Effects of Inter- and Intra-Row Spacing on Growth, Green Cob Number and Biomass Yield of Maize (Zea mays L.) Varieties at Agarfa, Southeastern Ethiopia

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Abstract
Maize (*Zea mays* L.) is an important grain crop of the world and it ranks second, after wheat in hectarage and first in total production and productivity. In Ethiopia, maize has increasingly become a popular crop with steady growth in production area and yield. However, green cob maize production packages, including its appropriate spacing, are not yet determined. Evidences on effects of inter and intra-row spacing on growth and green cob yield of maize are not well explored. Therefore, this study was conducted at Agarfa from March 2015 to July 2015 to determine the effects of inter-and intra-row spacing on growth, green cob number and biomass yield of maize (Zea mays L) varieties under supplemental irrigation. The experiment was laid out in a randomized complete block design with factorial combination of four inter-row (55 cm, 65 cm, 75 cm, and 85 cm) spacing, two intra-row spacing (25 cm and 30 cm) and two maize varieties (Melkassa-II and BHQPY-545) with three replication. Data were collected on growth, green cob number and biomass yield and analyzed using GenStat, (2012) The experiment result revealed that leaf area and number of cobs per plant were highly significantly ($P<0.01$) affected by inter-row spacing x variety while cob length, number of cobs per hectare and above ground fresh biomass yield were significantly ($P<0.05$) affected by inter-row spacing x variety. The highest cob number (65232.32 ha^{-1}) was recorded for variety BHQPY-545 and (61739.39 ha^{-1}) for variety Melkassa-II at narrowest inter-row spacing of 55 cm (Table 5). Similarly, the highest fresh biomass yield of 51.3 and 48 ton ha^{-1} was obtained from variety BHQPY-545 and Melkassa-II respectively at 55 cm inter-row spacing. In general, significantly higher number of marketable green cobs and aboveground fresh biomass yield were obtained at closer inter-and intra-row spacing for maize varieties tested in the study area. Therefore, it can be concluded that spacing combination of 55 cm x 25 cm favored attaining of higher economic returns, green cob number and fresh biomass yield of maize in the area under supplemental irrigation.
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Introduction

Maize (*Zea mays* L.) is an important grain crop of the world and it ranks second, after wheat in hectarage (187,959,116ha) and first in total production (1,060,107,470MT) and productivity (5.64 t ha-1) (FAOSTAT, 2016). The advantages of maize in ethanol industry also keep it in high demand among other cereal crops. Rosegrant *et al.,* (2010) reported that maize consumption by human in many developing and developed countries is steadily increasing though much of the world maize production is utilized for animal feed.

In Ethiopia, maize has increasingly become a popular crop in the country with steady growth in production area and yield (Doss *et al*., 2003). It is Ethiopia's leading cereal in produced in by about 10.9 million farmers across about 2.1 million hectares of land in 2017*Meher* season (CSA, 2017).

Agarfa district, where the study was conducted, is one of maize producing districts in Bale Zone. Maize is the 3rd cereal crop in production next to wheat and barley in the area. According to CSA, (2017) 108384.8 ton of maize was produced on about 33951 ha of land during 2017 in *Meher* season with yield of 3.2 ton ha^{-1}. In the area, the production of maize under supplemental irrigation takes on a special significance; because there is high demand for green maize consumption during off season as long as water is available for irrigation and production can be carried out during the off season. As it is grown as green cob in the area, maize is important food and income sources for many farmers (BoA of Agarfa district, 2015).

As compared to other cereals; maize can attain the highest potential yield per unit area. World average yield for maize is about 4.5 t ha^{-1} and that of developed countries is 6.2t ha^{-1} while the average yield in developing countries is 2.5t ha^{-1}. In Ethiopia the national average yield is about 3.68 t ha^{-1} (CSA, 2017). Although significant gains have been made in maize production over the past decades, there remains large potential to increase productivity.

The majority of smallholder farmers in Ethiopia are aware of the benefits of adopting input technologies to enhance their maize productivities. However, this awareness is mainly about some improved varieties, commonly used fertilizers like Urea and DAP while the knowledge about micro-nutrients and recommended agronomic packages like optimum plant density are almost not sufficient. Likewise, there is much room for improvement in getting farmers adopt and implement the recommended package of agronomic management methods including proper land preparation and tillage, row planting, maintaining the right planting depth, plant population, time and frequency of weeding and proper time of harvesting (ATA, 2013).

Three production variables that a producer can manipulate to influence the production of a given crop are plant population, row arrangement and hybrid selection (Zaffaroni and Schneiter, 1991). Optimum inter- and intra-row spacing varies with soil fertility status, soil moisture, the nature of the crop and degree of weed infestation (Singh *et al*., 1997).

Though, most of appropriate agronomic practices and requirements of maize have been studied and determined for grain production, there is limited information on plant population and row arrangement for green cob maize production according to different situations like height and maturity period of variety, soil fertility status etc. Hence, realizing the importance of developing appropriate cultural practices such as plant spacing for optimum production of maize as green cob in Agarfa district under supplemental irrigation, this study was envisaged.

Most of the maize producing farmers in Agarfa district do not use the national recommendation and they have been using narrower spacing ranging 55-65 inter-row spacing and 25-30 intra-row spacing (Personal observation). This variation in spacing needs to be evaluated with the recommended 75x30 cm with that of farmers practice. Objectives of this study, therefore, was to investigate the effects of inter-and intra-row spacing on growth, green cob number and biomass yield of maize varieties; and to determine economically optimum inter- and intra- row spacing to achieve higher number of green cob per hectare in the study area.

2. Materials and methods

2.1. Description of the study area

The study was conducted under rain-fed condition supplemented with irrigation during 2015 cropping season at Agarfa ATVET College demonstration site, southeast Ethiopia. The experimental site is located at 458 km away from Addis Ababa and 30 km from Bale Robe city. The site is found at an altitude of 2330 m.a.s.l level with mean maximum and mean minimum temperature of 24.75 ^{0}C and 7.1 ^{0}C respectively. The area receives the average annual rainfall of 829.4 mm (BoA of Agarfa district, 2015).

2.2. Description of Experimental Materials

Two maize varieties, namely Melkassa-II and BHQPY-545 were used in the experiment. Melkassa-II is an improved variety which was released in 2003 performing well in agro-ecological range of 1000-1700m.a.s.l with rainfall range of 600-800mm. It can give 4500-5500 and 3000-4000 kg grain yields per hectare in on-station and on farm experiments, respectively. It is moderately tolerant to disease and lodging (EARO, 2004). 'BHQPY-545' is an early maturing variety adapted to low-mid altitude (1000-1800 masl) areas with high protein. It was released in the year 2008 and its yield potential is 8-10 t ha^{-1} (EIAR, 2008). Variety Melkassa-II is open pollinated and BHQPY-545 is hybrid. Diammonium phosphate (DAP) and Urea fertilizers were used as a source of phosphorous and nitrogen.

2.3. Treatments and Experimental Design.

The treatment consisted of factorial combination of four inter-row spacing (55cm, 65cm, 75 cm and 85 cm), and two intra-row spacing (25cm and 30 cm) using two maize varieties (Melkassa-II and BHQPY-545). The experiment was laid out in randomized complete block design (RCBD) in factorial arrangement with three replications. There were 4, 5, 6 and 7 rows for 85, 75, 65 and 55 cm row spacing respectively. The blocks were separated from each other by a 1.5 m wide space and the distance between each plot was 1 m. The gross plot size was 4.5 x 3.90 (17.55m^2) accommodating 7, 6, 5, and 4 rows for 55, 65, 75 and 85 cm inter-rows respectively. The net plot size for 55, 65, 75 and 85 cm was 10.725 m^2 (5*0.55mx3.90m), 10.14 m^2 (4*0.65mx3.90m), 8.775 m^2 (3*0.75mx3.90m) and 6.63 m^2 (2*0.85mx3.90m) respectively. The central rows left aside for data recording were 5, 4, 3, and 2 rows for 55, 65, 75, and 85 cm inter-row spacing, respectively.

2.4. Management of the Experimental Field

Prior to sowing, the land was well prepared by repeated ploughing using oxen plough. Maize seeds were planted as per proposed inter and intra-row spacing. Initially two seeds per hill were planted and latter thinned to one plant at the stage of 3 to 4 leaves. At time of planting, all plots were received a basal application N and P_2O_5 at the rate of 18kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} in the form of diammonium phosphate (DAP). In addition all plots were top dressed with 23 kg N ha^{-1} at knee height and 23 kg N ha^{-1} at boot stage. All other agronomic and cultural practices like hoeing, weeding, etc were applied to all treatments as per recommended.

2.5. Economic Analysis

Mean cob and fresh biomass yields of the treatments were used in partial budget analysis using CIMMYT, (1988). The field price that farmers receive from the sale of one cob and 1 ton of fresh biomass of maize respectively was taken as 3 Birr and 500 Birr base on the market price of maize at Agarfa town, near the experimental site, 449 km from Addis Ababa. The green cob number and fresh biomass yield was adjusted by 10% and gross benefit was calculated as 10% adjusted green cob number and fresh biomass yield ha^{-1} multiplied by field price that farmers receive for the sale of one cob and 1kg of fresh biomass.

Dominance analysis: was carried out by first listing all the treatments in their order of increasing costs that vary (TVC) and their net benefits (NB) are then put aside. Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefits) is dominated treatment (marked as "D").

Marginal rate of return (MRR) (%): was calculated by dividing change in net benefit (ΔNB) by change in total variable costs (ΔTVC) and then multiplied by 100.

2.6. Crop Data Collected

Samples were taken randomly from the central rows and data on crop phenology (days to 50% tasseling, days to 50% silking and days to late milk stage) were recorded at their respective stages. Leaf area at 50% silking, leaf area index (LAI), plant height, stand count percent, number of ears per plant, number of cob per net plot, number of cob per hectare, cob length, cob weight, and above ground fresh biomass yield were collected.

2.7. Statistical Data Analysis

The measured variables were analyzed using Statistical Soft ware (GenStat, 2012) as per the model described for randomized complete block design. Effects were considered significant if P values are < 0.05. Significance difference among treatment means were compared using LSD at 5% level of significance (Gomez and Gomez, 1984).

3. Results and Discussion

3.1. Crop Phenology

The main effects of inter-,intra-row spacing and variety as well as the interaction of inter-row, intra-row spacing and variety did not affect significantly days to 50% tasseling, days to 50% silking and days to late milk stage (Appendix Table 1). The present result agree with that of Gozubenli (2004) who reported that the effect of inter- and intra-row spacing did not significantly affect days to tasseling and maturity. Similarly, Zenebe (2004) reported that the effect of plant population was not significant on days to 50% flowering and days to 90% maturity of sorghum.

3.2. Growth Parameters

3.2.1. Plant height

The main effects of inter-row spacing and variety and inter-row x variety showed highly significant ($P<0.01$) effects and interaction of inter-row spacing, intra-row spacing and variety showed significant ($P<0.05$) effect on plant height (Appendix Table 2). The variety BHQPY-545 gave the highest plant height (289.9 cm) at narrowest spacing of 55 x 25 cm although the difference statistically not significant with that of 55 cm x 30 cm while the variety Melkassa-II gave the lowest (223.2 cm) at the widest spacing of 85 x 30 cm.

Generally, plant height increased with decrease in inter-row and intra-row spacing. When the inter-row spacing was decreased from 85 to 55 cm and intra-row spacing from 30cm to 25 cm, plant height was increased from 223.2 cm to 261.7 cm for Melkassa-II and 272.6cm to 289.9 cm for BHQPY-545 (Table 1).

Table 1. Interaction effects of inter-row, intra-row spacing and variety on plant height of maize (cm)

Treatments	Melkassa-II		BHQPY-545	
	Intra-row spacing (cm)		Intra-row spacing (cm)	
Inter-row spacing (cm)	25	30	25	30
55	261.7^{e}	257.0^{f}	289.9^{a}	288.8^{ab}
65	247.5^{h}	252.6^{g}	285.4^{b}	285.3^{b}
75	243.9^{h}	247.1^{h}	279.9^{c}	275.3^{d}
85	239.1^{i}	223.2^{j}	273.7^{d}	272.6^{g}
LSD (0.05) = 8.687				
CV (%) =2.0				

Where, LSD (0.05) =Least Significant Difference at 5% level; NS=Non-Significant; CV=Coefficient of Variation. Means in rows and column followed by the same letters are not significantly different at 5% level of significance.

The increase in the plant height of maize varieties at narrowest inter-row and intra-row spacing (higher plant densities) may be due to strong competition among the plants for light and mutual shading. **This result agrees** with the finding of Raouf *et al.,* (2009) who reported that the plant height significantly increased with the increase in plant densities in maize hybrids.

3.2.2. Leaf area

The analysis of variance showed that leaf area was highly significantly (P<0.01) affected by the main effect of inter-row spacing, variety and inter-row x variety, but intra-row spacing and all other interaction did not significantly affect LA (Appendix Table 2).

The highest leaf area (7637.33 cm^2) was recorded at inter-row spacing of 85 cm for variety BHQPY-545 while the lowest leaf area (6076 cm^2) was recorded at inter-row spacing of 55 cm for variety Melkassa-II (Table 4).

Table 2. Effects of inter-row spacing x variety on leaf area of maize (cm^2)

	Maize Varieties	
	Melkassa-II	BHQPY-545
Inter-row spacing (cm)		
55	6076.00^{e}	6522.67^{d}
65	6231.67^{e}	7116.67^{b}
75	6449.50^{d}	7510.33^{a}
85	6826.33^{c}	7637.33^{a}
	LSD (0.05)= 209.740	
	CV (%)= 2.6	

Where, LSD (0.05) =Least Significant Difference at 5% level; NS=Non-Significant; CV=Coefficient of Variation. Means in column followed by the same letters are not significantly different at 5% level of significance.

Increasing inter-row spacing from 55 cm to 85 cm increased the leaf area in 10.99% and 14.59% for variety Melkassa-II and BHQPY-545 respectively and the increment was consistent.

The reduced leaf area with narrow inter-row spacing for the two maize varieties might be due to high competition for assimilates at higher plant density, hence less average leaf area per plant. This is in agreement with Enujeke, (2013) who reported that the interactions of variety and inter-row spacing showed significant effect and positively affected leaf area of maize.

3.3. Cob yield and yield components of maize

3.3.1. Plant stand count percent

The analysis of variance showed that there were highly significant (P<0.01) effect on stand count percent due to main effect of inter-row spacing, intra-row spacing and variety and their interactions showed significant (P<0.05) effect on stand count percentage (Appendix Table 3).

The highest stand count of 97.37 %and the lowest stand count of 89.53% were recorded at inter-row and intra-row spacing of 85 cm x 30 cm and 55 cm x 25 cm respectively for variety BHQPY-54 (Table 3). In general, plant stand percent of maize varieties decreased with reduced inter-and intra-row spacing (as plant population increased) and that might be due to crowding effect. There is a possibility that at narrowest inter- and intra-row spacing (with higher population density) smaller plants crowded out and disappeared. At lower population comparatively, availability of more space might have resulted in less competition for resources (nutrients, moisture and light) whereas at high density due to more intra-specific competition the weaker plants might have died by the time the crop approached maturity.

The result indicated that variety BHQPY-545 is comparatively sensitive to higher plant density than variety Melkassa-II. The variation in stand count percentage between the two maize varieties tested might be due to genetic variability, better utilization of resources like space, air, water and nutrients.

This result is in agreement with the findings of Ahmad *et al.,* (2012) who reported that both plant population density and variety showed significant difference in final plant population of maize.

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Table 3. Interaction effects of inter-row spacing, intra-row spacing and variety on Stand Count percentage of Maize

Treatments	Melkassa-II		BHQPY-545	
	Intra-row spacing (cm)		Intra-row spacing (cm)	
Inter-row spacing (cm)	25	30	25	30
55	89.87^{g}	90.40^{fg}	89.53^{g}	94.73^{bcd}
65	92.23^{ef}	93.67^{de}	94.13^{cde}	95.60^{abcd}
75	94.47^{cde}	95.60abcd	97.07^{a}	96.23^{abc}
85	96.00^{abc}	96.77^{ab}	96.00^{abc}	97.37^{a}
LSD (0.05)= 2.255				
CV (%) =1.4				

Where, LSD (0.05) =Least Significant Difference at 5% level; CV=Coefficient of Variation. Means in rows and column followed by the same letters are not significantly different at 5% level of significance.

This result was also in line with that of Sangoi *et al.,* (2001) who reported that wider inter- and intra-row spacing of 75 cm x 26.6 cm had greater plant stand count percent of maize as compared to the initial count than that of narrow inter- and intra-row spacing of 50 cm x 17.7 cm. Similarly, Eskandarnejada *et al*., (2013) reported that higher plant stand count percent was achieved due to the wider spacing combinations of 75 cm x 30 cm than narrower spacing of 55 cm x 20 cm.

3.3.2. Cob length

The main effect of inter-row spacing and variety showed highly significant (P<0.01) effect and inter-row spacing x variety showed significant (P<0.05) effect while the main effect of intra-row spacing and all other interaction did not show significant effect on cob length (Appendix Table 3).

Statistical analysis result showed that the increase in cob length became progressively smaller as planting density increased (Table 4). The highest cob length (29.47 cm) was recorded at 75 cm for variety BHQPY-545 while lowest cob length (20.23) was recorded at 55 cm for variety Melkassa-II (Table 6). This indicates that unhusked marketable cob length of maize decreased linearly and similarly in both varieties as inter-row spacing decreased and planting density increased. This is in agreement with observation by Bavec and Bavec (2002).

Maize variety BHQPY-545 was superior to the other variety with regard to cob length at all planting densities. The difference in relation to planting density effects on cob length is certainly due to environmental factors and characteristics of the evaluated varieties.

This result is also in line with finding of Enujeke, (2013) who reported that spacing x variety were significantly affected cob length of maize.

Table 4. Effects of inter-row spacing x variety on cob length of maize (cm)

	Maize Varieties	
Inter-row spacing (cm)	Melkassa-II	BHQPY-545
55	20.23^{f}	25.57^{d}
65	21.58^{e}	27.60^{c}
75	23.10^{d}	29.47^{b}
85	24.47^{c}	28.02^{a}
LSD (0.05) = 1.303		
CV (%) =4.4		

Where, LSD (0.05) =Least Significant Difference at 5% level; CV=Coefficient of Variation. Means in column followed by the same letters are not significantly different at 5% level of significance.

3.3.3. Number of cobs per plant

Analysis of variance showed that main effects of inter-row spacing and variety and inter-row spacing x variety had highly significant (P<0.01) effect on number of cobs per plant while the main effect of intra-row spacing and all other interaction effect did not show significant effect (Appendix Table 4).

This result is in line with the finding of Enujeke, (2013) who reported that interaction of spacing and variety was significantly affected the number of cob/plants.

Significantly lowest number of cobs per plant (1.03) was recorded at the narrowest spacing of 55 cm for variety Melkassa-II while significantly highest number of cobs (1.42) was recorded at the widest spacing of 85 cm for variety BHQPY-545 (Table 5). Inter-row spacing of 55 cm, 65 cm and 75 cm did not show statistically difference tough there were numerical differences.

In general, number of cobs per plant was decreased as inter-row spacing decreased for both varieties. The decrease in number of cobs per plant with decrease in plant inter-row spacing for the maize varieties could be due to increased intra specific competition which eventually caused reduction in number of cobs per plant. In contrast, the increase in the number of cobs per plant with increased inter-row spacing might be due to higher net assimilation rate of the maize varieties and partitioning and reduction of competition in wider spacing.

Ahmad *et al*., (2006) reported that the highest number of ears per plant in maize crop sown in 75 cm spaced rows than crop grown at 55 cm and 45 cm. This is similar to the findings of Kim, (1997) and Olakojo *et al.,* (1993) who reported that highest number of cobs yield were obtained from higher plant density due to narrow spacing.

3.3.4. Number of cobs per hectare

Analysis of variance indicated that the main effects of inter-row spacing and variety had highly significant (P<0.01) and inter-row spacing x variety had significant (P<0.05) effect on number of cobs per hectare while the main effects of intra-row spacing and all other interaction effects did not show significant effects (Appendix Table 4).

Significantly the lowest number of cobs per hectare (47738.95) was recorded at widest inter-row spacing of 85 cm for variety Melkassa-II while the highest cob number of 65232.32 for variety BHQPY-545 and 61739.39 cobs per hectare for variety Melkassa-II was recorded at narrowest inter-row spacing of 55 cm (Table 5). This agrees with the finding of Raja, (2001) who reported that rising of corn plant population from 53333 to 88888 plants per hectare significantly increased the fresh ear yield.

Regarding the number of cobs per hectare recorded, both maize varieties (BHQPY-545 and Melkassa-II) gave the highest number of cobs ha^{-1} at the narrower inter-row spacing of 55 cm. Computing the differences between the two maize varieties in number green cobs recorded per hectare, BHQPY-545 gave statistically higher number of cobs than Melkassa-II at inter-row spacing of 65, 75 and 85 cm. This could be attributed to genetic differences that exist between maize varieties with respect to yield, and its components and ability to combine traits between maize cultivars as response to plant density. This is similar to finding of Odeleye and Odeleye (2001) who reported maize varieties differ in their growth characteristics, yield and its components and therefore suggested that breeders must select most promising varieties which have the ability to combine good traits in their breeding programs.

3.3.5. Above ground fresh biomass

Analysis of variance indicated that main effect of inter-row spacing and variety had highly significant (P<0.01) and inter-row spacing x variety had significant (P<0.05) effect on above ground fresh biomass, while the main effect of intra-row spacing and all other interaction effect did not show significant effect.(Appendix Table 4).

Statistically highest fresh biomass yield of 51.3 and 48 ton ha^{-1} was obtained at 55 cm inter-row spacing for variety BHQPY-545 and Melkassa-II respectively while the lowest above ground fresh biomass yield of 33.2 ton ha^{-1} was obtained at wider row spacing of 85 cm for variety Melkassa-II (Table 5). In general, fresh biomass yield was increased with decreased inter-row spacing for both maize varieties. The increases in above ground fresh biomass yield with lower inter-row spacing (higher plant densities) could be due to more number of plants in per unit area of land for both varieties.

There was significant difference of above ground fresh biomass yield between the two maize varieties at widest inter-row spacing and variety BHQPY-545 was performed better as compared variety Melkassa-II. Although the difference was statistically not significant at the inter-row spacing of 55 cm, variety BHQPY-545 gave significantly higher biomass as at inter-row spacing of 65, 75 and 85 cm as compared with variety Melkassa-II. This result agrees the finding of Tolera *et al.*, (1999) who suggested that breeders should select maize varieties that combine high yield with desirable stover characteristics because of the large differences that exist between cultivars.

This result is also in line with the finding of Dicu *et al.,* (2016) who reported that the lowest fresh biomass yield of 30.7 tons ha^{-1} was obtained at row spacing of 75 cm (at plant density of 100,000 plants.ha^{-1}) while the highest fresh biomass yield of 32.5 tons ha^{-1} was obtained at row spacing of 37.5 cm (plant density of 120,000 plants ha^{-1}) for two maize hybrids tested. Similarly, Aslam *et al.,* (2011) reported that dry matter accumulation was much in high plant densities compared to low plant densities.

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Table 5. Effects of inter-row spacing x variety on number of cobs per plant, number of cobs per hectare and above ground fresh biomass (ton ha^{-1}) of maize

Treatments	Maize Varieties					
	Melkassa-II			BHQPY-545		
	NCPP	NCPH	AGFB (ton/ha)	NCPP	NCPH	AGFB (ton/ha)
Inter-row spacing(cm)						
55	1.03^{d}	61739.39b^{abc}	48.0^{ab}	1.07^{cd}	65232.32^{a}	51.3^{a}
65	1.10^{bcd}	57493.68^{c}	43.6^{d}	1.18^{b}	63052.99^{ab}	48.9^{ab}
75	1.10^{bcd}	49924.52^{d}	38.4^{e}	1.33^{a}	61452.89^{abc}	47.1^{bc}
85	1.15^{bc}	47738.95^{d}	33.2^{f}	1.42^{a}	59000.13^{bc}	44.2^{cd}
LSD (0.05)	0.086	4365.591	3.32	0.086	4365.591	3.32
CV (%)	6.2	6.4	6.4	6.2	6.4	6.4

Where, LSD (0.05) =Least Significant Difference at 5% level; NS=Non-Significant; NCPP=Number of Cobs per Plant; NCPH=Number of Cobs per Hectare; AGFB=Above Ground Fresh Biomass; CV=Coefficient of Variation. Means in column followed by the same letters are not significantly different at 5% level of significance.

3.4. Economic Analysis

To assess the cost benefit related to different treatments, the partial budget analysis techniques of CIMMYT (1988) was applied. From the partial budget analysis summary (Table 6), the highest net return of 197788.64 with an acceptable marginal return rate of 4086.04% and 192081.35 Birr ha^{-1} with an acceptable marginal return rate of 25961.41% was obtained for variety BHQPY-545 and Melkassa-II respectively from spacing combinations of 55 cm x 25 cm (72727 plants ha^{-1}) followed by 65 cm x 25 cm spacing combinations (61538 plants ha^{-1}) that gave net return of 192302.32 Birr ha^{-1} for BHQPY-545 while the lowest net economic return was obtained at the spacing combinations of 85 cm x 30 cm (39215 plants ha^{-1}) for both varieties (Table 6).This indicates that for both maize varieties, 55 x 25 cm gave the highest and 85 cm x 30 cm the lowest economic return.

The currently used spacing combination of 75 cm x 30 cm (plant population of 44444 plants ha^{-1}) gave an economic return of 136190.95 Birr ha^{-1} and 171771.66 Birr ha^{-1} for Melkassa-II and BHQPY-545 respectively. Thus, the use of 55 cm inter-row spacing with 25 cm intra-row spacing (72727 plants ha^{-1}) resulted in 29.1% economic return increments to Melkassa-II and 13.15% increment to BHQPY-545 maize variety than economic return from that of the currently used inter- and intra-row spacing of 75 cm x 30 cm (44444 plants ha^{-1}). Thus, using inter-row spacing of 55 cm and intra-row spacing of 25 cm (72727 plants ha^{-1}) resulted in higher increment to the number of green cob maize income from that of the currently used practice by the farmer's (44444 plants ha^{-1}). This result is in line with the finding of Trinh *et al.,* (2008) who obtained higher net economic benefit from higher planting density.

Table 6. Partial budget analysis of inter-row and intra-row spacing on maize varieties

Treatment	ACY	AFBY (ton/ha)	CYR (Birrr/ha)	FBYR (ton/ha)	GR (Birr/ha)	TVC (Birr/ha)	NR (Birr/ha)	MRR (%)
85 x 30xV1	39845.88	28.98	119537.64	14490	134027.64	9223.92	127403.72	1381.23
75 x 30xV1	42064.02	33.3	126192.06	16650	142842.06	9251.11	136190.95	32317.87
85 x 25xV1	46084.24	30.78	138252.72	15390	153642.72	9264.71	146978.01	79316.61
75 x 25xV1	47800.13	35.82	143400.4	17910	161310.4	9286.67	154613.07	23406.06
65 x 30xV1	48984.62	38.07	146953.85	19035	165988.85	9297.33	159302.18[D]	
55 x 30xV1	52592.72	42.12	157778.17	21060	178838.17	9335.15	172103.02	26404.37
65 x 25xV1	54504	40.41	163512	20205	183717	9340.00	176977.00	100494.43
55 x 25xV1	58898.18	44.37	176694.53	22185	198879.53	9398.18	192081.35	25961.41
85 x 30xV2	49255.29	38.97	147765.87	19485	167250.87	9490.59	160360.28	1662.28
75 x 30xV2	52600	41.85	157799.99	20925	178724.99	9553.33	171771.66	18188.34
85 x 25xV2	56944.94	40.59	170834.83	20295	191129.83	9584.71	184145.12	39431.10
65 x 30xV2	54418.46	43.65	163255.39	21825	185080.39	9635.38	178045.01[D]	
75 x 25xV2	58015.2	43.02	174045.59	21510	195555.59	9660.00	188495.59	42447.52
55 x 30xV2	56872.73	45.54	170618.18	22770	193388.18	9747.27	186240.91[D]	
65 x 25xV2	59076.93	44.46	177230.78	22230	199460.78	9758.46	192302.32	54168.09
55 x 25xV2	60545.46	46.89	181636.37	23445	205081.37	9892.73	197788.64	4086.03

Where, IRS=Inter-Row Spacing; INRS=Intra-Row Spacing; V=Variety; V1=Variety 1 (Melkassa-II); V2=Varity 2 (BHQPY-545); ACY=Adjusted Cob Yield, AFBY=Adjusted Fresh Biomass Yield, CYR=Cob Yield Return, FBYR=Fresh Biomass Yield Return, GR=Gross Return, NR=Net Return, TVC=Total Variable Costs, D=Dominated Treatment

4. SUMMARY AND CONCLUSION

The results of the present study concluded that the highest green cob number and biomass yield was obtained at spacing combination of 55cm inter row spacing and 25 cm intra row spacing for maize varieties tested in the area. Comparing the two maize varieties tested, BHQPY-545 maize variety was superior to Melkassa-II maize variety in most agronomic parameters and economic returns. Therefore, it can be recommended for use by farmers to produce BHQPY-545 maize variety with 55 cm x 25 cm spacing combinations for more profitable production of maize as green cob.

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APPENDICES

Appendix Table 1. Mean square values of ANOVA for phenological parameters of maize varieties as affected by inter- and intra-row spacing

		Mean Squares		
Sources of Variations	df	Days to 50% Tasseling	Days to 50% Silking	Days to Late Milk Stage
Block	2	3.083	4.771	20.27
Inter-row Spacing	3	36.722	34.806	46.06
Intra-row Spacing	1	5.333	0.750	4.08
Variety	1	468.750	507.000	2760.33
Inter-row x intra-row spacing	3	0.278	0.028	0.58
Inter-row spacing x Variety	3	0.139	1.500	0.28
Intra-row spacing x Variety	1	0.083	0.333	0.08
Inter-row x Intra-row spacing x Variety	3	0.250	2.500	0.14
Error	30	2.039	2.726	11.18
CV		1.8	2.0	2.5

Where df=Degree of freedom; CV=Coefficient of Variation

Appendix Table 2. Mean square values of ANOVA for plant height, leaf area and leaf area index of maize varieties as affected by inter-and intra-row spacing

		Mean Squares		
Sources of Variations	df	Plant Height (cm)	Leaf Area (cm2)	Leaf Area Index
Block	2	33.83	9458.00	0.00466
Inter-row Spacing	3	903.55**	1941187.00**	2.59250
Intra-row Spacing	1	33.00	334167.00	3.88754
Variety	1	14008.33**	7696809.00**	2.08306
Inter-row x intra-row spacing	3	82.05	1875.00	0.01416
Inter-row spacing x Variety	3	148.25**	200221.00**	0.03490
Intra-row spacing x Variety	1	24.37	3763.00	0.01998
Inter-row x Intra-row spacing x Variety	3	104.26*	38311.00	0.00772
Error	30	27.14	31642.00	0.01350
CV		2.0	2.6	3.2

Where df=Degree of freedom; CV=Coefficient of Variation; * and **=significantly different at 5% and 1% level of significance

Appendix Table 3. Mean square values of ANOVA for stand count percentage, cob length and cob weight of maize varieties as affected by inter-and intra-row spacing

		Mean Squares		
Sources of Variations	df	Stand Count (%)	Cob Length (cm)	Cob Weight (gm)
Block	2	1.163	1.189	1563.000
Inter-row Spacing	3	70.136**	31.061**	4151.000
Intra-row Spacing	1	22.963**	6.021	408.000
Variety	1	25.521**	339.203**	1122.000
Inter-row x intra-row spacing	3	3.826	0.333	101.000
Inter-row spacing x Variety	3	1.870	4.714*	26.000
Intra-row spacing x Variety	1	2.083	0.053	2.000
Inter-row x Intra-row spacing x Variety	3	5.807*	0.584	23.000
Error	30	1.829	1.221	8533.000
CV		1.4	4.4	8.6

Where df=Degree of freedom; CV=Coefficient of Variation; * and **=significantly different at 5% and 1% level of significance

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Appendix Table 4. Mean square values of ANOVA for number of cobs per plant, number of cobs per hectare and above ground fresh biomass of maize varieties as affected by inter-and intra-row spacing

		Mean Squares		
Sources of Variations	df	Number of Cobs Per Plant	Number of Cobs Per Hectare	Above Ground Fresh Biomass (ton/ha)
Block	2	0.023333	54220000	5.358
Inter-row Spacing	3	0.120764**	247500000**	267.573**
Intra-row Spacing	1	0.038542	466200000	45.047
Variety	1	0.285208**	760400000**	601.375**
Inter-row x intra-row spacing	3	0.001875	3392000	0.070
Inter-row spacing x Variety	3	0.035208**	49350000*	35.380*
Intra-row spacing x Variety	1	0.001875	929000	3.685
Inter-row x Intra-row spacing x Variety	3	0.000764	2195000	0.290
Error	30	0.005333	13710000	7.944
CV		6.2	6.4	6.4

Where df=Degree of freedom; CV=Coefficient of Variation; * and **=significantly different at 5% and 1% level of significance