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Growth and yield of *rabi* maize (*Zea mays* L.) as influenced by different varieties and crop geometries

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Abstract
The experiment was conducted at College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand with a view to study the response of different varieties of *rabi* maize (*Zea mays* L.) to crop geometries during *rabi* season of the year 2017-18. The experiment consisted of twelve treatment combinations comprised of three varieties *viz.,* V_1: HQPM 1, V_2: GAYMH 1 and GAWMH 2 and four crop geometries *viz.,* G_1: 30 cm x 30 cm; G_2: 45 cm x 20 cm; G_3: 60 cm x 15 cm and G_4: 60 cm x 20 cm. The results revealed that varietal treatment V_1 (HQPM 1) recorded significantly higher plant height at harvest. While significantly higher plant dry biomass, crop growth rate and relative growth rate at 30 and 60 DAS were recorded under varietal treatment V_3 (GAWMH 2). Among all the crop geometries, treatment G_3 (60 cm x 15 cm) recorded significantly higher plant height at 30 DAS, 60 DAS and at harvest. While significantly higher plant dry biomass, crop growth rate and relative growth rate at 30 and 60 DAS were recorded under treatment G_3 (60 cm x 15 cm). With respect to grain and straw yield, interaction effect was found significant between different varieties and crop geometries. Among all the treatment combinations, treatment combination V_2G_2 (GAYMH 1 + 45 cm x 20 cm) recorded significantly higher grain yield (6039 kg ha^{-1}) and treatment combination V_1G_3 (HQPM 1 + 60 cm x 15 cm) recorded significantly higher straw yield (10882 kg ha^{-1}).

Keywords: Crop geometries, varieties, growth, maize

Introduction

Maize (*Zea mays* L.) is the third most important cereal crop next to rice and wheat and has the highest production potential among cereals. There is no any cereal on the earth, which has so immense potentially as to maize and also gives high biological yield as well as grain yield in a short period due to its unique photosynthesis mechanism owing to C_4 mechanism and hence, occupied a place as “Queen of cereals”. Maize is nutritionally superior to most other cereals as it contains 9.0% protein, 3.4% fat, 1.1% ash, 1.0% starch fiber, 0.30% thiamine, 0.08% riboflavin and 1.9% niacin (Paliwal *et al.*, 2000) [11].

An increase in the yield of crop can be brought forward either by increasing the area under cultivation or by increasing the productivity per unit area. Since the area is limited, yield level per unit area has to be increased. Finding the optimum crop geometry that produce maximum yield per unit area under a given environmental conditions is the major concern of the Agronomist. Systemic development of agro-techniques particularly proper plant population through appropriate crop geometry and suitable cultivar are equally important to achieve higher production in a specific agro-climatic situation. Optimum crop geometry is one of the important factors for higher production, by efficient utilization of underground resources and also harvesting as much as solar radiation and in turn better photosynthates formation. The planting patterns of maize also significantly influence growth and yield parameters (Saif *et al*., 2003) [13]. In this respect, (Kandil *et al.*, 2017) [4] summarized that maize hybrids responses to agronomic characters positively which leads to increasing grain yield and consequence to get higher net income. A spatial arrangement of plant governs the shape and size of the leaf area per plant, which in turn influences efficient interception of radiant energy as well as proliferation and growth of roots and their activity. Maximum yield can be expected only when crop geometry allows individual plant to achieve their maximum inherent potential. Thus, there is need to work out an optimum crop geometry by adjusting inter and intra row spacing in relation to other agronomic factors.

Keeping all these facts in view the present field experiment was carried out to evaluate the response of different varieties of *rabi* maize (*Zea mays* L.) and crop geometries on growth and yield of maize.

Material Method

A field experiment was conducted during *rabi* season of the year 2017-18 at College Agronomy Farm, Anand Agricultural University, Anand. The soil of the experiment field was loamy sand, popularly known as "*Goradu*" soil. It is alluvial in origin, having pH of 8.10, 0.45 organic carbon, 243.42 kg ha^{-1} available N, 47.42 kg ha^{-1} available P_2O_5 and 248.20 kg ha^{-1} available K_2O. Twelve treatment combination comprising three varieties and four geometries were included in the experiment. Three varieties (V_1: HQPM 1, V_2: GAYMH 1, V_3: GAWMH 2) were allotted to main plot while four geometries (G_1: 30 cm x 30 cm, G_2: 45 cm x 20 cm, G_3: 60 cm x 15 cm, G_4: 60 cm x 20 cm) were embedded as sub plot in Split Plot Design with four replications. Seeds were dibbled at a depth of 5 cm in conventionally tilled soil on 15th November 2017 keeping the distance as per the treatment to get desired plant population. The maize crop was fertilized with recommended dose of fertilizer (120:60:00 kg N, P_2O_5 kg ha^{-1}). Total quantity of phosphorus and 50 percent of the nitrogen was applied in the soil at the time of sowing. At 25-30 DAS, top dressed 25 percent of the nitrogen. The remaining 25 percent nitrogen was top dressed at 45-50 DAS. The N was supplied through urea and phosphorous was supplied through SSP. The biometric observations for studying of individual plant characters were recorded from five randomly selected and tagged plants for easy recognition from the net plot area of each treatment. Data on various observations during the experiment period was statistically analyzed as per the standard procedure developed by Panse and Sukhatme (1967) [12].

Result and Discussion

Effect of varieties

Varieties were found non-significant with respect to plant population ha^{-1} recorded at 20 DAS as well as at harvest (Table 1). Significant influence on plant height was observed when measured at 30 and 60 DAS as well as at harvest. Significantly higher plant height of 52.90 and 191.95 cm was recorded under varietal treatment V_3 (GAWMH 2) at 30 and 60 DAS, respectively. Whereas, varietal treatment V_1 (HQPM 1) registered significantly higher plant height of 215.44 cm at harvest. The variation in the plant height of maize varieties measured during different growth stages of the crop might be due to differences in genetic characteristics of the individual varieties, including rapid growth rates, tallness or shortness of the species and depends on maturity period too. Similar line of results was also reported by Nand (2015) [9] and Scaria *et al.* (2016) [14] in different maize varieties.

Significantly higher plant dry biomass (8.25 and 75.72 g $plant^{-1}$) and lower plant dry biomass (7.22 and 70.17 g $plant^{-1}$) were noticed under varietal treatment V_3 (GAWMH 2) and V_1 (HQPM 1) at 30 and 60 DAS, respectively. It might be due to variation in plant height measured at 30 and 60 DAS as stated earlier in Table 1. These results are in corroborating with the findings of Ibeawuchi *et al*. (2008) [3] wherein, they also observed significant differences in dry matter accumulation among hybrid maize varieties and local cultivars.

Crop growth rate (CGR) of maize was remarkably influenced due to different varieties. Varietal treatment V_3 (GAWMH 2) recorded significantly higher crop growth rate of 0.27 g day^{-1} and 2.25 g day^{-1} at 0-30 DAS and 30-60 DAS, respectively. The higher CGR may be due to the variety might have higher photosynthesis rate and finally higher plant dry biomass accumulation as the dry matter of plant directly related to higher crop growth rate. It was also obvious that CGR was derived from dry matter content which also showed almost similar trend (Table 2). These results are in line of the results reported by Singh *et al*. (2015) [16]. The effect of varieties was found significant on relative growth rate wherein, significantly the highest relative growth rate of 0.070 g g^{-1} day^{-2} and 0.073 g g^{-1} day^{-2} were recorded under varietal treatment V_3 (GAWMH 2) at 0-30 DAS and 30-60 DAS, respectively. Similar line of result was also observed by Nwogboduhu (2016) [10]. He reported that sammaz 17 and 18 produced higher relative growth rate (g g^{-1} day^{-2}) than the other maize varieties.

Grain yield was significantly affected by different varieties (Table 2). In general, varietal treatment V_2 (GAYMH 1) recorded significantly the highest grain yield (5507 kg ha^{-1}). The increase in grain yield under varietal treatment V_2 (GAYMH 1) might be due to the increase in yield attributing characters *viz.*, number of seed cob^{-1}, cob $length^{-1}$ and seed index. Similar line of results was also reported by Nand (2015) in maize wherein, he noticed that variety DHM 117 out yielded than other varieties. Among all the varietal treatments, treatment V_1 (HQPM 1) lagged behind all other treatment by producing significantly the highest straw yield. The higher straw yield (9408 kg ha^{-1}) under varietal treatment V_1 (HQPM 1) may be due to variety would have utilized the available space, nutrients and water more effectively for the production of biomass towards harvest and this would have resulted in more dry matter accumulation. Similar line of result was also reported by Scaria *et al.* (2016) [14].

Effect of crop geometries

Plant population ha^{-1} recorded at 20 DAS as well as at harvest showed significant differences due to crop geometries (Table 1). Decreasing plant to plant distance there was linearly increased the plant height of maize from treatment G_1 to G_3 at 30 and 60 DAS as well as at harvest wherein, treatment G_3 (60 cm x 15 cm) recorded significantly the highest plant height (52.04, 185.57 and 216.24 cm) and treatment G_1 (30 cm x 30 cm) recorded minimum (45.43, 165.52 and 190.44 cm) plant height at 30 and 60 DAS and at harvest, respectively. The tallest plant under crop geometry of G_3 (60 cm x 15 cm) might be due to the phytochrome system of plants undergoes changes from red to far-red light ratios caused by shade as well as its proximity to neighbours to which plants respond with increased plant height (Hutchings and De Kroon, 1994) [2].

Plant dry biomass (g $plant^{-1}$) was found non-significant at 30 DAS while significant differences with respect to plant dry biomass (g $plant^{-1}$) was noticed at 60 DAS due to different crop geometries. Treatment G_3 (60 cm x 15 cm) recorded significantly higher plant dry biomass of 75.11 g $plant^{-1}$at 60 DAS. Higher dry matter production under G_3 treatment could be attributed to increased plant height and higher leaf area maintained throughout the crop growth period resulting in enhanced carbohydrate synthesis (Kumar *et al.* 2006) [6]. Besides, optimum plant density at this geometry might have promoted better light interception by the leaves, enhanced photosynthesis and carbon dioxide assimilation leading to higher dry matter production as was noticed in the present study corroborates with earlier findings of Mahdi *et al*. (2010) [7].

Crop growth rate (g day^{-1}) recorded at 0-30 days of crop remained significantly unchanged while it was significantly influence at 30-60 days of crop under different crop geometries. Treatment G_3 (60 cm x 15 cm), G_4 (60 cm x 20 cm) and G_2 (45 cm x 20 cm) remain at par with each other and found to be significantly superior over treatment G_1 (30 cm x 30 cm) with respect to recording higher values of crop growth rate at 30-60 days of crop. The possible reason of significant increase in CGR may be due to plants were healthy and vigorous under treatment G_3 and G_4 which may helped the plants to absorb water, nutrients and light more efficiently that may have resulted in the higher values of CGR. In contrast the decrease in CGR at the higher plant density (G_2 and G_1) may be due to shortage of water and nutrients availability in the dense plants that negatively affected assimilates formation and hormonal mechanism of plants at the higher plant density. Relative growth rate (g g^{-1} day^{-2}) showed non-significant influence due to different crop geometries (Table 2).

Significantly higher grain yield (5405 kg ha^{-1}) was registered under treatment G_2 (45 cm x 20 cm) while significantly the lowest grain yield (4234 kg ha^{-1}) was recorded under G_4 (60 cm x 20 cm) treatment. Plants grown with wider spacing consume more nutrients and absorb more solar radiation for efficient photosynthesis and hence, perform better at individual basis. The reason for deviation of this linearity in case of grain yield because yield does not solely depend on the performance of individual plant but rather depend on total number of grains cob^{-1} and other yield contributing characters. The results are in close conformity with those obtained by Singh *et al.* (2008) [15] they also found that geometries also influenced the grain yield of forage maize. These assumptions are confirmed by the findings of Katuwal *et al*. (2015) [5] they reported that maize grain yields were the highest at geometry of 45 cm x 25 cm. Similar line of results was also noticed for straw yield.

Interaction effect

The interaction between different varieties and crop geometries showed significant variation with respect to grain yield (Table 3). Significantly higher grain yield (6039 kg ha^{-1}) was recorded under treatment combination V_2G_2 (GAYMH 1 + 60 cm x 20 cm) as compared to rest of the treatment combinations except treatment combinations V_2G_1 (GAYMH 1 + 30 cm x 30 cm), V_3G_2 (GAWMH 2 + 45 cm x 20 cm), V_1G_3 (HQPM 1 + 60 cm x 15 cm) and V_2G_3 (GAYMH 1 + 60 cm x 15 cm). Farnham (2000) [1] concluded that optimum plant densities for narrow-row corn production are similar to those required to produce maximum yields for conventional wide-row corn production. The results confirm the findings of Kandil *et al.* (2017) [4] in different maize hybrid.

With respect to straw yield, significantly higher straw yield (10882 kg ha^{-1}) was recorded under treatment combination V_1G_3 (HQPM 1 + 60 cm x 15 cm) as compared to rest of the treatment combinations except V_3G_2 (GAWMH 2 + 45 cm x 20 cm) it was statistically comparable with each other (Table 3). Mangal *et al*. (2017) [8] also observed higher yield with hybrid variety with narrow crop geometries as compared to wider geometries.

Table 1: Growth of maize as influenced by different varieties and crop geometries

Treatments	Plant population ha^{-1}		Plant height (cm)			Plant dry biomass (g plant^{-1})	
	20 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS
Varieties: (V)							
V_1: HQPM 1	100679	100317	43.57	159.14	215.44	7.22	70.17
V_2: GAYMH 1	101120	100781	50.27	181.45	187.15	7.96	72.04
V_3 : GAWMH 2	101182	100839	52.90	191.95	201.57	8.25	75.72
SEm ±	1325	1603	1.44	4.77	5.34	0.14	1.09
CD at 5%	NS	NS	4.99	16.51	18.50	0.49	3.79
CV %	5.25	6.37	11.80	10.75	10.62	7.27	6.04
Geometries: (G)							
G_1: 30 cm x 30 cm	106701	106261	45.43	165.52	190.44	7.52	70.13
G_2: 45 cm x 20 cm	107707	107278	48.03	177.10	198.61	7.87	71.98
G_3: 60 cm x 15 cm	107556	107243	52.04	185.57	216.24	7.94	75.11
G_4: 60 cm x 20 cm	82010	81802	50.15	181.86	200.26	7.91	73.36
SEm ±	1195	1510	1.494	4.726	5.721	0.13	1.11
CD at 5%	3468	4383	4.33	13.71	16.60	NS	3.23
Interaction V x G	NS	NS	NS	NS	NS	NS	NS
CV %	4.10	5.20	10.58	9.22	9.84	6.11	5.32

Table 2: Growth attributes and yields of maize as influenced by different varieties and crop geometries

Treatments	Crop growth rate (g day^{-1})		Relative growth rate (g g^{-1} day^{-2})		Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
	0-30 DAS	30-60 DAS	0-30 DAS	30-60 DAS		
Varieties: (V)						
V_1: HQPM 1	0.240	2.10	0.065	0.069	4450	9409
V_2: GAYMH 1	0.265	2.14	0.069	0.069	5507	8262
V_3 : GAWMH 2	0.274	2.25	0.070	0.073	4827	8471
SEm ±	0.005	0.034	0.001	0.001	155	249
CD at 5%	0.016	0.11	0.003	0.003	536	862
CV %	7.26	6.20	5.28	5.44	12.58	11.44
Geometries: (G)						
G_1: 30 cm x 30 cm	0.250	2.08	0.066	0.070	4880	8546
G_2: 45 cm x 20 cm	0.262	2.14	0.068	0.069	5405	9582
G_3: 60 cm x 15 cm	0.264	2.25	0.069	0.071	5191	9302
G_4: 60 cm x 20 cm	0.263	2.18	0.068	0.071	4234	7427

SEm ±	0.005	0.031	0.001	0.001	160	268
CD at 5%	NS	0.091	NS	NS	463	776
Interaction V x G	NS	NS	NS	NS	Sig.	Sig.
CV %	6.10	5.03	4.23	4.85	11.23	10.64

Table 3: Interaction effect of different varieties and crop geometries on grain and straw yields

Yields (kg ha^{-1})								
	Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
Treatments	G_1		G_2		G_3		G_4	
V_1	4008	8357	4535	9254	5362	10882	3895	9140
V_2	5830	8299	6039	9324	5354	8252	4802	7173
V_3	4803	8980	5641	10168	4857	8770	4006	5968
	Grain				**Straw**			
S. Em. ±	277				463			
C. D. at 5%	803				1345			
C. V. %	11.23				10.64			

Conclusion
It was concluded that variety GAYMH 1 performed better in order to crop geometries of 45 cm x 20 cm, 30 cm x 30 cm and 60 cm x 15 cm, respectively while variety GAWMH 2 performed better at crop geometries at 45 cm x 20 cm and variety HQPM 1 at crop geometry 60 cm x 15 cm with respect to achieved higher grain yield of *rabi* maize.

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