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Effects of Spacing on Growth and Green Cob Yield of Maize Under Supplementary Irrigation in Eastern 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 area cultivated 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 9° 26' N latitude and 42° 03' E longitude, at an altitude of 1980 m a. s. l), Ethiopia from October 2020 to January 2021 to determine the effects of inter and intra-row spacing on growth, green cob number and biomass yield of maize (melkesa-II maize variety) under supplementary 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 and three intra-row spacing (20 cm, 25 cm and 30 cm) with three replications. Data were collected on growth, green cob number and biomass yield and analyzed using SAS, (2002). The experiment result revealed that leaf area index, number of cobs per plant, cob length, number of cobs harvested per hectare and above ground fresh biomass yield and their interactions were highly significantly ($P<0.01$) affected by inter and intra-row spacing while cob diameter was significantly ($P<0.05$) affected by inter and intra-row spacing. The highest cob number harvested (90313 ha^{-1}) was recorded at narrowest inter and intra-row spacing of 55 cm x 20 cm while the lowest cob number harvested p (45098 ha^{-1}) was recorded from at widest inter and intra-row spacing of 85 cm x 30 cm (Table 8). Similarly, the highest fresh biomass yield of 31.27 and 28.66 ton ha^{-1} was obtained at 55 cm and 65 cm inter-row spacing respectively. In general, significantly higher number of marketable green cobs and above ground fresh biomass yield were obtained at closer inter-and intra-row spacing for melkesa-II maize variety tested in the study area. Therefore, it can be concluded that spacing combination of 55 cm x 20 cm favored attaining of higher green cob number and above ground fresh biomass yield of melkesa-II maize variety in the area under irrigation.

Keywords: Phenology, Green Cob, Spacing, Biomass, Leaf Area Index

1. Introduction

Maize (Zea mays L.) is the most important cereal crop that ranks third, after wheat and rice in hectarage and total production [1]. It is recognized worldwide as a strategic food and feed crop that provides an enormous amount of protein and energy for humans and livestock. Its advantages in the ethanol industry also keep maize in high demand.

Ethiopia is among the countries in which maize is highly cultivated and utilized for different purpose. It ranks second after teff in area coverage and first in total production. Maize is one of the most important cereals broadly adapted worldwide [2]. It is the top ranking cereal in grain yield per hectare and is the most productive species of food crops and its demand is projected to increase by 50% worldwide and by 93% in sub-Saharan Africa between 1995 and 2020 [3].

Maize grows well below 500 to over 2400 m.a.s.l, the major production zone being between 1000 to 2000 m.a.s.l in Ethiopia. It is currently grown across 13 agro-ecological zones, which together cover about 90 percent of the country. Moreover, it is an increasingly popular crop in Ethiopia. It is grown on an area of 2,367,797.39 hectares, with total annual production of 7,847,174.66 tons and productivity of 3.675 tons ha^{-1} 2018 cropping season. Grain crops, i.e. cereals, pulses and oilseeds, cover the total land areas of about 12,772,191.221 hectares. Out of which 80.71%

(10,232,582.23 hectares) was under cereals. Teff, maize, sorghum and wheat took up 23.85% (about 3,023,283.50 hectares), 16.79% (about 2,128,948.91 hectares), 14.96% (1,896,389.29 hectares) and 13.38% (1,696,907.05 hectares) of the grain crop area, respectively [4].

Considering its importance in terms of having wider adaptation, higher total production and higher productivity, compared to other crops, maize has been selected as one of the high priority crops to feed the ever-increasing human population of Ethiopia. Past research, efforts in Ethiopia resulted in the development and release of open-pollinated (OPV) and hybrid varieties for the different agro-ecologies of the country [5]. However, the national average yield is still 3.38 t ha^{-1}, which is far below the world average of 5.5 t ha^{-1} [6]. The yield of maize is less in Ethiopia (3.38 t ha^{-1}) when compared to other countries like Spain (11.4 t ha^{-1}), Germany (10.7 t ha^{-1}), USA (10.7 t ha^{-1}), Italy (10.6 t ha^{-1}), Canada (9.4 t ha^{-1}), Egypt (7.8 t ha^{-1}), Argentina (6.8 t ha^{-1}) and South Africa (5.3 t ha^{-1}) [7].

One of the greatest challenges in maize production is poor agronomic practices including maintaining appropriate inter-row spacing and intra-row spacing of maize crop. The plant spacing has serious effect on crop yields under both rain fed and irrigations, which could ultimately affect productivity and quality of the crop. There are different recommendations made for plant spacing in maize. The national recommendation made for maize spacing is 30 cm between plant and 75 cm between rows. However, there is no spacing recommendation made for maize production under irrigations. Farmer especially at Haramaya District practice of plant spacing is traditional. There is no or few previous studies on plant inter- and intra- row spacing on yield and yield components of maize. Due to this, the farmers in the district are getting very low numbers of green cabs. In addition, the effect of plant inter-and intra-row spacing on crop growth and yield reduction is still not known and the same needs to be investigated at Haramaya District, little effort was made to determine optimum agronomic requirement of maize crop. Thus, proper plant inter-and intra-row spacing need to be determined for optimum green cop maize yield at the study area. Therefore, the objective of this study was to investigate the effect of plant inters-and intra-row spacing on growth parameters, green cob yield and yield components of maize under supplementary furrow irrigation.

2. Materials and Methods

2.1. Description of the Study Area

2.1.1. Location

The field experiment was conducted at Haramaya, Ethiopia during 2020/21 dry season from November to January. Haramaya is located in east Harerghe zone of Oromia regional state and found at 530 km from Addis Ababa in the eastern direction.

2.1.2. Climate

The climate of the study area is situated in the semi-arid tropical belt of eastern Ethiopia. It is characterized by a sub-humid type tropical climate with an average annual rainfall of 790 mm, annual mean temperature of 17°C with mean minimum and maximum temperature of 8.3°C and 25°C, respectively. The rainy season of the area is bimodal where the short rainy season stretches from March to May and the main rainy season from June to September.

2.1.3. Geology and Soil

The main geo-morphological unit of the experimental area was recognized as the recent alluvial plain, which resulted from the Haramaya Lake. Alluvial sandy loam deposits were dominated the irrigated and Mountainous/hill lands, and out-washed gravely Aerosol on non-irrigated plains. The soil type in the experimental field is almost sandy loam, where 75-80% of the experimental area was defined as plain land.

2.1.4. Land Uses

All the land uses of the area are agriculture farming systems. Agricultural crops such as khat, (Catha *edulis* FORRESK) maize, sorghum, onion, tomato, pepper, banana, guava, sugarcane, kazmir, and mango characterize mainly the land use pattern of the study area.

2.2. Experimental Materials

In this study, maize variety Malkasa II, which was released in 2004 EARO, [8] was used. It is mainly cultivated under both rain fed and irrigation farming systems in Awash Valley. It matures in 90–120 days. It was accepted both by producers, consumers and was successfully produced by both small farmers and commercial growers. Melkasa II is a lowland maize, performing well in agro-ecological climate at low moisture stress with rainfall ranging from 600-1000 mm. It gives 5500-6500 kg/ha and 4500-5500 kg/ha yield on-station and on-farm experiments, respectively. It is moderately tolerant to disease and lodging with plant height of 170-190 cm (Crop Variety Register Issue No. 12, 2009). The nationally recommended blended NPS rate of 100 kg ha^{-1} and urea of 50 kg ha^{-1} was used.

2.3. Treatments and Experimental Design

The treatments consisted of three intra-row spacing of (20, 25, 30) cm and four inter- row spacing (55, 65, 75, 85) cm. The experiment was laid out in a randomized complete block design (RCBD), in a factorial arrangement with three replication. Thus, there are 3x4 = 12 treatment combinations constituting 36 plots. There were five rows for 85 cm and 75 cm row spacing, six rows for spacing of 65 and seven rows for spacing of 55 cm. Plots size was (4.25 x 3) m, (3.75 x 3) m, (3.9 x 3) m and (3.85 x 3) m for 85 cm, 75 cm, 65 cm and 55 cm respectively. The spacing between plants was 30 cm. adjacent plots and blocks were separated by 1 m and 1.5 m spacing, respectively. Data was collected from central rows by excluding one row from each side of the plot and one plant from both ends of the row.

2.4. Irrigation Management

For the first month field was shallow irrigated at 7 interval days, while after a month until to tasseling and silking irrigation 10 to 12 days interval applied deeply by furrow system and at critical time at tasseling and silking stage field was irrigated by 4 days interval to initiate flowering and silking. Most of the time irrigation has been done after noon to avoid loses of water from the field by evaporation.

2.5. Data Collection and Measurement

2.5.1. Phenological and Growth Parameters of Maize

Days to 50% anthesis, Days to 50% silking, Leaf area, Leaf area index (LAI); Plant height (cm) and Plant height (cm) were measured.

2.5.2. Yields and Yield Component

Number of ears per plant, Ear height (cm), Number of kernels per ear, hundred kernels weight (g), Grain yield ($kg \cdot ha^{-1}$) and Harvest index were collected at the time of data collection.

2.6. Statistical Data Analysis

The measurement variables were analyzed using the statistical analysis system (SAS) as per the RCBD factorial model. Mean separation was conducted using LSD at 5% level of significance.

3. Results and Discussion

3.1. Phenological and Growth Parameters

3.1.1. Days to 50% Tasseling

The main effect of inter row spacing showed highly significant (P< 0.01) effect while intra- row spacing and the interactions did not affect significantly on days of 50% tasseling. The longest and shortest days to 50% tasseling (81.43 days) and (76.64 days) were recorded from (85 cm) and (55 cm) inter and intra row spacing, respectively, (Table 9). This could be due to higher competition of plants for resource in the closer spacing that lead the plants to stress and ultimately the plants tassel early instead of prolonged vegetative growth. These finding are in contradict with Park *et al*. [9] who reported that plant density did not affect days to tasseling.

3.1.2. Days to 50% Silking

The main effect of inter row spacing showed highly significant (P< 0.01) effect while intra- row spacing and the interactions did not affect significantly on days of 50% silking. The longest and shortest days to 50% tasseling (85.33 days) and (79.80 days) were recorded from (85 cm) and (55 cm) inter and intra row spacing, respectively, (Table 9). This could be due to higher competition of plants for resource in the closer spacing that lead the plants to stress and ultimately the plants tassel early instead of prolonged vegetative growth. These finding are in contradict with Park *et al*. [9] who reported that plant density did not affect days to tasseling.

Table 1. *Inter row spacing and intra row spacing on days to 50% anthesis, and days to 50% silking of maize.*

Inter row spacing (cm)	Days to 50% tasseling	Days to 50% Silking
85	81.43	85.33^{a}
75	79.50	83.72^{b}
65	78.19	82.04^{c}
55	76.64	79.80^{d}
LSD (5%)	0.30	0.27
Intra row spacing (cm)		
20	78.96	82.75^{ab}
25	78.85	82.57^{b}
30	79.00	82.85^{ab}
LSD (5%)	0.26	0.24
CV (%)	0.39	0.34

Means of a variable followed by the same letter are not significantly different at 5% level of significance.

3.1.3. Days to 90% Physiological Maturity

The interaction effect of inter and intra row spacing significantly influenced on days to 90% maturity (P <0.05) while inter and intra row spacing showed a highly and non-significant effect on days to 90% maturity, respectively, (Table 9). Numerically the treatments having plant population 47058.82 plants ha^{-1} (85x25 cm) took maximum days to physiological maturity (127.90 days), while the minimum (120.17 days) was recorded from spacing combination of 55x20 cm (90909.09 plant ha^{-1}) (Table 2). Plants in the high population density matured the earliest, while plants at the lower population density matured lately because of high competition for light, soil moisture and nutrients in higher population density and days to tasseling and silking of plants were earlier in higher plant population density than lower plant population density. The result of the present investigation has consistency with previous findings reported by Mengistu and Yomoah [10] who concluded that closer spacing had shortened days to maturity as compared to days of 50% silking.

Table 2. *Inter row spacing and intra row spacing on days to hard drought stage of maize.*

Inter row spacing (cm)	Days to physiological maturity		
	Intra row spacing (cm)		
	20	25	30
85	127.20^{ab}	127.90^{a}	126.37^{c}
75	126.30^{c}	126.55^{bc}	126.07^{c}
65	124.32^{d}	124.50^{d}	124.90^{d}
55	120.17^{e}	121.33^{e}	120.83^{e}
LSD (5%)	0.72		
CV (%)	0.34		

Means of a variable followed by the same letter are not significantly different at 5% level of significance.

3.2. Growth Parameters of Maize Wider Spacing

3.2.1. Plant Height

Statistical analysis of the data revealed that the interaction effect of inter and intra row spacing were a highly significantly affected (P <0.01) on plant height of maize (Table 9). Numerically among the treatments, the highest plant height was recorded from plant population of 90909.09 plants ha^{-1} at (55x20 cm) was (262.50) while the shortest plant height was produced at spacing combination of 52632 plats ha^{-1} at (85x30cm) was (227.2 cm) (Table 3). Highest plant height in closer inter and intra row spacing there might be due to the presence of higher competition for sun light, crowding effect of the plant and other resources that decrease in the stem diameter and number of green leaves. Earlier results explained that the number of plants increased in a given area, the competition among the plants for nutrients uptake and sunlight interception also increased Sangakkara *et al.*, [11]. These finding is in agreement with Hassan [12] who revealed that plant height increased with increasing plant density from 47600 to 71400 plants ha^{-1}.

Table 3. Inter row spacing and intra row spacing on plant height of maize.

Inter row spacing (cm)	Plant height (cm)		
	Intra row spacing (cm		
	20	25	30
85	230.53^{g}	238.60^{f}	227.20^{g}
75	247.10^{d}	249.90^{e}	249.10^{cd}
65	248.70^{c}	252.53^{cd}	252.70^{c}
55	257.30^{h}	262.50^{a}	258.30^{b}
LSD (5%)	3.85		
CV (%)	0.92		

Means of a variable followed by the same letter are not significantly different at 5% level of significance.

3.2.2. Leaf Area Index

Statistical analysis of the data revealed that inter row, intra row and their interaction had highly significantly (p <0.01) affected leaf area (Table 9). The highest LAI (4.30 cm^2) was recorded under 20 cm intra-row spacing with plant density of 90909.09 plants ha^{-1} and the lowest (2.2 cm^2) was observed under 30 cm intra-row spacing with 44444.44 plants ha^{-1}. Leaf area index significantly decreased as plant density increased from 38,093 plants ha^{-1} (35 cm intra row) to 90909.09 plants ha^{-1} (20 cm intra-row) (Table 4). In the current study, increase of LAI at narrowest row spacing (44444.44 plants ha^{-1}) and decrease with increasing intra-row indicates that LAI decrease as plant density increase. This study agrees with that of Kahiu *et al.*, [13] who reported that LAI is influenced by genotype, plant population, climatic condition and soil fertility. He also reported maximum LAI from the lowest plant density and minimum LAI from the highest plant density. In this case, increase in number of plants per unit area beyond optimum level could probably reduce the amount of light availability to the individual plant, especially, to lower leaves due to shading. Generally, consistent increments in LAI were observed with increased plant population density. This dramatic increase in LAI with reduced intra row spacing or with increase in the plant population density might be due to occupation of more unit area by green canopy of the plants.

Table 4. Inter row spacing and intra row spacing on Leaf area index (cm^2) of maize.

Inter row spacing (cm)	Intra row spacing (cm)		
	20	25	30
85	2.96^{cd}	3.81^{b}	2.20^{e}
75	2.70^{d}	3.27^{c}	2.86^{cd}
65	3.95^{ab}	2.89^{cd}	3.16^{c}
55	4.30^{a}	2.25^{e}	3.87^{ab}
LSD (0.05)	0.44		
CV (%)	8.20		

Means of a variable followed by the same letter are not significantly different at 5% level of significance.

3.3. Leaf Area

Statistical analysis of the data revealed that inter and intra row spacing had highly significant effect (P <0.01) on leaf area while their interaction had no significant (P >0.05) effect on leaf area (Table 9). The highest leaf area (6764.2 cm^2) was recorded from 85 cm inter-row spacing (58823.53 plants ha^{-1}) which was statistically at par with at 30cm intra-row spacing, while the lowest (6079 cm^2) was recorded from 55 cm inter-row spacing (90909.09 plants ha^{-1}) (Table 5). This might be due to that reduction of leaf area because of increasing plant density that led to the accelerated leaf senescence, increased shading of leaves, and reduced net assimilation of individual plants. This is in agreement with Kahiu *et al.*, [13] who reported that the leaf area per plant tended to decline with increasing plant density in maize. Similarly, he also reported that lower plant population got more nutrients and water compared to higher population, thus contributed increased leaf area unlike high plant population density that shown leaf area of maize decreased.

Table 5. Inter row spacing and intra row spacing on leaf area of maize.

Inter row spacing (cm)	Leaf area (cm^2)
85	6764.2^{a}
75	6456.2^{b}
65	6235.7^{c}
55	6079^{d}
LSD (5%)	0.74
Intra row spacing (cm)	
20	6384.5^{a}
25	6383.9^{a}
30	6383.1^{b}
LSD (5%)	0.64
CV (%)	1.01

Means of a variable followed by the same letter are not significantly different at 5% level of significance.

4. Yield Components and Yield of Maize

4.1. Number of Ear Per Plant

Analysis of variance revealed that the main effect of inter row, intra row spacing and their interaction effect were highly significantly (P <0.01) influenced the number of ear per plant (Table 10). The maximum number of ear per plant (1.61) was recorded at 20 x 85 cm inter and intra row spacing while the minimum number was recorded at 20 x 55 cm

(1.01) (Table 6). This study agrees with Kunoskan, [14] who report that as plant density in unit area increased the numbers of ears per plants become decrease due to competition among the plants. The result also in line with Zamir *et al*., [15] reported significantly higher number of cobs plant-1 at lower plant density compared to higher plant density.

4.2. Ear Diameter

Statistical analysis of the data shown that inter row spacing had highly significant effect (P <0.01) on ear diameter while the intra row spacing and their interaction had significant (P >0.05) effect on ear diameter (Table 10). Numerically thickest mean value of ear diameter (4.78) were recorded from 85 cm inter row spacing and its effect was statistically significant from inter row spacing of 75, 65 and 55 cm while the thinnest was (2.45 cm) recorded from 55 cm inter row spacing (Table 6). Wider inter row spacing had maximum ear diameter because of availability of more resources and competition is less when we compared with narrow (intra) row spacing for nutrients, sunlight and soil moisture. These finding was in disagreement with Zamir *et al*. [15] who reported that inter and intra row spacing interaction did not show significant difference on ear diameter.

Table 6. *Inter row spacing and intra row spacing on ear diameter and number of ear per plant of maize.*

Inter row spacing (cm)	Ear diameter			Number of ear per plant		
	Intra row spacing (cm			Intra row spacing (cm)		
	20	25	30	20	25	30
85	4.54^{ab}	4.67^{a}	4.78^{a}	1.61^{a}	1.47^{b}	1.45^{bc}
75	4.21^{bc}	4.02^{cd}	4.26^{bc}	1.40c^{d}	1.38^{d}	1.36^{d}
65	3.33^{e}	3.83^{d}	3.90^{cd}	1.21^{f}	1.27^{e}	1.17^{f}
55	2.99^{ef}	2.45^{g}	2.94^{gh}	1.01^{g}	1.01^{g}	1.01^{g}
LSD (5%)	0.38			0.056		
CV (%)	5.87			2.60		

Means of a variable followed by the same letter are not significantly different at 5% level of significance.

4.3. Ear Length

Statistical analysis of the data revealed that the effect of inter row, intra row and their interaction effect had highly significant effect (P>0.01) on ear length (Table 10). Statistical analysis result showed that the increase in ear length became progressively smaller as planting density increased. The highest ear length (26.41 cm) was recorded at 85 cm while lowest cob length (20.95 cm) was recorded at 55 cm (Table 7). These results are in line with Shafi *et al.* [16] who announced that because of interplant competition ear length was decreased at higher plant populations.

4.4. Plant Stand Count Percent at Harvest

The analysis of variance showed that inter row spacing, intra row spacing and their interaction were highly significantly (P<0.01) on plant stand count (Table 10). The highest stand count of 97.33% and the lowest stand count of 89.52% were recorded at inter-row and intra-row spacing of 85 cm x 20 cm and 55 cm x 20 cm respectively (Table 7). This is in agreement with Kena [17] who reported that plant stands count percent increased from 89.52% to 97.33% by increasing the inter row from 55 cm to 85 cm respectively. Eskandarnejada *et al*. [18] reported that higher plant stand count percent (98%) was achieved due to the wider spacing combinations of 75 cm x 30 cm than narrower spacing of 55 cm x 20 cm.

Table 7. *Inter row spacing and intra row spacing on ear length and stand count of maize.*

Inter row spacing (cm)	Ear length			Stand count % at harvest		
	Intra row spacing (cm)			Intra row spacing (cm		
	20	25	30	20	25	30
85	26.41^{a}	26.20^{ab}	26.03^{abc}	97.33^{a}	96.67^{ab}	96.00^{b}
75	25.42^{d}	25.71^{cd}	25.76^{bcd}	95.00^{c}	93.33^{d}	94.00^{d}
65	23.13^{e}	21.32^{g}	22.48^{f}	91.77^{e}	91.33^{e}	91.33^{e}
55	21.38^{g}	20.95^{g}	21.01^{g}	89.52^{g}	90.48^{f}	90.00^{fg}
LSD (5%)	0.45					
CV (%)	1.10					

Means of a variable followed by the same letter are not significantly different at 5% level of significance.

4.5. Number of Cobs Harvested Per Hectare

Analysis of variance for cobs harvested showed that there was highly significant interaction effect (P <0.01) among inter and intra row spacing (Table 10) on cobs harvested per hectare. Plant population of 90909.09 plants ha^{-1} (55x20 cm) had significantly produced higher cobs harvested (90313) as compared to the others. On the other hand, the lowest mean cob harvested (45098) was recorded from plant population of 39215.68 plants ha^{-1} (85x30cm) (Table 8). Generally closest inter and intra row spacing resulted in higher number of cobs harvested ha^{-1}. This is due to higher number of plants harvested in closer spacing as compared to wider spacing. It is clear from the result that number of cobs harvested ha^{-1} increased in response to increasing plant density and also possibly due to higher LAI, plant height, number of cobs per plant and biomass yield in the treatment of high plant population density of 90909.09 plants ha^{-1} (55x20 cm) and 76923.07 plants ha^{-1} (65x20 cm) respectively. As spacing increased from 55x20 cm to 65x20 cm number of cobs harvested ha^{-1} decreased from 90313 ha^{-1} to 82653 ha^{-1}. This is due to low plant population harvested ha^{-1} in wider spacing. Thus, balanced growth and development of plants need optimum plant density because optimum density enables plants efficient utilization of available nutrients, soil water and better light interception coupled with other growth influencing factors. The result shows that as inter and intra row spacing decrease there was a linear increase in many cobs harvested due to plant density increase leads to cob weight increase and directly grain yield increase. Similar report by Allessi and Power [19] revealed that maize cob weight decreased with increased plant population.

4.6. Above Ground Biomass (Ton ha^{-1})

Statistical analysis of the data revealed that inter row, intra row and their interaction had highly significantly (p <0.01) affected biomass yield (Table 10). The Maximum biomass yield 31.27 ton ha^{-1} and 28.66 ton ha^{-1} were produced by plant population of 90909.09 plants ha-1 (55x20 cm) and 76923.07 plants ha^{-1} (65x20 cm) respectively (Table 8). On the other hand, the minimum biomass yield was obtained from plant population of 39215.68 plants ha^{-1} (85x30 cm) (15.78 ton ha^{-1}) and 44444.44 plants ha^{-1} (75 x 30 cm) (17.11 ton ha^{-1}) (Table 8). The result showed that biological yield was increased by increasing plant density due to high grain yield, LAI, number of grain per ear and plant height in the treatment of high plant population density of 90909.09 plants ha^{-1} (55 x 20cm). This result is in line with the finding of Dicu *et al.* [20], 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.

Table 8. *Inter row spacing and intra row spacing on number of cob per ha and above ground biomass (ton ha^{-1}) of maize.*

Inter row spacing (cm)	Number of cobs harvested (kg ha^{-1})			above ground biomass (ton ha^{-1})		
	Intra row spacing (cm)			Intra row spacing (cm		
	20	25	30	20	25	30
85	66681^{f}	52036^{j}	45098^{l}	23.00^{e}	18.21^{i}	15.78^{k}
75	73000^{c}	58667^{h}	48822^{k}	25.33^{c}	20.53^{g}	17.11^{j}
65	82653^{b}	67692^{e}	54396^{i}	28.66^{b}	23.69^{d}	19.04^{h}
55	90313^{a}	71858^{d}	61212^{g}	31.27^{a}	25.15^{c}	21.42^{f}
LSD (5%)	918.48			0.442		
CV (%)	0.84			1.16		

Means of a variable followed by the same letter are not significantly different at 5% level of significance.

5. Conclusions and Recommendations

Maize is one of the major grain crops in Ethiopia in terms of both production and consumption. Even though it is such an important crop in Ethiopia, its green cob yield is low as compared to its potential yield due to many production constraints such as minimum use of improved varieties, low soil fertility and plant population, Spacing, management activity, lack of location specific fertilizer recommendation in Ethiopia in general and in Eastern Oromiya zone. Among agronomic practices, intra and inter spacing require special attention. Therefore, the present study was carried out to determine the effects of intra and inter row spacing on growth and green cob yield of maize, to estimate the most optimum inter and intra row plant spacing for green cob and above ground biomass yield of maize under Haramaya, Eastern Ethiopia.

The analysis of variance indicated that interaction effect of inter and intra row spacing on days to 50% tasseling, days to 50% silking, leaf number and leaf area were not significant. The interaction effect of leaf area index and plant height were highly significant while days to 50% physiological maturity was significant. The interaction effect of inter and intra row spacing on number of green cobs per hectare, stand count, ear length, ear diameter, number of ear per plant and biomass yield per hectare were highly significant. The maximum number of days to 50% tasseling (81.43), days to 50% silking (85.33) and days to 50% physiological maturity (127.90) were recorded at 85 cm, 85 cm and 85x25 cm respectively while their minimum value recorded at 55, 55 and 55x20 cm respectively. The highest leaf area index (4.30 cm2), plant height (262.5 cm), leaf area (6764.2) were recorded at 55 x 20 cm, 55 x 25 cm and 85 cm respectively.

The results of study indicated that increasing spacing further from 55x20cm to 65x30cm decreased number of cobs harvested per yield significantly and from 55x20cm to 85x30cm decreased biomass yield significantly similarly decreasing spacing from 55x25cm to 55x20cm decreased leaf area index, days to 50% physiological maturity number of cobs harvested and biomass yield significantly. From this experimental result it can be concluded that the maximum number of cobs harvested per hectare and biomass yield per hectare was recorded with 55x20cm inter and intra row spacing treatment combination using melkassa-II maize variety which contradicted the previous recommendation 75x30cm inter and intra row spacing resulted in the production of biomass yield. Therefore, it is advisable for farmers in the study area to produce melkassa-II maize variety under irrigation using 55x20cm inter and intra row spacing to achieve maximum number of cobs yield and biomass yield than the other treatment combination. Future line of work, since the experiment was conducted for one season, off season and in one location using one variety additional one to two seasons under rain fed condition, different growing season, involving different varieties and Promoting action research and increasing awareness through training and demonstration of melkassa-II maize is suggested to come up with conclusive result.

Appendix

Table 9. *Analysis of variance (ANOVA) for days to 50% anthesis, 50% Silking, hard drought stage, plant height, Leaf area (cm^2) and leaf area index (cm^2) of maize.*

Source of variation	DF	Phenology and growth parameters					
		DT	DS	PH	DPM	LA	LAI
Replication	2	0.15	0.23	3.85	0.46	0.32	0.25
Inter row spacing (A)	3	37.05 **	50.32**	1175.84**	68.66**	793845**	0.61**
Intra row spacing (B)	2	0.07^{ns}	0.25^{ns}	7.80^{ns}	0.60^{ns}	6.16**	0.78**
A X B	6	0.16^{ns}	0.12^{ns}	53.88**	0.57*	0.73^{ns}	1.95**
Error	22	0.09	0.08	5.17	0.18	0.57	0.068

DF=degree freedom; DT=days to 50% tasseling; DS=days to 50% silking; PH=plant height; DPM=days to physiological maturity; La=Leaf area; LAI= Leaf area index; ***, **** Significant at 1% and 5%.

Table 10. *Mean square values of yield components of maize as influenced by Inter row spacing and Intra row spacing.*

Source of variation	DF	Yield and yield components parameters					
		SC	EL	ED	NEPP	CWPH	AGB
Replication	2	0.52	0.25	0.11	0.12	0.10	0.26
Inter row spacing (A)	3	77.88**	55.81**	5.71**	0.42**	7883005**	84.33**
Intra row spacing (B)	2	1.09**	0.88**	0.18*	0.011**	4200044**	231.38**
A X B	6	1.08**	0.67**	0.15*	0.0073**	350593**	1.39**
Error	22	0.16	0.068	0.02	0.0011	5.66	0.067

DF=degree freedom; SC=stand count; EL=Ear length; ED=ear diameter; NEPP=number of ear per plant; CWPH=cob weight per ha; AGB=above ground biomass; ***, **** Significant at 1% and 5% probability level, respectively.

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