal crops grown in the main cropping season and during the rainy season and the major crops grown in the area are maize, sorghum, millet and finger millet Source from Unpublished Gumbi Bordode woreda Agricultural Office, 2022 (Table 1).

Experiment Materials used for the Experiments

Variety	year of release	Altitude (m)	Rainfall (mm)	Maturity (days)	Average Yield(t/ha)	Seed color
M-2	2004	1200-1700	600-800	90-130	5	White
M-6	2008	1000-1750	500-800	90-120	5	White
BH-546	2005	1000-2000	600-1000	90-120	6	White

Source: (EARO, 2005).

Table 1: Description of the three maize varieties named Melkassa 2 (M-2), Melkasa 6Q (M-6) and BH-546 were used for study.

Treatments and Experimental Design

The treatment consists of factorial combination of 4 intra-row spacing (20, 25, 30, 35cm and 40cm) and three varieties of maize Melkassa Two, Melkassa six, BH-546. The recommended inter row spacing of 75cm for maize was used uniformly. The experiments were laid out in randomized complete block design (RCBD) in 5 x 3 factorial arrangements with three replications with lifesaving irrigation (supplementary irrigation). The space between plot and block was 0.5 m and 1 m respectively. The gross plot consists of 5 rows, each 2.25 m long. The net plots were the middle 3 rows; the remaining 2 rows of each plot were used as border rows. Thus, the size of the gross and net plot was 8.44 m^2 (2.25 m x 3.75 m) and 5.06 m^2 (2.25 x2.25 m) respectively. Thus, the plant population corresponding to the 20cm x 75cm, 25cm x 75cm, 30cm x 75cm, and 35cm x 75cm and 40cm x 75cm intra and inter row spacing were 55 plants $plot^{-1}$, 45 plants $plot^{-1}$, 35 plants $plot^{-1}$, 30 plants $plot^{-1}$ and 25 plants per plot respectively.

Field Management Practices

Land Preparation and Sowing: Prior to sowing the land was finely prepare following conventional tillage practices and plough three times by using oxen-driven local plough (maresha). The last ploughing as done for sowing and planting was done on July17, 2022, using the require rate of seeds for each treatment and propose spacings, and seeds will be sow in furrows. To ensure uniform stand and less missing hills, initially two seeds per hill (hole) were sowing. After 13 days of sowing (before plant competition starts) seedlings was thinned to one plant per hole to keep a good stand of seedlings growing up to maturity.

Fertilizer Application: fertilizer levels for different treatments based on the gross plot size and the number of plants per plot was calculating as per the national recommended rate.

Weeding: Hand weeding, hoeing and other crop management practices were applied uniformly to all plots as per the recommendations for maize.

Irrigation Management: lifesaving water for compensation of soil moisture using supplemental irrigation uniformly apply by furrow system for all plot depending on the pattern of rain fall and the stage of maize varieties (critical time at tasseling and silking stage). Most of the time irrigation has been done after noon to avoid loses of water from the field by evaporation.

Harvesting: finally, maize plants in the net plot area were harvested at harvesting maturity.

Data Collection

Data was collected from the net plot area. In this experiment data was taken on five representative randomly selected sample plants from the net plot and then averaged.

Phenological Parameters

Days to 50% Tasseling: Days was counted from sowing to the day when 50% of the maize plants shed pollen grains from the main branch of the tassel and from a few others branches in each plot by visual observation.

Days to 50% Silking: It was recorded as the number of days required from sowing to the silk emergence on 50% of the plants or when 50% of the maize plants showed extrusion of silking each plot by visual observation.

Days to Physiological Maturity: The days to physiological maturity were recorded as the duration from the date of sowing up to a stage when 90% of plants formed black layer at the base of the kernel (at the point where the kernel attaches with the cob) and kernels were difficult to be broken by thumbnail.

Growth Parameters

Leaf Area Index (LAI): The leaf area, at the stage of tasseling, were determined first from five randomly selected plants from the net plot by multiplying leaf length and maximum leaf width at the middle section of the leaf and adjusted by a correction factor of 0.75 (0.75 x leaf length x leaf width) as suggested by Daughtry, et al. Then leaf area index will be determined by dividing the total leaf area of a plant to the ground covered Area of by green single leaf per plant [23].

Plant Height (cm): It was measured as the height from the soil surface to the tip excluding the tassel of five randomly select plants from the net plot area at physiological maturity.

Ear Height (cm): were record from five randomly select ears from each net plot area and measure their ear height from the ground level to the node bearing the top useful ear with a meter rod at physiological maturity.

Yield and Yield Components

Stand Count Percentage: It was recorded by counting the number of plants reached to harvesting from the net plot area and calculated as the ratio of actual plant stand to the number of seedlings left after thinning multiplied by 100 [24].

Plant Stands Count = **(**Actual plant stand/ Number of seedlings after thinning) x 100

Number of Ears per Plant (No): The number of ears per plant was record from the count of five randomly sample plants per net plot at harvest.

Ear Length (cm): It was measured from the base to the tip of the ear from randomly taken five ears in the net plot area at crop harvest. The ear length was measure after removing the husk cover and the average values were compute for each plot.

Number of Grain Rows per Ear (No): The numbers of rows were count on five randomly select ears and the average value was computed for each plot.

Number of Grain per Row (No): It was determined by counting the number of kernels in each grain row of five randomly taken ears from the net plot area at crop harvest and averages it.

Number oOf Grain per Ear (No): This represented the average number of kernels obtained from five ears of plants randomly taken from the net plot area at crop harvest.

Hundred –Grain Weight (kg): It was determined from 1000 randomly taken grains (by hand counting) from each plot and weighed using a digital balance.

Grain Yield (kg hek^{-1}): The total numbers of plants in the net plots were harvested. After that, grains were shelled from the ears of each plot. Then, the field weight of grains and the moisture content thereof was immediately measured using electronic balance and moisture tester, respectively in each plot. The measured values were adjusted to the standard moisture content of 12.5 % Biru Abebe, and then it was multiplied by the field weight of the actual yield of each plot to determine the adjusted yield of the plot and finally converted in to hectare basis using the following formulas:

Grain Yield (kg plot^{-1}) =

Above Ground Dry Biomass Yield(kg): All plants with ears attached from the net plot was harvest at harvest maturity and weight after sun drying which defined it as above ground dry biomass (biological yield).

Harvest Index: It was calculated as the ratio of grain yield to total above ground dry biomass yield multiplied by 100 at harvest from the respective treatments [24].

Harvest Index (HI %) =

Hand weeding, hoeing and other crop management practices were applied uniformly to all plots as per the recommendations for maize. Finally, maize plants in the net plot area were harvested at harvest maturity.

Data Analysis

Data collected was subject to analysis of variance (ANOVA) appropriate to factorial experiment in RCBD according to the General Linear Model (GLM) procedure of SAS version9.4 [25]and interpretations were made following the procedure describe by Gomez, et al. [26] . Whenever the effects of the treatments will be found significant, the means was compared using the Least Significance Difference (LSD) test at 5% level of significance.

Partial Budget Analysis

An economic analysis was done using partial budget procedure described by CIMMYT [27]. The cost of seed was considered as variable costs. The net benefits /returns/ and other economic analysis was based on the formula developed by CIMMYT [27] and given as follows:

- **Adjusted Grain Yield (AGY) (kg ha^{-1}):** was the average yield adjusted downwards by a 10% to reflect the difference between the experimental yield and yield of farmers.
- **Gross Field Benefit (GFB) (ETB ha^{-1}):** were computed by multiplying field/farm gate price that farmers receive (25 ETB kg^{-1}) for the crop when they sell it as adjusted yield. GFB =
- **Total Variable Cost (TVC) (ETB ha^{-1}):** it was calculated by summing up the costs that vary, including the cost of seed (30.00ETBkg^{-1}) at the time of planting (July15, 2022). The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding, harvesting, irrigation and threshing were considered the same for all treatments or plots.
- **Net Benefit (NB) (ETB ha^{-1}):** was calculated by subtracting the total variable costs (TVC) from gross field benefits (GFB) for each treatment as: NB =
- **Marginal Rate of Return (MRR) (%):** was calculated by dividing change in net benefit (ΔNB) by change in total variable cost (ΔTVC). × 100 Finally, among the non-dominated treatments, the treatment which gave the highest net return and a marginal rate of return greater than the minimum considered acceptable to farmers (100%) were considered for recommendation.

Results and Discussion

Phenological Parameters of Maize

Crop Phenology: Results from analysis of variance revealed that both main effect and their interactions effect of varieties and intra-row spacing were highly significant (p<0.01) on days to 90% maturity, days to 50% tasseling and days to 50% silking of maize on the main effect of was highly significant (p<0.01) on varieties (Appendix Table 2), days to 50% tasseling was significant(p<0.05) whereas days to 50% silking were highly significant (p<0.01) on the main effect of intra-row spacing. Days to 50% silking of maize was highly significant (p<0.01) and days to 50% tasseling was non-significant. The experimental results of Raouf, et al. [28], Gungula, et al. [29] Maize took more time to tasseling when maize planted narrow intra-row spacing. They stated that the maximum of days to 50% tasseling was recorded at application of maize with a narrow intra-row spacing and the mini-mum was recorded when maize planted a wider intra-row spacing. They also suggested that increase in plant density might have increased the rate of photosynthesis and delayed pheno-logical characteristics such as tasseling in maize. Amanullah, et al. [30] reported that plots maintained at high density took slightly more time to tasseling, silking, and physiological maturity than the plots maintained at wider intra-row spacing and low density. They suggested that dense planting might have slightly slowed down the rate of plant development because of more competition in dense populations and narrow intra-row spacing [31]. The results of this study, is also in line with Gozubenli, et al. [32] reported that the effect of intra-row spacing did not significantly affect the tasseling and maturity period of maize. The longest days (67.60) to 50% tasseling was recorded at BH-546 while the shortest days (60.47) to 50% tasseling was recorded at M-6 (Table 2). The longest days (69.87) to 50% silking was recorded BH-546 while the shortest days (62.87) to 50% silking was recorded in M-6 (Table 2). The longest days (115.20) to 90%maturity was recorded BH-546 while the shortest days (108.27) to 90% maturity was recorded in M-6 (Table 2). The differential with respect to days to 90% maturity, number of days to 50% tasseling and number of days to 50% silking was observed between the varieties these might be attributed to differences in genetic characteristics of the individual varieties. Gozubenli, et al. [33] and Thiraporn, et al. [34] reported that tasseling period was variable in maize and longer season cultivars took more time to reach tasseling and maturation than did the shorter seasonal cultivar. Regarding the intra-row spacings the longest days (114.67) to 90% maturity, days (67.33) to50% silking was recorded from small(20cm) intra–row spacing and the smallest days (107.78) to 90% maturity, days (64.11) to 50% silking was record from large (40cm) intra-row spacing (Table2). Amanullah et al. [30] noted that there was not much synchrony in flowering with higher density and they reported that higher plant density delayed days to 50% silking of maize crop.

Maize varieties	Days to physiological maturity (days)	Days to 50% tasselling	Days to 50% silking
M-6	108.27b	60.47c	62.87c
BH-549	115.20a	67.60a	69.87a
M-2	109.20b	62.07b	64.13b
LSD (p0.05)	1.83	0.9	0.89
Intra-row spacing			
20	114.67a	63.44 ab	67.33a
25	113.33a	63.56 ab	66.56ab
30	109.78b	63.22ab	65.56bc
35	108.89b	62.56b	64.56cd
40	107.78b	64.11a	64.11d
LSD (p0.05)	2.36	1.16	1.15
CV (%)	2.21	1.89	1.82

Mean followed by the same letter with the same column are statistically non-significant at p<0.05 according to the least significant difference (LSD) test at P<0.05.

Table 2: Mean effects of intra-row spacing with maize varieties on phenological data of maize.

	Days to physiological maturity			Days to 50% tasselling		
Intra-row spacing	Maize Varieties					
	M-2	**BH-546**	**M-6**	**M-2**	**BH-546**	**M-6**
20	115.00abc	117.00ab	112.00cd	60.00c	68.00a	62.33b
25	108.33de	118.00a	113.67bc	60.00c	68.00a	62.67b
30	106.00e	115.00abc	108.33de	60.00c	68.00a	61.67bc
35	106.00e	114.67abc	106.00e	60.00c	68.00a	61.67bc
40	106.00e	111.33cd	106.00e	62.33b	68.00a	62.00bc
LSD (p0.05)	4.09			2		
CV (%)	2.21			1.89		

Table 3: Interaction effects of both maize varieties with intra-row spacing the agronomic and yield components of Maize varieties with different intra-row spacing.

Growth Parameters of Maize

Plant Height: The analysis of variance showed that the main effect of intra-row spacings was significant (p<0.05) and varieties on plant height was highly significant (p<0.01). However, the interaction effect was also highly significant (Appendix Table 1). The tallest plant height (218.22cm) was observed under the narrowest intra-row spacing of 20cm, while the shortest plant height (184.60 cm) was recorded at the widest intra-row spacing (40 cm) (Table 4). With regard to the effect of intra-row spacings, plant height increased with decreasing intra-row spacing from 20 cm to 40 cm. This increasement in plant height at narrowest plant spacing (higher plant density) may be due to strong intra-specific competition among plants for light that might be attributed to more vegetative development resulting in increased plant height due to mutual shading with intermodal extension being responsible for increasing the plant height.

The result is supported by the previous findings of Khan et al. [35], who reported that increasing plant population density increased the plant height and similarly, Matthews, et al. [36] also reported that maize planted with plant spacing of 25 cm had significantly taller plants than those planted with 30 cm plant spacing. The result also agreed with the previous findings of Abuzer, et al. [37] who reported that plant height increased with decreasing intra-row spacing. Accordingly, significantly taller plant height (225.25 cm) was obtained from the variety BH-546 and the smallest plant height was non- significantly observed from variety malkasa-2 (186.62 cm) (Table 4). The treatment of means showed that the maximum plant height was recorded at narrow in intra-row spacing and the minimum value was obtained from wider intra-row spacing. This trend explains that as the number of plants increased in a given area the competition among the plants for nutrients uptake and sunlight interception also increased. Increase in plant height may also be due to prolonged vegetative growth which increased plant height. So, the comparison of means showed that days to tasseling or the vegetative growth period increased when the intra-row spacing was decreased. Similar results were reported by [28,30].

The differential growth with respect to plant height observed between the varieties this might be attributed to differences in genetic characteristics of the individual varieties, including the height of the varieties. This variation showed the existence of genetic difference among the varieties. In conformity with this result, Kunoskan and Gozubenli, et al. [33] reported considerable varietal variation among plant height of maize cultivars. Similarly, Azam, et al. [38] stated that various varieties of maize have genotypic differences for plant height where the tallest plant height (145cm) was recorded for variety Cargill 707 and the shortest plant height (134 cm) was recorded for variety Baber. In conformity with this result, Abuzar, et al. [39] who reported considerable varietal variation among plant height of maize cultivars.

Maize varieties	Plant height (cm)	Leaf area index	Ear height (cm)
M-6	189.16b	5.67b	3.144ab
BH-549	225.25a	6.56a	3.30a
M-2	186.62b	5.82b	3.01b
LSD (p0.05)	18.22	2.05	0.27
Intra-row spacing			
20	218.22a	5.75b	3.08a
25	208.68ab	6.71a	3.20a
30	204.92abc	5.85b	3.12a
35	185.29bc	6.02b	3.20a
40	184.60c	5.74b	3.16a
LSD (p0.05)	23.49	0.45	0.34
CV (%)	12.14	7.76	11.32

Mean followed by the same letter with the same column are s
tatistically non-significant at p<0.05 according to the least significant difference (LSD) test at P<0.05.

Table 4: Mean effects of intra-row spacing with maize varieties on growth and yield components of maize.

Intra-row spacing	Plant height (cm)			Leaf area index		
	Maize Varieties					
	M-2	BH-546	M-6	M-2	BH-546	M-6
20	202.80bc	260.26a	191.60c	5.50de	5.95bcde	5.80bcde
25	190.87c	246.48a	188.70c	5.27e	8.55a	6.30bc
30	186.27c	243.08ab	185.40c	5.62cde	6.05bcde	5.86bcde
35	184.53c	190.60c	180.73c	6.42b	6.28bcde	5.37e
40	181.33c	185.80c	186.67c	5.50de	5.97bcde	5.76bcde
LSD (p0.05)	40.69			0.78		
CV (%)	12.14			7.76		

Where M-2= Melkasa two, M-6=Melkasa six q.

Table 5: Interaction effects of both maize varieties with intra-row spacing the agronomic and yield components of Maize varieties with different intra-row spacing.

Ear Height: The analysis of variance revealed that the main effect due to varieties on ear height was significant ($p < 0.05$) and intra-row spacings was non-significant ($p > 0.05$), while the interaction effect was significant ($p < 0.05$) on ear height (Appendix Table 1). The highest ear height (3.64cm) was obtained from the variety BH-546 at 25cm intra-row spacing, while the lowest ear height (2.87cm) was obtained at the variety m-6 at 30cm intra-row spacing (Table 4). The differential growth with respect to ear height observed between the varieties might be attributed to differences in genetic characteristics of the individual varieties. This study was in line with the experimental result of Karasu [40] who reported that ear heights of maize cultivars were significantly different and the greatest ear height (144.1cm) was obtained from LG 2687 cultivar and the lowest ear height (131.5 cm) was obtained from a GH2547 cultivar. Anjorin, etr al. [41] also reported that plant and ear heights are important yield determinant features in maize, the higher the ear height the more the number of ears that can develop from the nodes beneath.

Regarding the effect of intra-row spacing, ear height increased with decreased intra-row spacing from 40 cm to 25 cm. The tallest ear height (3.20 cm) was recorded under the narrowest intra-row spacing of 25 cm, while the shortest ear height (3.16 cm) was recorded at the widest intra-row-spacing of 40cm (Table 4). This increase in ear height at narrowest plant spacing may be due to strong intra-specific competition among plants for light that might be attributed to more vegetative development resulting in increased ear height due to mutual shading with intermodal extension being responsible for increasing the ear height. Generally, ear height showed a linear increase with an increase in planting density increase due to high density resulted in competition for resources. The current result was in agreement with Abuzar, et al. [39] the main effect of planting density showed that ear height was relatively responsive to the change in planting density than N levels.

Intra-row spacing	Days to 50% silking		
	Maize Varieties		
	M-2	BH-546	M-6
20	60.00c	68.00a	62.33b
25	60.00c	68.00a	62.67b
30	60.00c	68.00a	61.67bc
35	60.00c	68.00a	61.67bc
40	62.33b	68.00a	62.00bc
LSD (p0.05)	2		
CV (%)	1.89		

Mean followed by the same letter with the same column are statistically non-significant at $p < 0.05$ according to the least significant difference (LSD) test at $P < 0.05$.

Table 6: Interaction effects of both maize varieties with intra-row spacing the agronomic and yield components of Maize varieties with different intra-row spacing.

Leaf Area Index: The analysis of variance showed that the main effects due to intra-row spacings were significant ($p < 0.05$) and varieties on leaf area index (LAI) were highly significant ($p < 0.01$), while the interaction effect was highly significant ($p < 0.01$) on leaf area index (Appendix Table 1). Analysis of variance depicted that the highest leaf area index (8.55) was obtained from variety BH-546 at intra (25 cm) row spacing. The lowest leaf area index (5.27) was attained from variety M-2 at intra (25 cm) row spacing (Table 5). The possible reasons for the highest leaf area index for variety BH-546 at 25cm intra-row spacing might be due to a greater number of leaves produced owing to a greater number of plants per unit area. They further reported that the highest physiological growth indices are achieved under high plant density, because photosynthesis increases by development of leaf area. In our research, increase in leaf area index explains the general crop trends that decreasing intra-row spacing increases leaf area index on account of more area occupied by green canopy of plants per unit area. On the other hand, increasing leaf area index is one of the ways of increasing the capture of solar radiation within the canopy and accumulation of dry matter. Leaf area index is in reverse to leaf area per plant, that is the maximum leaf area per plant occurred at wider spacing and at the same time the minimum leaf area index occurred at the widest spacing. Generally, Leaf area index showed an increasing trend with decreasing intra-row spacing.

In line with this result, Ahmad, et al. who reported the highest leaf area index (5.82) was obtained from variety Pioneer-30D55, while the lowest leaf area index (5.55) was obtained from variety pioneer-3012 due to a smaller number of leaves per plant and less leaf breadth. Similarly, Abuzar, et al. [39] who revealed that leaf area index was significantly affected and increased in a linear fashion from 1.21 to 2.77 when plant population increased from 40, 000 to120,000 plants ha^{-1} of maize, respectively. It was also in agreement with Shafi, et al. [42]who showed that the leaf area index of maize was significantly affected by planting density and varieties, leaf area index increased from 2.5 to 3.5 as plant population increased from 45, 000 to65, 000 plants·ha-1. AmonaTolka also showed that the highest leaf area index (4.19) was obtained at the narrowest plant spacing (55 cm X 25 cm) and the lowest leaf area index (2.67) was registered at the widest plant spacing (75cm x 30cm) of maize. Valadabadi, et al. [43] they stated that leaf area is influenced by genotype, plant population, climate and soil fertility.

Yield and Yield Components of Maize

Ear Length: The analysis of variance revealed that the main effect of inter row spacing and variety on ear length was highly significant ($p<0.001$) and intra-row spacings was significant ($p<0.05$). However, the interaction effect had no significant ($p>0.05$) on ear length (Appendix Table 3). Regarding the effect of intra- row spacing, ear length decreased with decreasing plant spacing from 40 cm to 20 cm. The highest ear length (1.72 cm) was recorded from the widest-spaced plants (40 cm), while the lowest ear length (1.56 cm) was recorded from the narrowest row-spacing of 20 cm (Table 7). This reduction of ear length in narrowly spaced plants might be attributed to inefficient supply of assimilates from source to sink as a result of mutual shading or low photosynthetic process of leaves. This result is in line with the findings of Azam, et al. [44] who reported that intra-row spacing affected cob length due to intense competition for growth-limiting factors like nutrient, moisture, air and light.

Regarding the effect of varieties in ear length, higher ear length (1.87 cm) was produced from variety BH-546 while shorter ear length (1.64 cm) was produced from M-6 (Table 7). Variations in ear length observed might be due to maize hybrids could have different varietal characteristics for this trait. This result is in line with the findings of Konuskan [45] and Gozubenli, et al. [33] who reported that variations in ear characteristics of maize depend upon genotype and environmental conditions. Similar reported by the study of Rangarajan, et al. [46] which revealed that a significant difference among the varieties of maize on ear length.

Maize varieties	Ear length (cm)	Number of grain row/ear
M-6	1.64b	15.46 a
BH-546	1.87a	15.25a
M-2	1.67b	14.45b
LSD (p0.05)	0.12	0.78
Intra-row spacing		
20	1.56a	15.18b
25	1.65a	15.28a
30	1.67a	14.20b
35	1.69a	14.71b
40	1.72a	16.35b
LSD (p0.05)	0.15	1
CV (%)	9.17	6.9

Mean followed by the same letter with the same column are statistically non-significant at $p<0.05$ according to the least significant difference (LSD) test at $P<0.05$.

Table 7: Mean effects of intra-row spacing with maize varieties on yield components of maize.

Number of Grain Rows per Ear: The analysis of variance indicated that the main effect of intra-row was highly significant ($p<0.01$) and variety was significant effect ($p< 0.05$) on the number of grain rows per ear while the interaction effect was highly significant ($p < 0.01$) effect on number of grains rows per ear (Appendix Table 3). The number of grain rows per ear increased with increasing the intra row-spacing from 20cm to 40cm. The highest number of grain rows per ear (16.35) was obtained from the widest intra-row spacing (40 cm), while the lowest number of grain rows per ear (15.18) was recorded from the narrowest row-spacing (20 cm) but it is statistically at par with that obtained under number of grain rows per ear (14.20) with medium intra row spacing (30) cm (Table 7). This increase in number of grain rows per ear in response to increasing intra-row spacing might be due to better availability of growth limiting resources both in the soil and outside the soil system that perhaps enabled plants to grow vigorously and produce fully viable big ears that can carry several numbers of grain rows on it. This result is in line with the previous findings of Aghdam, et al. [47] who reported that increasing row space increased corn growth and development, which increased number of grain rows per ear.

Regarding the effect of number of grain rows per ear, the highest number of grain rows per ear (15.46) was obtained in variety M-6, while the lowest number of grain rows per ear (14.45) was recorded in variety M-2. This is due to the effect of the corn growth and development is M-6 good performing than BH-546 and M-2. Similar result was reported by Abdulatif who observed significant variation at row spacing and maize varieties on number of kernel rows per ear.

Number of Grains per Row: The analysis of variance showed highly significant (p< 0. 01) effect of variety and inter-row spacing on the number of grains per row, but their interaction had significant effect (Appendix Table 3). With regard to intra-row spacings, the number of grains per row increased with increasing plant spacing from 20 cm to 40 cm. The highest grains per row (38.80) was recorded at the widest plant spacing (40 cm), but it is statistically at par with that obtained under (30 cm) (37.02) and the lowest number of grains per row (35.73) was recorded from the narrowest plants pacing (20cm) (Table 8). This increased number of grains per row with increasing plant spacing might be due to the availability of growth-limiting factors that encouraged better plant growth and development attributing to more interception and conversion of light through leaves and set early sink for the accumulation of assimilates. This result is in tune with the findings of Kumar [48] reported that increasing plant spacing reduced inter-plant competition and increased photosynthetic efficiency favoring better source sink relationship which might have been responsible for increased cob size, number of rows per ear and number of grains per ear. The interaction effect of both varieties and intra-row spacings showed that, the highest number of grains per row (45) was recorded in BH-546 at 25cm intra-row spacing while the lowest number of grains per row (34.27) was recorded in M-6 at 30cm intra-row spacing (Table 8).

Maize varieties	Number of grain/row	Number of grain/ear
M-6	35.79b	548.64ab
BH-546	39.95a	599.25a
M-2	35.44b	504.31b
LSD (p0.05)	1.9	53.36
Intra-row spacing		
20	35.73ab	502.37ab
25	36.07a	535.94a
30	37.02b	537.64b
35	37.67ab	572.93a
40	38.80b	604.79ab
LSD (p0.05)	2.45	68.88
CV (%)	6.84	12.95

Mean followed by the same letter with the same column are statistically non-significant at p<0.05 according to the least significant difference (LSD) test at P<0.05.

Table 8: Mean effects of intra-row spacing with maize varieties on yield components of maize.

Intra-row spacing	Number of grain row per ear			Number of grain per row		
	Maize Varieties					
	M-2	BH-546	M-6	M-2	BH-546	M-6
20	15.33bc	15.07bc	14.13c	39.53bc	38.47bcd	35.00d
25	15.27bc	18.86a	14.93bc	35.13d	45.00a	36.27bcd
30	14.67bc	13.67c	14.27c	34.73d	38.20bcd	34.27d
35	14.80bc	15.20bc	14.13c	35.20d	40.47b	35.40cd
40	16.20b	14.53bc	14.80bc	34.33d	37.60bcd	36.27bcd
LSD (p0.05)	1.74			4.24		
CV (%)	6.9			6.84		

Table 9: Interaction effects of both maize varieties with intra-row spacing the agronomic and yield components of Maize varieties with different intra-row spacing.

Number of Grain per Ear: In the present study, number of kernels per ear was non significantly (p< 0. 05) effect by the main effects of variety and intra- row spacings but there were no two or three-way interactions effects (p> 0.05) between or among the experimental variables (Appendix Table 3). Higher number of grains per ear (599.25) were recorded from variety BH-546 while the lower (504.31) was recorded M-2 (Table 9). The difference in number of grains per ear observed between two varieties might be due to the fact that number of kernels per ear depends on traits like ear length. Similarly, AmonaTolka reported that the variety BH-140 gave the highest number of kernels per ear (502) than varieties BHPQY-545 and BH-540 owing to the difference in genetic makeup among the cultivars.

Regarding to the effect of intra row, spacings the highest number of grain per ear (604.79) was recorded at 40 cm intra-row spacing and the lowest number of kernel (502.37) was recorded at 20 cm intra-row spacing, but it is statistically at par with that obtained under 30 cm (537.64cm) (Table 6). In wider spacing there is enough resources in case no competition so the amount of kernel is high. In agreement with this result, Eskandar nejada, et al. [49] reported that the intra-row spacing of 30 cm produced a greater number of grains per ear than that of 20 cm. Similarly, Mukhtar, et al. [50] observed that decreased number of grains per ear with increase in plant density in maize.

Number of grain /ear			
Maize Varieties			
Intra-row spacing	M-2	BH-546	M-6
20	569.97bc	549.23bc	493.73c
25	500.56c	784.45a	529.36bc
30	496.18c	522.33bc	488.59c
35	629.63b	582.13bc	507.04c
40	546.87bc	558.12bc	502.83c
LSD (p0.05)	119.31		
CV (%)	12.95		

Table 10: Interaction effects of both maize varieties with intra-row spacing the agronomic and yield components of Maize varieties with different intra-row spacing.

Hundred Grain Weight: The analysis of variance showed that the main effects of variety and intra-row spacings were highly significant (p<0.01) and interactions was non-significant on hundred grain weight (Appendix Table 4). The highest mean hundred grain weight (42.67g) was recorded significantly from the combination of 75cm x 25cm spacing of variety BH-546 and statistically at par 75 cm x 30 cm spacing of variety BH-546, while the lowest mean thousand grain weights (29.33g) was recorded from 75cm x 40cm spacing of variety M-2 (Table 11). This might be due to optimum spacing provided better opportunity for crop to utilize available resources with less competition leading to increased plant capacity for building large amounts of metabolites to be used in increasing this yield component. In addition, optimum spaced plants that improved the supply and partioning of assimilates from source to sink to be stored in the grains might be the reason for producing higher seed weight. This result is in tune with the findings of Azam, et al. [44] who observed maximum 100-seed weight (339 g) at plant spacing of 30.5 cm and minimum 100-seed weight of (315.44 g) at 15.24 cm, and also agreed with the findings of several workers [49-51] who reported that the lowest plant population increased 100-seed weight.

Maize varieties	Hundred grain weight (g)	Harvest index (%)
M-6	32.00b	28.07522
BH-546	35.13a	26.3574
M-2	32.07b	29.18519
LSD (p0.05)	2.11	Ns
Intra-row spacing		
20	33.11b	26.92ab
25	36.89a	30.27a
30	32.78b	27.62ab
35	31.67b	25.80b
40	30.89b	28.75ab
LSD (p0.05)	2.73	4.04
CV (%)	8.54	15.03

Mean followed by the same letter with the same column are statistically non-significant at p<0.05 according to the least significant difference (LSD) test at P<0.05.

Table 11: Mean effects of intra-row spacing with maize varieties on yield and yield component of maize.

Intra-row spacing	Hundred grain weight (g)			Above ground biomass (kg ha^{-1})		
	Maize Varieties					
	M-2	BH-546	M-6	M-2	BH-546	M-6
20	32.67bcd	36.00b	30.67cd	28287.22b	28223.98ab	18893.28cd
25	33.00bcd	42.67a	35.00bc	19828.72cd	34334.65a	25362.32bc
30	32.67bcd	34.00bcd	31.67bcd	19080.37cd	25322.79bc	19433.47cd
35	32.33bcd	31.33bcd	31.33bcd	18774.70cd	23699.60bc	20092.23cd
40	29.33d	31.67bcd	31.67bcd	13175.23d	18445.32cd	15794.47d
LSD (p0.05)	4.72			7544.54		
CV (%)	8.54			20.58		

Mean followed by the same letter with the same column are statistically non-significant at p<0.05 according to the least significant difference (LSD) test at P<0.05.

Table 12: Interaction effects of both maize varieties with intra-row spacing the agronomic and yield components of Maize varieties with different intra-row spacing.

Above Ground Dry Biomass Yield: Analysis of variance to above ground dry biomass yield revealed that main effect of intra- row spacings and varieties were highly significant (p<0.01) and interaction effect non- significant (Appendix Table 4). Accordingly, the highest aboveground dry biomass yield (34334.65 kg ha^{-1}) was obtained at narrow intra (25 cm) row spacing in variety BH-546 and statistically at par under narrow intra (30 cm) row spacing in variety BH-546 while the lowest aboveground dry biomass (13175.23kg ha^{-1}) was attained at wider intra (40 cm) row spacing in variety M-2 (Table 13). The highest aboveground dry biomass might be due to the presence of high number of plant stand per unit area and the late maturity of the variety that took more days to maturity and hence had a better chance to utilize more nutrients and more photosynthetic activity, which ultimately resulted in higher biomass production. The result shows that an increase in biomass yield with increasing plant population density and plant height also directly contribute to biomass yield increment. This result was in line with Borras, et al. [52] found that the highest aboveground dry biomass yield (21.54-ton h^{-1}) for late maturing cultivar Ehsan, while the lowest aboveground dry biomass yield (16.83-ton ha^{-1}) was obtained from early maturing cultivar Pahari of maize. Similarly, Amona Tolka who reported the highest dry biomass (28.4 ton ha^{-1}) of maize at the plant density of 61,538 plants ha^{-1} (65 cm x 25 cm), but the lowest dry biomass (21.19 ton ha^{-1}) at plant density of 44,444 plants ha^{-1} (75cmx30cm) which might be due to the result of variation in the crop stand per unit area. Aslam, et al. reported that dry matter accumulation was much in high plant densities compared to low plant densities.

Maize varieties	Above ground biomass (kg ha-1)	Adjusted grain yield (kg ha-1)
M-6	19829.25b	5355.520b
BH-546	26005.27a	6763.407a
M-2	19915.15b	5697.458b
LSD (p0.05)	3355.342	536.55
Intra-row spacing		
20	25134.83ab	6345.96b
25	26508.56 a	7932.82a
30	21278.88b	5738.69bc
35	20855.51b	5229.864cd
40	15805.01c	4446.640d
LSD (p0.05)	4355.84	863.79
CV (%)	20.58	15.06

Mean followed by the same letter with the same column are statistically non-significant at p<0.05 according to the least significant difference (LSD) test at P<0.05.

Table 13: Mean effects of intra-row spacing with maize varieties on yield and yield component of maize.

Adjusted Grain Yield: Grain yield is the ultimate goal of any crop production system aimed at increasing the economic yield. Grain yield is the end product of all metabolic processes of crop plants over the growing season. The analysis of variance showed that both main effect was very highly significant (p<0.001) and also interaction effect of intra- row spacings and variety were significant (p<0.05) (Appendix Table 5).

Accordingly, the highest grain yield (10325.47kgha^{-1}) was obtained in combination of 25 cm × BH-546 variety while the lowest grain yield (3735.18kgha^{-1}) was obtained at wider intra row spacing combination 40 cm x M-2 (Table 13). A statistically at par to the highest grain yield (6722.00kgha^{-1}) which was obtained in BH-546 with spacing 30 cm (Table 14). The result observed for the two varieties revealed that the blanket recommendation of 75cm x 30 cm is not an appropriate to insure better grain yield of maize. The higher grain yield for variety BH-546 could be due to its tallness as well as its late maturity which had a better chance to utilize more nutrients and more photosynthetic activity, which ultimately resulted in higher yield production. The possible reason for the lowest grain yield at widest spacing might be due to the presence of a smaller number of plants per unit area. This indicated that low plant density per unit area that could get better available growth factors like moisture, nutrients, light, and space could not offset the grain yield obtained from high plant density per unit area. This might be due to the fact that high plant population ensured early canopy coverage and maximized light interceptions facilitating better crop growth, development and biomass resulting in increased yield of maize. Previous research findings also indicated that plants grown on wider spacing absorb more nutrients and solar radiation for improved photosynthesis and hence produce better grain yield on an individual basis but yield per unit area reduced due to a low plant stand [53].

In addition, this increase in maize grain yield under decreased intra-row spacings might be due to the efficient utilization of available resources and also because of planting density-induced increase of leaf area index, light interception and photosynthesis [54]. These findings, is in agreement with Eskandarnejada et al. [48] reported that higher grain yield of maize (15.25 t ha^{-1}) was obtained from narrower (55 cm x 20 cm) spacing combination than the wider (75 cm x 30 cm) spacing combination which yielded 11.43-ton ha^{-1}. Shrestha [55] also reported that grain yield (5.11 t. ha^{-1}) under 60 cm x 25 cm spacing was significantly higher than that of 60 x 30cm spacing but that was at par with the yield obtained from 60cm x 20cm spacing. A similar trend in yield increments with increasing plant density has been observed by Mukhtar, et al. [49] reported that the highest grain yield of 8.37-ton ha^{-1} produced under narrower spacing of 12.5cm x 70cm, while the lowest grain yield of 6.65-ton ha^{-1} was recorded from 17.5cm x 70cm spacing combination. Finally, the grain yield of maize depends on a lot of agrotechnical factors such as nutrient supply, planting distance and environmental factors such as high temperature, water availability for plant uptake etc.

Intra-row spacing	Adjusted grain yield (kg ha^{-1})			Harvest index		
	Maize Varieties					
	M-2	BH-546	M-6	M-2	BH-546	M-6
20	6056.39bcde	6705.07bc	6276.49bcde	22.60c	24.96bc	33.19a
25	6299.08bcd	10325.47a	7173.91b	31.91ab	30.55ab	28.36abc
30	5358.37cde	6722.00bc	5135.71def	28.30abc	27.01abc	27.55abc
35	5328.590cde	5262.19cde	5098.81def	28.73abc	23.14c	25.54bc
40	3735.18f	4802.37ef	4802.37ef	28.84abc	26.12bc	31.29ab
LSD (p0.05)	1496.13			7		
CV (%)	15.06			15.03		

Table 14: Interaction effects of both maize varieties with intra-row spacing the agronomic and yield components of Maize varieties with different intra-row spacing.

Harvest Index (%): The analysis of variance revealed the harvest index significantly affected by the main effect was significant (p<0.05) and their interaction effects variety × intra row spacing were non- significant (p<0.001) (Appendix Table 5). The highest harvest index (31.91%) was obtained from variety M-2 in 25 cm while statistically equivalent harvest indices were observed from combinations of 30 cm and 35 cm while the lowest harvest index (22.60%) was attained from variety M-2 with 20 cm (Table 14). The highest harvest index for variety M-2 could be due to the fact that variety M-2 had effective utilization of growth factors like moisture, nutrients, light, and space when there is adequate rainfall resulted in high photosynthesis activity and thereby to high partitioning of photosynthetic into grain yield as compared to variety BH-546 and M-6. In agreement with this result Bismillah, et al. [56] reported that the harvest index varied significantly among different cultivars of maize.

Economic Analysis: Economic analysis was performed to know the economic feasibility of different variety and intra-row spacing combinations (treatments) [57-61]. From the budget summary of economic analysis, the highest net return (Birr 243,371 ha^{-1}) was obtained from BH-546 with intra row spacing of 20cm,25cm, 30cm, 35cm and 40cm while the lowest net economic return (Birr 718.18 ha^{-1}) was recorded from variety M-6 with intra row spacing of 40 cm (Table 15).

Maize V.	SP	AGY kg/ha	AGY birr/ha	SC	TVC (ETB ha^{-1})	GFB (ETB ha^{-1})	NB	MRR (%)
BH-546	20	10138.34	253458.48	937.5	10,087.50	253458.5	243,371.00	2512.6
BH-546	25	10138.34	253458.48	937.5	10,087.50	253458.5	243,371.00	2512.6
BH-546	30	10138.34	253458.48	937.5	10,087.50	253458.5	243,371.00	2512.6
BH-546 D	35	10138.34	253458.48	937.5	10,087.50	253458.5	243,371.00	2512.6
BH-546 D	40	10138.34	253458.48	470	11,670.00	253458.5	243,371.00	2171.88
M-2 D	20	10138.34	253458.48	703.8	10,878.75	253458.5	243,371.00	2329.85
M-2 D	25	10138.34	253458.48	586.9	11,274.38	253458.5	243,371.00	2248.09
M-2 D	30	253458.48	243,371.00	1100	25,345.50	243,371.00	218,03.50	960.21

M-2 D	35	5247.04	131175.89	535	11,935.00	131175.89	119,240.89	1099.09
M-2 D	40	4624.5	115612.68	470	11,670.00	115612.65	103,942.65	990.68
M-6 D	20	9337.94	233448.62	1125	10,275.00	233448.62	223,173.62	2272.01
M-6 D	25	4624.51	115612.65	900	12,700.00	115612.65	102,912.65	910.34
M-6 D	30	5602.77	140069.17	750	12,350.00	140069.17	127,719.17	1134.16
M-6 D	35	6047.43	151185.77	771	12,371.00	151185.77	138,814.77	1222.1
M-6 D	40	3379.45	84486.16	564	11,764.00	84486.17	72,722.17	718.18

Where, Maize V.= Maize varieties, SP= spacing, AGY= adjusted grain yield, SC=Seed cost (Ethiopian birr), TVC=total variable cost (Ethiopian birr), GFB=Gross field benefit; NB=Net benefit.

Table 15: Partial budget analysis of variety and intra-row spacing of maize production.

Summary and Conclusion

The results depicted that the main effect of variety had a significant effect on all parameters of maize except stand count percent, number of ears per plant, number of grain per ear and harvest index [62-78]. The results obtained from the experiment had showed that maize crop phenological parameters like days to 50% tasselling, days to 50% silking and days to 90% physiological maturity was highly significantly affected by the main effects of variety. However, their interaction effect was not significant except days to 50% silking were highly significant effect. The analysis of variance revealed that the main effects due to varieties were significant while, intra-row spacings and interaction effect of the two factors was not significant effect on ear height [79-85]. Similarly, the results showed highly significantly differences on growth parameters such as plant height and leaf area index due to the main effects of variety while, intra-row spacing were significant effect. Both growth parameters were increased with decreasing intra-row spacing from 40 cm to 20 cm, respectively. The maximum mean plant height and leaf area index were obtained from the interaction of narrow (25cm) intra-row spacing at variety BH-546, while the minimum was from the widest (40 cm) intra-row spacing at variety M-2 [86-93].

Variety and intra- row spacing had highly significant effect on ear length, number of grain per row and number of grain rows per ear. All these yield parameters were increased with increasing intra-row spacing. Variety and intra- row spacings had very highly significant effect on aboveground dry biomass yield and grain yield, while the number of grains per ear was non -significant effect. Harvest index also highly significantly affected by combination of variety and intra-row spacings and significantly by intra- row spacings [94-104].

The highest grain yield was recorded from BH-546 at 25 cm spacing, whiles the lowest mean grain yield and above ground dry biomass was recorded at 40cm spacing combinations of variety M2. The analysis of budget summary indicated that the highest net return was obtained from BH-546 at spacing of 25cm, with marginal rate of return greater than 100%, while the minimum net return was recorded from BH-546 at 30cm spacing. The overall results from the present finding indicated that it can be concluded that optimum intra-row spacing combination for the maximum grain yield was 25 cm at BH-546 variety in the study area [105-107]. From the results obtained it is clear that the national or blanket recommended intra-row spacing of 30 cm is not satisfactory for the maize M-2, M-6 and BH-546 productivity. Therefore, 25 cm intra-row spacing is suitable and recommendable for achieving maximum profit of maize BH-546 in the study area and similar agro-ecologies. Generally, the experimental result of this study showed that variety and intra-row spacing had significant influences on most of the phonological parameters, yield and yield components of maize. The result also indicated that variety BH546 was the most suitable of the three maize varieties tested, and 25cm intra-row spacing was better to achieve optimum yield. However, this is a one season experiment at one location, thus the experiment must be repeated over locations and seasons to reach at a better reliable conclusion [108-113].

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