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RESEARCH PAPER

Yield and Growth Indices of Hybrid Maize (Zea mays L.) as Influenced by Inter and Intra Row Spacing

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A B S T R A C T:
To study the yield and indicators of biological development of hybrid maize a field experiment was conducted during the main cropping season under irrigation conditions in late of July to October in 2020 and 2021 at Ankawa Research Center and Qushtapa zones of northern Iraq to evaluate the impacts of inter and intra row spacing on growth development, yield components, and yield of hybrid maize. One maize hybrid (CASH F1) was used in the experiment. The experimental design was a Factorial Randomized Complete Block Design (RCBD) with three replications. Treatments were three inter-row spacing's of (55 cm, 65 cm and 75 cm) with three intra row spacing's of (25 cm, 30 cm and 35 cm) replicated thrice making a total of nine plots. At 15-day intervals, Dry matter partition, growth rate characteristics, and dry matter accumulation of distinct plant sections were all collected. Almost all yield and production indexes showed considerable variances, according to the findings. Plant and ear height were significantly impacted by the major influence of inter, intra row spacing and locations. Inter and intra row spacing (55 cm × 25 cm) and (75 cm × 30 cm) combination gave the taller ear and plant height. Accordingly, crop growth rate CGR and relative growth rate RGR gave the highest mean values at the interaction combinations inter and intra row spacing (75 cm × 30 cm) and (75 cm × 35 cm).

KEY WORDS: Maize, Growth Indices, Crop growth rate, Relative growth rate.
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1. INTRODUCTION:

Maize (*Zea mays* L.) is a member of the Poaceae (Gramineae) family and has a substantially higher grain protein content than rice. In comparison to rich countries, maize production in underdeveloped countries is low. Low productivity can be caused by a variety of factors. Mismanagement of plant density is seen as the most serious of these factors. As a result, in order to increase maize production, this important component of production technology must be improved. Maize productivity is much more influenced by plant population density than other members of the grass family because of its limited tillering capacity, monoecious floral organization, and short blooming time.

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(Vega *et al*., 2000 and Sangoi *et al., 2002*). However, there is no clear relationship between maize yield and plant density. According to (Stanger and Lauer, 2007). Most plants in a concentrated populace stay barren; ear and ear size remain less important, the crops become sensitive to lodging, infection, and insects, and population of plants at sub-optimal levels results in poorer produce for each unit area. Plensicar and Kustori (2005) reported that increasing planting density resulted in the highest biological yield. The percentage of leaves was unaffected by plant density, according to (Sharratt and McWilliams, 2005), However, as plant density increased, the fraction of stems risen (Oktem and Oktem, 2005). Seeds row spacing is an agronomic practices consideration management approach utilized by farmers to optimize soil and plant ecosystem husbandry with the purpose of boosting agricultural yields from sowing to harvest. Crop row spacing has an impact on canopy architecture, which is a defining feature that influences how light, water, and nutrient are used. Crop phenological is one of the highly significant characteristics of determining crop output and accurately predicting phenology; as a result, it is vital to forecasting physiological reactions in a variety of field circumstances (Hodges, 1991). Summaries of prior data (1970s and 1980s) from several research on maize plant population densities show that planting densities in the range of 4-7 plants/m^2 resulted in higher yields, Debelle *et al*., (2002). Later research demonstrated that in humid environments, medium to late maize maturity groups provided the highest yields at 5-7 plants/m^2, while early maturity groups generated the highest yields at greater densities in both humid and moisture stress areas, Debelle *et al*., (2002). Plant population density has an impact on crop growth and yield, especially in maize. Because of the increasing number of smaller cobs per unit area, increased plant populations could contribute to improved yields under ideal climatic and management circumstances Bavec & Bavec (2002). Population of plants is the most important aspect in achieving maximum production, which is determined by crop inter and intra-row spacing. In any given plant population, reducing the space between neighbor rows offers various potential benefits. Firstly, because of a more equidistant plant layout, decreases competition for light, water, and nutrients among plants within rows (Sprague and Dudley, 1988). Crops can benefit from shorter rows and/or higher population densities while competing against weeds. Narrow rows and/or higher population densities accelerate canopy closure and increase canopy radiation interception, resulting in higher crop growth rates and yields. (Andrade *et al*., 2002). Optimal maize populations vary with soil fertility, moisture status, variety used and time of planting (Sangoi, 2001). Calculating growth functions is used to describe how or more plant species react to a specific environmental circumstance. Environmental conditions will change significantly between years and within any one year for different treatments, such as planting date or location, in many experiments. These environmental variables muddle growth function comparisons for crops treated the same way for two or more years, or for crops treated differently in the same season. (Russelle *et al*., 1984 and Islam *et al*., 2019). The purpose of this paper is to assess the variation of biomass accumulation and plant growth rate at various phases of development and to demonstrate inter and intra row spacing as the divisor in growing study function crop growth rate and relative growth rate, using data from two previously completed experiments.

2. MATERIALS AND METHODS

2.1. Description of the Experimental Site

The chosen field trials were done at farmer’s and agriculture research center fields in the Ankawa and Qushtapa zones of northern Iraq in the main cropping season of 2020-2021 under irrigation conditions at Qushtapa and the Ankawa Research Center. At an altitude of 1980 meters above sea level, the site is located at 35.26'N latitude and 42.03'E longitude. The area's rainfall distribution is bimodal, describing the months of the two seasons. In 2021, the total amount of rainfall for the cropping season (October to March) was 549.2 mm, with mean maximum and lowest temperatures of 45 degrees Celsius and 10 degrees Celsius, respectively. During the 2021 cropping season, the overall quantity of rainfall was 184.2 mm, with 142.4 mm in the Ankawa zone and 22 °C in the Qushtapa zone. The soil at the test site is a deep alluvial with good drainage with a sandy clay loam and a silty clay texture in the subsoil. Samples were gathered from air dried soil in the field at a depth of 0 - 30 cm and evaluated for a variety of physical and chemical parameters, as given in the table (Table 1).

Table 1. Some selected properties of the soil at the experimental sites for both locations.

Soil sample	EC dSm^{-1}	pH	Total N %	P (ppm)	K (ppm)	O.M%	Classification			
							Clay%	Silt %	Sand%	Texture Class
Ankawa	0.3	7.82	0.11	6.3	196	0.92	38	43	19	Silty Clay
Qushtapa	0.3	7.74	0.12	9.6	253	0.95	42.7	46.3	18.7	Loam

2.2. Treatments and Experimental Design

One maize hybrid (CASH F1) was used in the experiment. The experimental design was a Randomized Complete Block in a factorial arrangement with three replications. The treatments were three inter-row spacing's of (55 cm, 65 cm and 75 cm) with three intra row spacing's of (25 cm, 30 cm and 35 cm) replicated thrice making a total of nine plots. The plot's total size was (4.5m × 2.2m) = (9.9 m2) the length and width are 4.5 m and 2.2m, respectively and accommodating 8, 7 and 6 rows for all 55cm, 65cm and 75cm inter-rows, respectively and 9, 7 and 6 number of plants for all 25cm, 30cm and 35cm intra-rows respectively. The net plot area was delineated by leaving two border rows at both sides of each plot. For a 5% level of significant, data are shown by error bars with standard errors identified with (Duncan, 1975) letters.

2.3. Management of the Experiment

In late July 2021, three seeds per hole were sowed after the earth had been thoroughly prepared. At the beginning of the first month of planting watering applied every day, then strategically reduced the watering to twice in three days, then to once every two days, and then watered as needed. When seedlings produced three to four leaves, each hill was thinned to a single plant. All additional agronomic treatments, such as hand weeding three times, harvesting was executed manually (October 2021) according to their seed dryness, to both experimental plots in accordance with the research area's recommendations for maize.

2.4. Physiological study

Every 15 days from plant establishment, randomly five samples collected from the inner lines of each plot for a total length of one meter for hybrid maize (DAS). The samples were dried for 48 hours at 60 degrees Celsius, and CGR ($g\ m^{-2}d^{-1}$) and RGR ($mg\ g^{-1}d^{-1}$) were calculated using conventional equations (Radford, 1967).

2.5. Estimation of Growth Indices

The RGR is the daily accumulation of dry matter relative to the existing plant dry weight, while the CGR is the daily output of plant dry matter per land unit area (Warren, 1981). Measurement of various mean rates changes in plant masses was used to conduct the growth analysis. The following formulas (Aliabadi *et al*., 2008) were used to calculate the compound growth rate (CGR) and absolute growth rate (AGR) at each interval:

1- Crop Growth Rate (CGR).

$$CGR\ (g\ m^{-2}d^{-1}) = w_2 - w_1 / t_2 - t_1$$

W_2 and W_1 = Plant dry matter (g) at time 2 and time 1, respectively.

T_2 and T_1 = Physical times (days)

2- Relative Growth Rate (RGR)

$$RGR\ (mg\ g^{-1}d^{-1}) = (\text{loge } w_2 - \text{loge } w_1) / (t_2 - t_1)$$

In = Natural logarithm (e = 2.718)

3. RESULTS AND DISSCUTION

3.1. Effect of combined location on some vegetative and reproductive traits.

Plant height is a critical growth metric that is influenced by both genetic and environmental factors. The result in figure 1 shows that all the parameters tested have significant variances ($P \leq 0.05$). The larger plant height, ear height and grain yields (62.69 cm, 151.78 cm and 166.21gm) respectively, were shown at Qushtapa location, as compared to Ankawa with the mean values of these traits (51.73 cm, 137.80 cm and 100.92 gm) respectively.

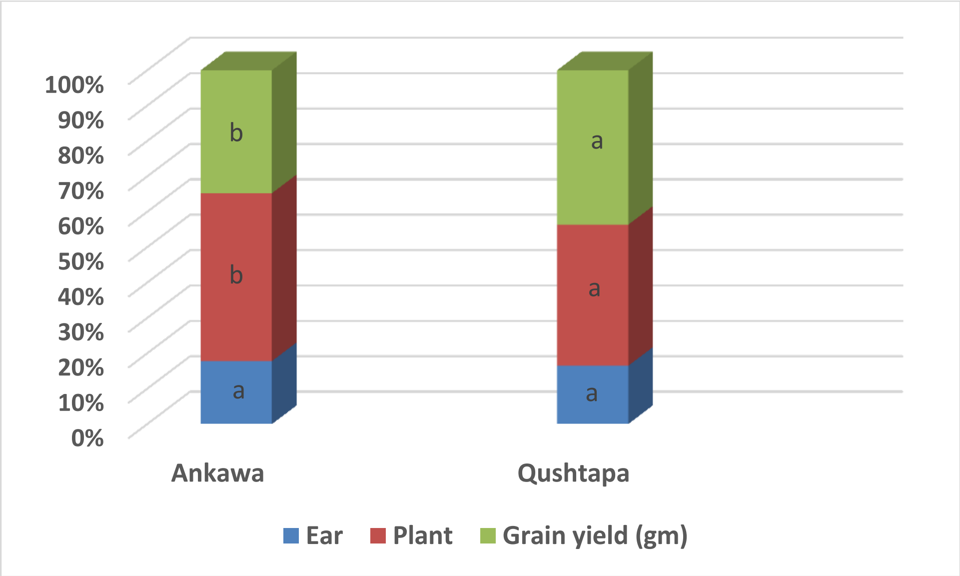


Figure 1: Effect of combined location on some vegetative and reproductive traits.

3.2. Effect of inter row spacing on some vegetative and reproductive traits.

Figure (2) disclosed that grain yield recorded the highest significant ($P \leq 0.05$) mean value of (137.82 g), in inter row spacing (55 cm), although the lowest mean value was (128.86) in inter row spacing (75 cm) respectively. However, ear and plant height were confirmed non-significant differences ($P \geq 0.05$) in inter row spacing (55 cm, 65 cm and 75 cm) respectively.

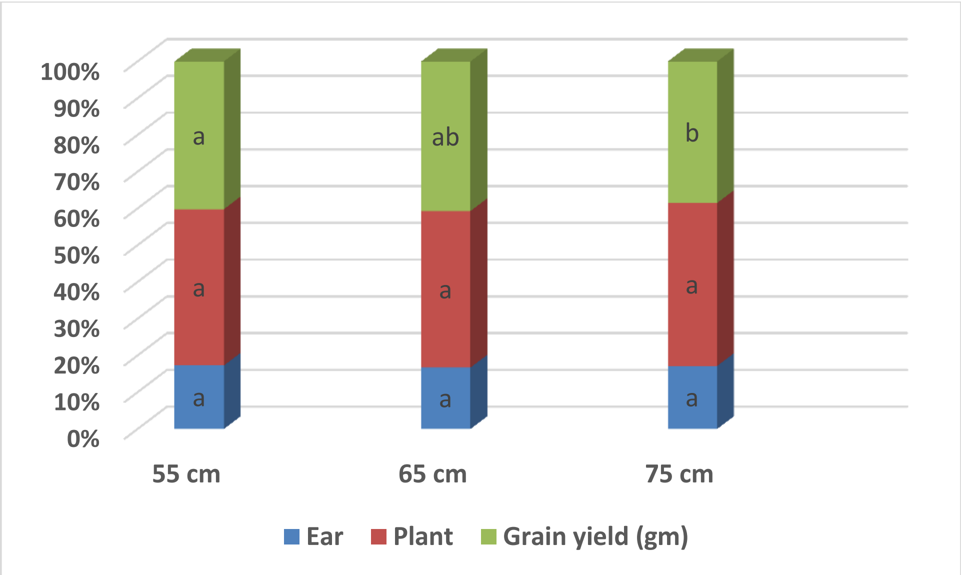


Figure 2: Effect of inter row spacing on some vegetative and reproductive traits.

3.3. Effect of intra row spacing on some vegetative and reproductive traits.

Ear height displayed in figure (3) reveals significant variations (P ≤ 0.05) in wide variation, the maximum mean value was (60.83 cm) in intra row spacing (25 cm), while the minimum mean value was recorded in intra row spacing (35 cm) respectively. Plant height and grain yield were confirmed non-significant differences at (P ≥ 0.05) by inter row spacing.

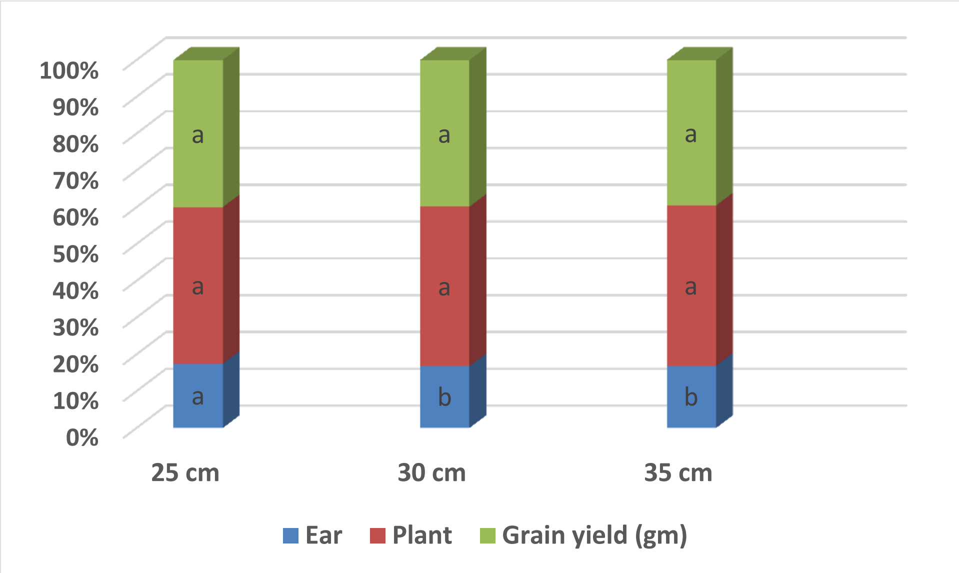


Figure 3: Effect of intra row spacing on some vegetative and reproductive traits.

3.4. Effect of interaction inter row spacing × intra row spacing on some vegetative and reproductive traits.

Figure (4) shows that the higher mean of ear height with a value of (150.40cm) was recorded at the interaction of (75cm inter × 30cm intra row spacing) followed by the value of (61.87 cm) in ear height at the interaction of (55 cm inter × 25 cm) intra row spacing. While the lowest mean value of (50cm) was recorded at interaction (65 cm inter × 30 cm intra row spacing). However, grain yield possessed non-significantly differences (P ≥ 0.05) by the interactions between inter and intra row spacing.

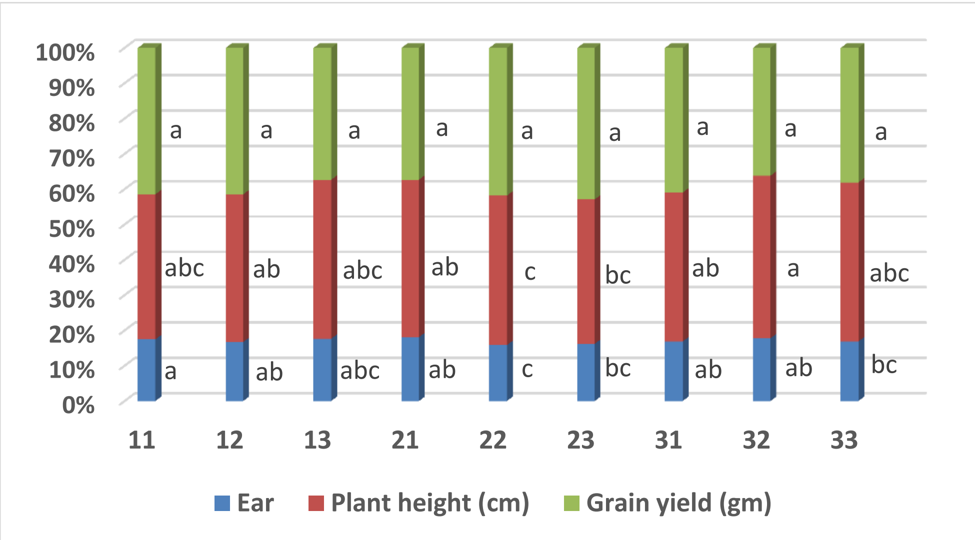


Figure 4: Effect of interaction inter row spacing intra row spacing on some vegetative and reproductive traits.

Note: 11: (55 cm × 25 cm), 12: (55 cm × 30 cm), 13: (55 cm × 35 cm), 21: (65 cm × 25 cm), 22: (65 cm × 30 cm), 23: (65 cm × 35 cm), 31: (75 cm × 25 cm), 32: (75 cm × 30 cm), 33: (75 cm × 35 cm)

3.5. Effect of interaction location × inter row spacing on some vegetative and reproductive traits.

The data presented in figure (5) turns out significant differences (P ≤ 0.05). The higher mean values of (64.2 cm, 159.47 cm and 171.77 gm) were recorded in ear height, plant height and grain yield at interaction Qushtapa location with (inter row spacing 75 cm × 55 cm) respectively, whereas the lower mean values (49.82 cm, 134.82 and 97.60 gm) were reached at interaction combination Ankawa with (inter row spacing 65 × 75 cm) respectively, as compared to other interaction between row spacing with the locations.

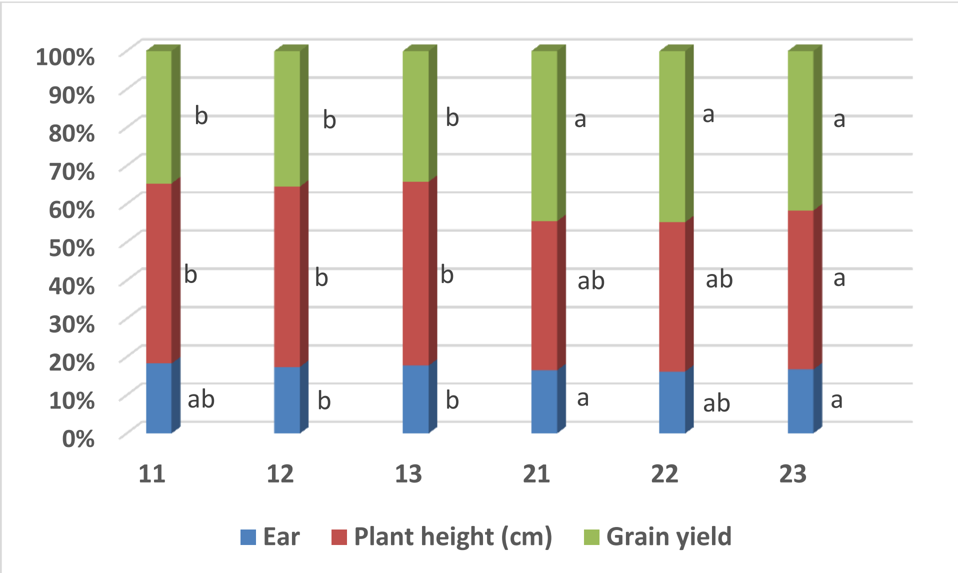


Figure 5: Effect of interaction location × inter row spacing on some vegetative and reproductive traits. Note: 11: (Ankawa×55cm), 12: (Ankawa×65cm), 13: (Ankawa×75cm), 21: (Qushtapa×55cm), 22: (Qushtapa×65cm), 23: (Qushtapa×75cm)

3.6. Effect of interaction location × intra row spacing on some vegetative and reproductive traits.

Statistical analysis of the data in figure (6) revealed that maximum mean values (68.91 cm, 156.3 cm and 175.7 gm) were recorded in ear height, plant height and grain yield at Qushtapa location with interaction treatments (intra row spacing 25 cm) respectively, while the minimum mean values (51.44 cm, 136.9 and 100.73 gm) were reached at Ankawa location with interaction treatments (intra row spacing 30 × 35 cm) respectively.

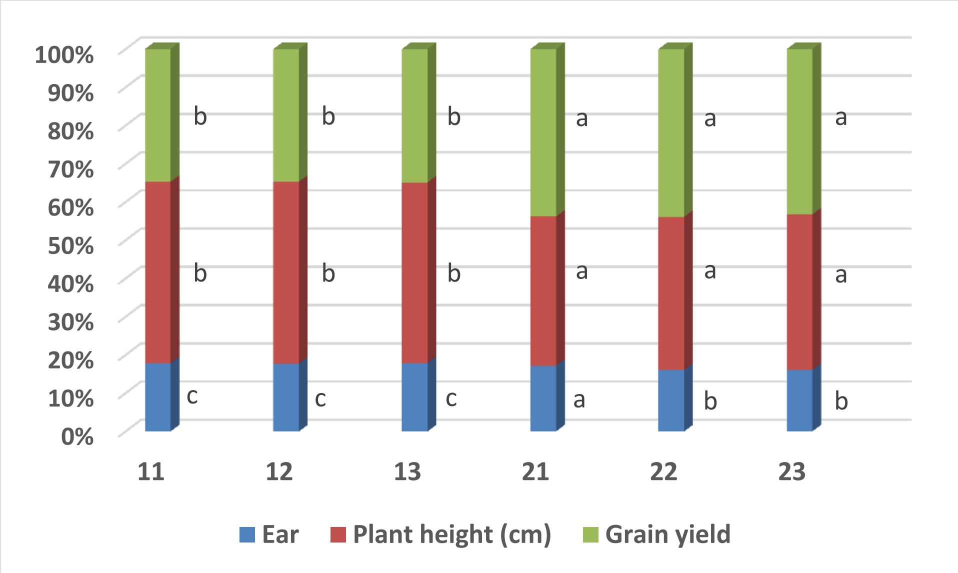


Figure 6: Effect of interaction location × intra row spacing on some vegetative and reproductive traits.

Note: 11: (Ankawa×25cm), 12: (Ankawa×30cm), 13: (Ankawa×35cm), 21: (Qwshtapa×25cm), 22: (Qwshtapa×30cm), 23: (Qwshtapa×35cm)

3.7. Effect of interaction location with inter and intra row spacing on some vegetative and reproductive traits.

The findings of the change inquiry in Table (2) shows that the highest mean values of ear height, plant height and grain yield were reached at the interaction of Qushtapa location with (inter and intra row spacing 55 cm × 25 cm and 75 cm × 25 cm) with their mean values (69.40 cm, 160.87 cm, 187.70 gm) respectively, whereas the lowest mean values of these traits were (46.00 cm, 132.67 cm and 92.53 gm) recorded at the interaction of treatment between Ankawa location with (inter and intra row spacing 55 cm × 30 cm, 55 cm × 35 cm and 75 cm × 30 cm) respectively.

Table 2. Interaction effect of location with inter and intra row spacing on some vegetative and reproductive traits.

Location×Inter row spacing ×Intra rowspacing	Ear Height (cm)	Plant height (cm)	Grain Yield (gm)
111	54.33 b-f	139.4 def	106.87 bc
112	55.20 b-f	141.93 b-f	109.60 bc
113	54.87 b-f	142.60 b-f	95.17 c
121	51.13 def	138.73 def	94.73 c
122	46.00 f	133.07 f	100.07 c
123	52.33 def	132.67 f	109.07 bc
131	50.07 ef	136.13 ef	101.20 c
132	53.13 c-f	140.07 c-f	92.53 c
133	48.53 ef	135.60 ef	99.07 c
211	69.40 a	151.80 a-e	187.20 a
212	63.40 ab	154.60 a-d	184.50 a
213	57.80 b-e	144.60 b-f	143.60 abc
221	68.67 a	156.27 abc	152.20 abc

222	55.20 b-f	137.33 def	167.40 ab
223	57.07 b-e	143.00 b-f	180.60 a
231	68.67 a	160.87 a	187.70 a
232	63.07 abc	160.73 a	144.10 abc
233	60.93 a-d	156.80 ab	148.57 abc

Note: 111: (Ankawa×55×25), 112: (Ankawa×55×30), 113: (Ankawa×55×35), 121: (Ankawa×65×25), 122: (Ankawa×65×30), 123: (Ankawa×65×35), 131: (Ankawa×75×25), 132: (Ankawa×75×30), 133: (Ankawa×75×35), 211: (Qwshtapa×55×25), 212: (Qwshtapa×55×30), 213: (Qwshtapa×55×35), 221: (Qwshtapa×65×25), 222: (Qwshtapa×65×30), 223: (Qwshtapa×65×35), 231: (Qwshtapa×75×25), 232: (Qwshtapa×75×30), 233: (Qwshtapa×75×35)

Ear height and plant height (cm)

Ear height and plant heights differed significantly (P 0.05) caused by genetic changes in hybrid maize. There is also a significant difference in ear height due to the smallest inter and intra-row spacing between plants, which is determined by location, under narrow space the plants compete each other on light, nutrient and other factors which affect the growth, yield. This discrepancy might be due to a type of soil texture for both locations and altitude and latitude on a couple of sides. Similarly, these results are in conformity with the results obtained by (Azam *et al*., 2007; Karasu, 2012, Anjorin and Ogunniyan, 2014 and Kebede, 2019) they stated that plant and ear heights are the very essential yield factor includes in maize, the higher the ear height the more the number of ears that can grow from the node underneath.

3.8. Effect of Interaction combined location on biological weight, crop growth rate, and relative growth rate.

The results of analysis of variance in figure (8) showed that the highest mean value of biological weight and crop growth rate were reached at Qushtapa location, while the lowest mean value of these traits were reached at Ankawa location, their mean values were (22.16 gm, 38.42 gm, 21.77 gm m^{-2} d^{-1}, 36.94 gm m^{-2} d^{-1}, 0.038 mg g^{-1} d^{-1}) and (15.91 gm, 27.02 gm, 15.59 gm m^{-2} d^{-1}, 25.96 gm m^{-2} d^{-1}, 0.033 mg g^{-1} d^{-1}) respectively. Compared to other interaction between row spacing and locations. However, combined locations didn't show any significant differences (P ≥ 0.05) in relative growth rate in the two growth stages.

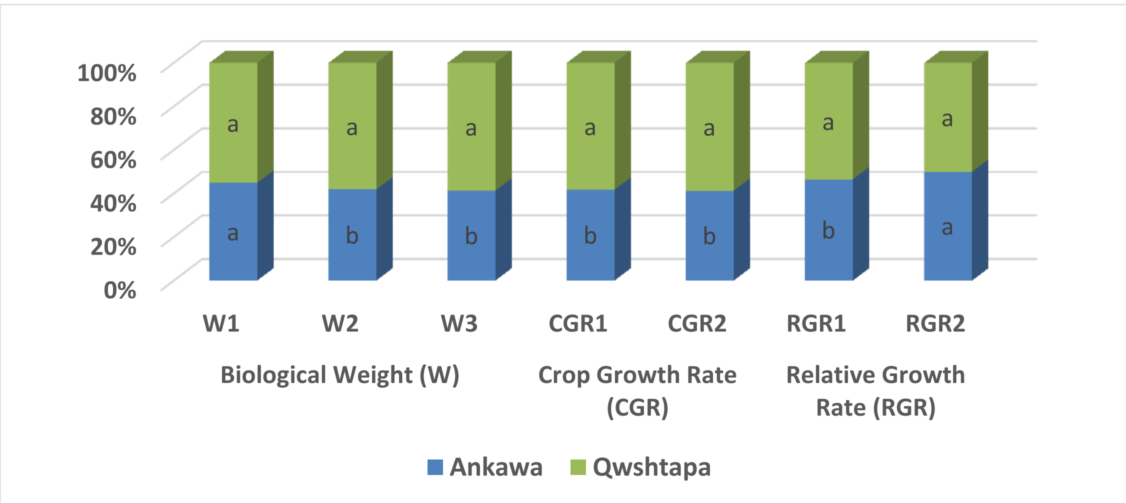


Figure 8. Effect of interaction combined locations on biological weight, crop growth rate, and relative growth rate.

3.9. Effect of inter row spacing on biological weight, crop growth rate, and relative growth rate.

Figure (9) shows that inter-row spacing didn't possess any significant differences at 5% probability among biological weight, crop growth rate and relative growth rate respectively.

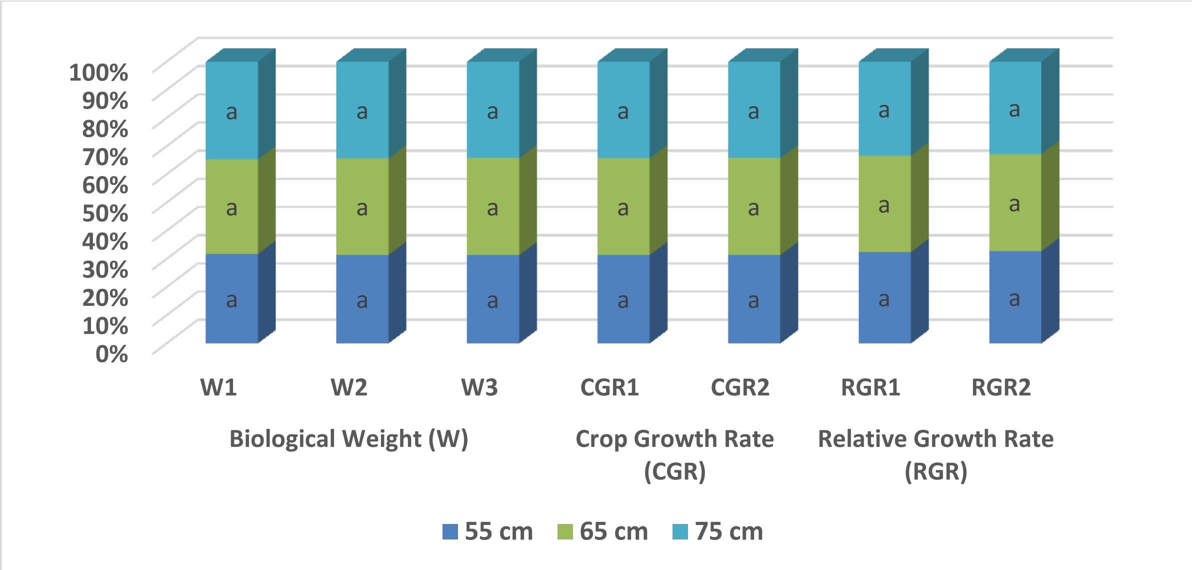


Figure 9. Effect inter row spacing on biological weight, crop growth rate, and relative growth rate.

3. 10. Effect intra row spacing on biological weight, crop growth rate, and relative growth rate.

The data presented in figure (10) shows that the maximum mean value of the relative growth rate was reached at intra row spacing 25 cm, whereas the minimum mean value of these traits reached at intra row spacing 30 cm, their mean values were (0.019 and 0.017 mg g^{-1} d^{-1}) respectively. Biological weight and crop growth rate doesn't affect significantly ($P \geq 0.05$) by intra row spacing at both two growth stages.

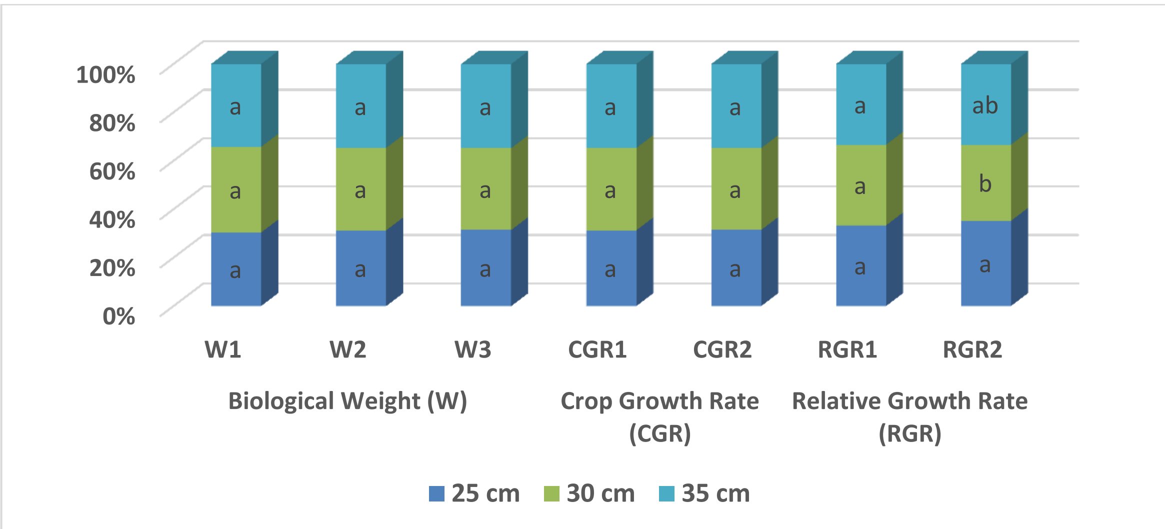
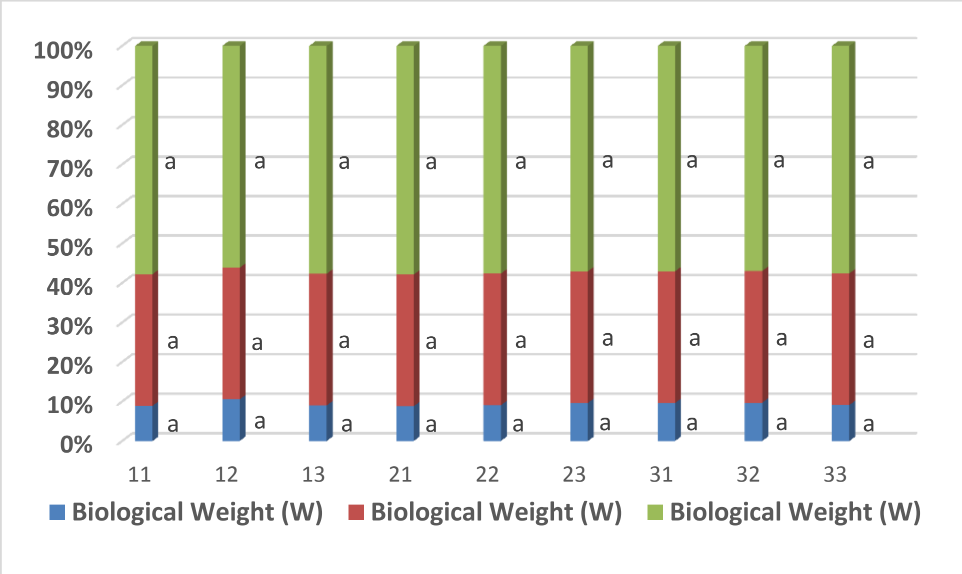


Figure 10. Effect intra row spacing on biological weight, crop growth rate, and relative growth rate.

3.11. Effect interaction inter row spacing × intra row spacing on biological weight, crop growth rate, and relative growth rate.

The results of biological weight, relative growth rate and crop growth rate assumed in figure (11) confirm non-significant differences (P ≥ 0.05) in the inter and intra-row spacing separately.



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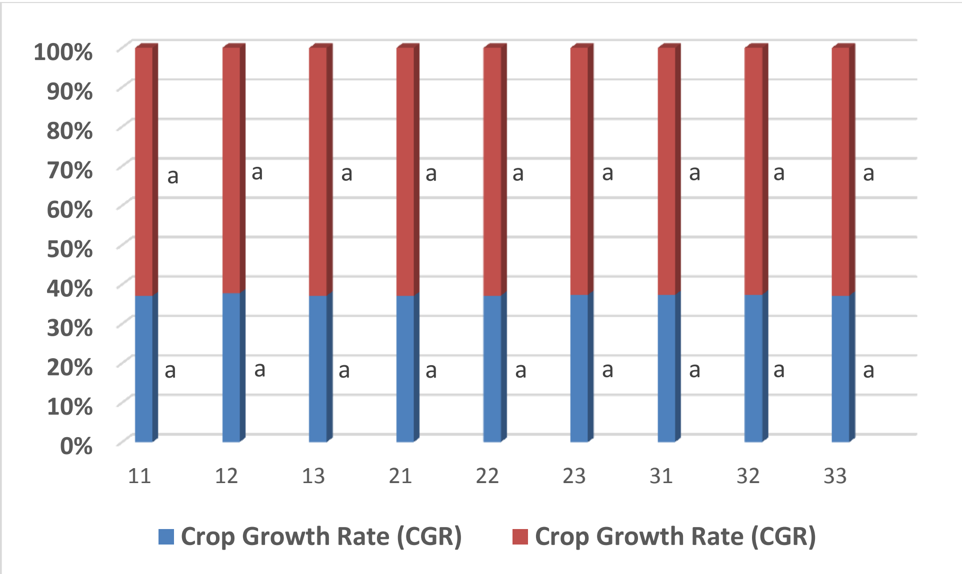

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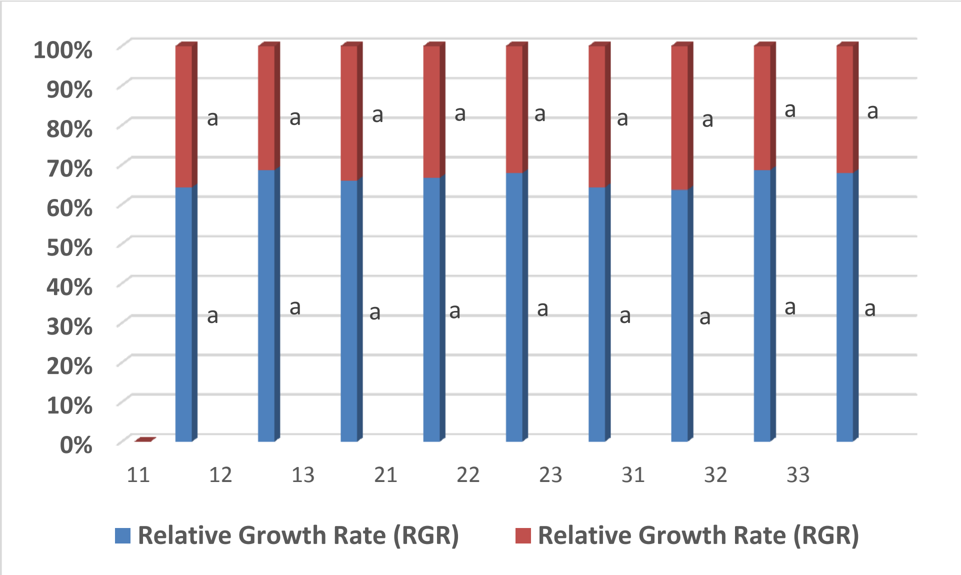
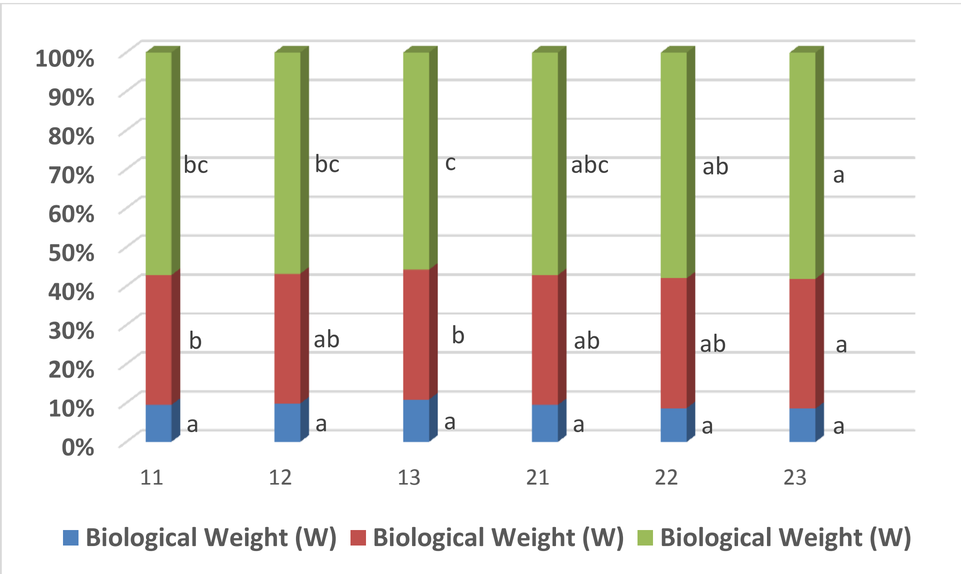


c.

Figure 11[abc]. Interaction inter row spacing × intra row spacing on biological weight, crop growth rate, and relative growth rate.

3.12. Effect of interaction location × inter row spacing on biological weight, crop growth rate, and relative growth rate.

The data shown in figure (12) shows that the higher significant mean value of biological weight and crop growth rate were possessed at the interaction combination between Qushtapa with inter row spacing 75 cm, while the lowest mean values of these traits possessed at the interaction combination between Ankawa Research Center with inter row spacing 75 cm, their mean values were (23.95 gm, 41.74 gm, 23.54 gm m^{-2} d^{-1}, 40.15 gm m^{-2} d^{-1}, and 15.26 gm, 25.53 gm, 14.93 gm m^{-2} d^{-1}, 24.51 gm m^{-2} d^{-1}) respectively.



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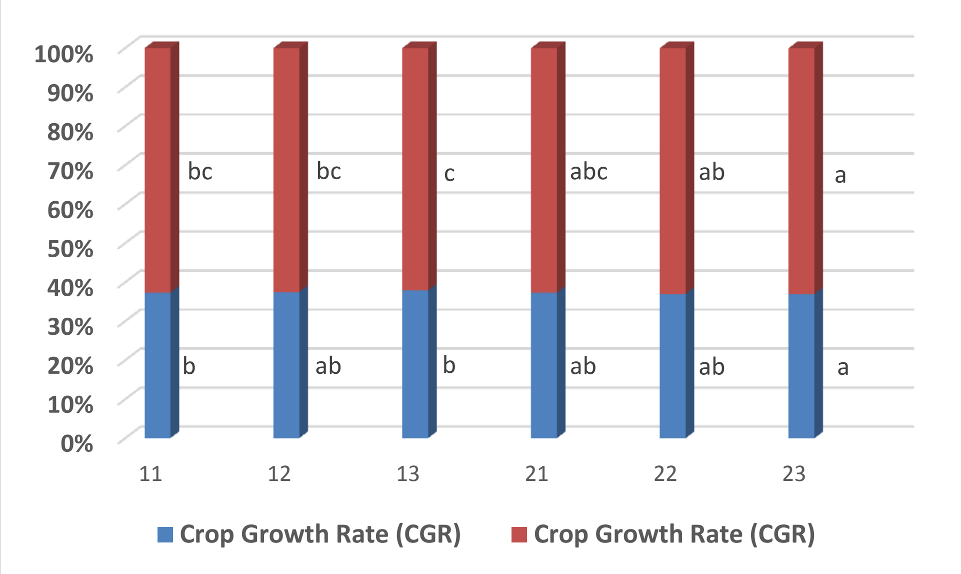

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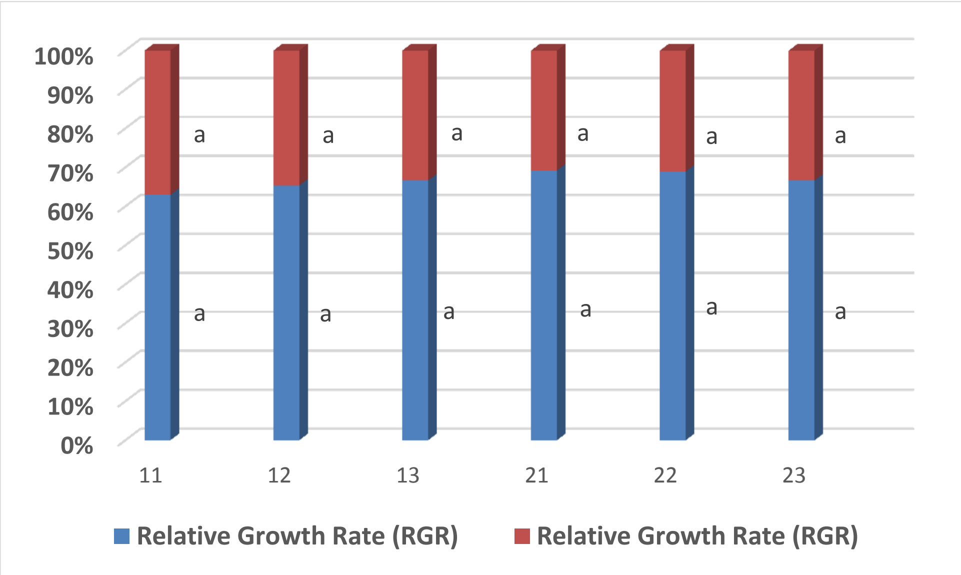
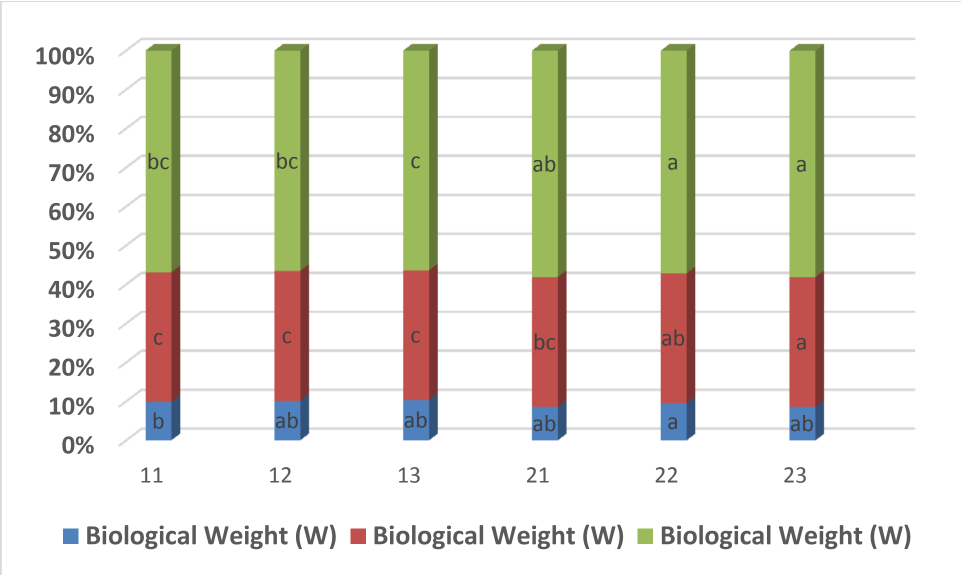


c.

Figure 12[abc]. Effect interaction location × inter row spacing on biological weight, crop growth rate, and relative growth rate.

3.13. Effect of interaction location × intra row spacing on biological weight, crop growth rate, and relative growth rate.

Figure 13 shows that there are significant differences ($P \leq 0.05$) between all the parameters tested. The maximum significant mean value of biological weight recorded at interaction Qushtapa location with intra row spacing 30 cm, while the minimum mean value of these traits reached at Ankawa location with intra row spacing 25 cm, their mean values for biological weight W_1 were (6.51 gm and 4.69 gm) respectively. Biological weight W_2, W_3, crop growth rate CGR_1 and CGR_3 possessed the highest and lowest mean value at interaction Ankawa with intra row spacing 30 cm, and Qushtapa with intra row spacing 35 cm with their mean values of (23.92 gm, 41.68 gm, 23.51 gm m^{-2} d^{-1}, 40.09 gm m^{-2} d^{-1}, 15.69 gm, 26, 53 gm, 15.37 gm m^{-2} d^{-1} and 25.48 gm m^{-2} d^{-1}) respectively. The higher mean value of relative growth rate RGR_1 and RGR_2 showed at interaction Qushtapa with intra row spacing 35 cm, 25 cm (0.040 mg g^{-1} d^{-1} and 0.020 mg g^{-1} d^{-1}) respectively, while the lower mean value showed at interaction Ankawa with intra row spacing 25 cm and Qushtapa with intra row spacing 30 cm (0.033 mg g^{-1} d^{-1} and 0.016 mg g^{-1} d^{-1}) respectively.



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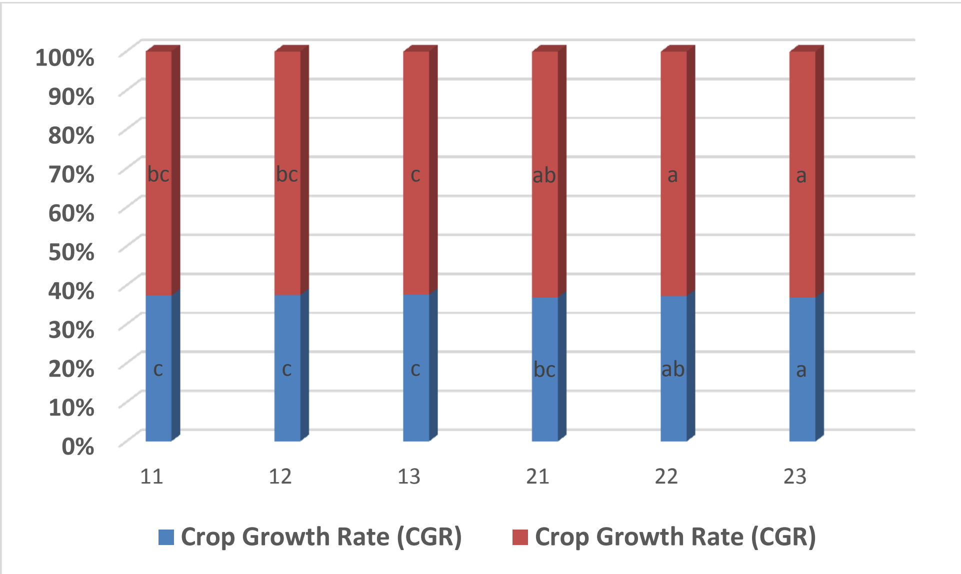

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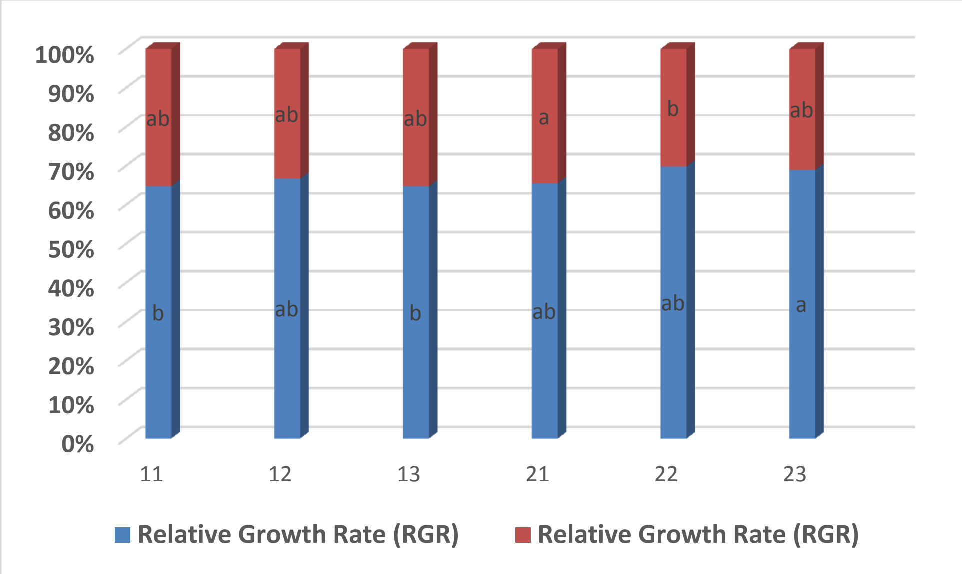

c.

Figure 13abc. Effect interaction location × intra row spacing on biological weight, crop growth rate, and relative growth rate.

3.14. Effect of interaction location × inter row spacing × intra row spacing on biological weight, crop growth rate, and relative growth rate.

Table (3) shows that the highest significant mean values of biological weight at different plant growth stages obtained at interaction Qushtapa × inter row spacing 65 cm× intra row spacing 35 cm (7.36 gm, 27.41 gm and 47.70 gm), while lowest mean values obtained at interaction Ankawa × inter row spacing 55 cm, 75 cm × intra row spacing 35 cm, 25 cm with a mean values of (4.11 gm, 15.21 gm and 23.90 gm) respectively, at different plant growth stages. Crop growth rates possessed the higher and lower mean values at the interaction Qushtapa × inter row spacing 65 cm× intra row spacing 30 cm, and Ankawa × inter row spacing 55 cm× intra row spacing 35 cm (26.94 gm m^{-2} d^{-1}, 45.88 gm m^{-2} d^{-1}) respectively. Relative growth rate obtained maximum mean values at different growth stages and at the interaction Qushtapa × inter row spacing 75 cm × intra row spacing 35 cm and Ankawa × inter row spacing 55 cm × intra row spacing 35 cm (0.043 mg g^{-1} d^{-1}, 0.020 mg g^{-1} d^{-1}), whereas the minimum mean values obtained at interaction of Ankawa × inter row spacing 75 cm × intra row spacing 30 cm (0.030 mg g^{-1} d^{-1}, 0.013 mg g^{-1} d^{-1}) respectively, as compared with other interactions.

Table 3. Effect interaction location × inter row spacing × intra row spacing on biological weight, crop growth rate, and relative growth rate.

Location×Inter row spacing ×Intra row spacing	Biological Weight (W)			Crop Growth Rate (CGR)		Relative GrowthRate (RGR)	
	W_1	W_2	W_3	CGR_1	CGR_2	RGR_1	RGR_2
111.00	4.72 ab	17.09 bc	29.48 bcd	16.78 bc	28.34 bcd	0.033 ab	0.020 a
112.00	4.72 ab	16.49 bc	28.25 bcd	16.17 bc	27.15 bcd	0.036 ab	0.020 a
113.00	4.11 b	14.00 bc	23.90 d	13.73 c	22.96 d	0.033 ab	0.020 a
121.00	4.65 ab	15.78 bc	26.89 bcd	15.46 bc	25.85 bcd	0.033 ab	0.016 ab
122.00	4.66 ab	16.57 bc	28.46 bcd	16.25 bc	27.36 bcd	0.036 ab	0.020 a
123.00	5.44 ab	17.54 bc	29.64 bcd	17.18 bc	28.47 bcd	0.033 ab	0.020 a
131.00	4.72 ab	15.21 b	25.71 cd	14.90 bc	24.69 cd	0.033 ab	0.020 a
132.00	5.22 ab	15.03 bc	24.84 cd	14.69 bc	23.84 cd	0.030 b	0.013 b
133.00	5.01 ab	15.53 bc	26.04 cd	15.20 bc	25.01 cd	0.033 ab	0.016 ab
211.00	4.38 ab	17.03 b	29.67 bcd	16.73 bc	28.53 bcd	0.040 ab	0.020 a
212.00	7.08 ab	20.86 abc	34.66 a-d	20.39 abc	33.27 a-d	0.033 ab	0.013 b
213.00	5.62 ab	22.03 abc	38.45 abc	21.66 abc	36.98 abc	0.036 ab	0.016 ab
221.00	4.95 ab	20.65 abc	36.33 a-d	20.32 abc	34.96 a-d	0.040 ab	0.020 a
222.00	5.33 ab	20.31 abc	35.28 a-d	19.95 abc	33.93 a-d	0.040 ab	0.016 ab
223.00	7.36 a	26.77 a	46.17 a	26.28 a	44.39 a	0.04 ab	0.020 a
231.00	5.86 ab	21.48 abc	37.10 a-d	21.09 abc	35.67 a-d	0.036 ab	0.020 a
232.00	7.12 ab	27.41 a	47.70 a	26.94 a	45.88 a	0.040 ab	0.020 a
233.00	5.47 ab	22.95 ab	40.43 ab	22.59 ab	38.90 ab	0.043 a	0.020 a

Crop growth rate (CGR) and Relative growth rate (RGR)

There were significant differences ($P \leq 0.05$) among the location, inter and intra-row spacing in periods of crop growth rate (CGR). The rate of crop growth was increased up to 45 days after establishment (DAS) and then it was declined dramatically until harvesting. The increase in crop growth rate is attributed to the plants accumulating more dry matter and increasing the inter and intra row spacing between the plants. It began to fall after 45 DAG because, while dry matter accumulation increased after the vegetative stage, the rate of accumulation was not as high as it was during the vegetative development stage. This result agrees with the findings by Aliu, 2010; Limpinuntana *et al*., 2010, Hokmalipour and Darbandi, 2011 and Islam *et al*., 2019, they note that during the early growth stage especially after 30 DAG, the crop growth rate (CGR) increases sharply till 45 DAS then it gradually reduces. The relative growth rate (RGR) of maize hybrid showed significant difference at different growth stage. The variation result of hybrid maize was because of the variant in dry matter accumulation. Hokmalipour and Darbandi (2011) discovered the most similar results, confirming that the relative growth rate (RGR) was considerably different and observing a diminishing pattern of relative growth rate (RGR) as the crop approached maturity.

4. CONCLUSIONS

Development suggestions for proper inter and intra-row spacing are crucial agronomical practice to incline the productivity of maize. The results described that the primary impact of location had a significant influence on almost all parameters of maize hybrids. Plant and ear height was significantly affected by the main effect of inter, intra-row spacing and location. Therefore, it was revealed from this study, that inter and intra row spacing of (55 cm × 25 cm) and (75 cm × 30 cm) combination gave the taller ear and plant height. Accordingly, the crop growth rate CGR and the relative growth rate RGR gave the highest mean values for interaction combination (75 cm × 30 cm) and (75 cm × 35 cm) inter and intra row spacing.

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Conflicts of Interest

The authors assert no conflicts of interest regarding the publication of this paper.

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