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Effect of high planting densities and cultivars on productivity of rainfed maize (*Zea mays*)

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ABSTRACT

An experiment was conducted at research farm of Advanced Centre of Rainfed Agriculture (ACRA), Rakh Dhiansar SKUAST-Jammu, using factorial randomized block design (FRBD) with three replications to study the effect of planting densities on plant growth and productivity of maize varieties. The experiment consisted of two maize varieties, viz. Double dekalb and Mansar and six plant spacings of 40 × 15, 40 × 20, 50 × 15, 50 × 20, 60 × 15 and 60 cm × 20 cm. Varieties and planting density had a significant effect on plant height, dry matter accumulation, leaf area index (LAI) and yield attributes like cob length, cob girth, number of grain row/cob, number of grains/cob row, number of grains/cob, grain and stover yield. The variety *Double dekalb* attained significantly higher growth and yield attributing parameter values and grain/stover yield. Spacing of 50 cm × 20 cm observed significantly higher values of grain yield and yield attributing characters. However, 40 cm × 15 cm spacing achieved significantly higher values of plant height, dry matter accumulation, LAI and stover yields. Also the spacing of 50 cm × 20 cm exhibited statistically higher values of N, P and K uptake while 40 cm × 15 cm spacing recorded significantly lowest values of nutrient uptake. Among the varieties Double dekalb exhibited higher values of net returns and B:C ratio values while among the different spacing's, 50 cm × 20 cm registered the highest net returns and B:C ratio values.

Key words: Economics, Growth, Maize, Planting density, Rainfed, Uptake, Varieties, Yield

Maize (*Zea mays* L.) is the third most important staple food crop of the world as well as that for India next to wheat and rice and is also called as the golden cereal of hills. It is a versatile multipurpose crop, which is used in various forms as grain/flour and feed/fodder for both humans and livestock, respectively and can be grown in varied agro-ecological conditions. In India, maize crop is cultivated on an area of about 10.20 mha with a production and productivity of about 26.26 MTs and 26.64 q/ha (Anonymous 2017). In Jammu and Kashmir state, maize crop is grown on an area of about 0.31 mha with a production of 0.48 MTs and an average productivity of 15.66 q/ha (Anonymous 2016). The major area of maize cultivation in Jammu region is mostly rainfed in nature and is mostly grown in foot- hill, mid-hill and high hill sloping lands under various cropping sequences, however productivity of maize in Jammu and Kashmir state is very low as compared to the national average.

The selection of suitable variety and maintenance of optimum planting density has always been a bottle neck for the farmers especially under rainfed areas. Maximum crop production could only be realized through the use of improved varieties, suitable growing environment and with optimum plant population. More so the optimum plant population is the prerequisite for obtaining maximum yield (Trenton *et al.* 2006) as on one hand the higher plant population leads to lodging, poor light penetration in the canopy, reduce photosynthesis due to shading of lower leaves and drastically reduce the yield (Lemerle *et al.* 2006). In dense population most plants remain barren; ear and ear size remain smaller, crop becomes susceptible to lodging, disease and pest, while plant population at sub-optimum level resulted in lower yields per unit area (Nasir 2000). Keeping the above facts in view the present study was undertaken to investigate the effect of planting density and varieties on growth, yield and yield attributes of maize crop during the rainy season under rainfed areas where rainfall is usually erratic and unpredictable.

MATERIALS AND METHODS

field experiments were conducted at Research Farm of Advanced Centre for Rainfed Agriculture (ACRA), Rakh-Dhiansar, SKUAST-J, Jammu and Kashmir state (32°39" N 74°53" E, elevation of 332 m MSL) during *kharif* of 2016 and 2017 under sub-tropical rainfed conditions. The soil of the experimental site was sandy loam having available nitrogen 178.4 kg/ha, phosphorus 14.5 kg/ha and potassium 112 kg/ha, with a pH of 6.62 and organic carbon content of 0.26%. The maximum temperature recorded in

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maize crop was in the range of 39.7 to 23.2°C and 37.8 to 25.2°C, however the minimum temperature was recorded in the range of 27.9 to 14.1 and 27.8 to 16.8°C, during the *kharif* of 2016 and 2017, respectively. Whereas, total rainfall received during the cropping seasons was 658.5 and 576.5 mm, during *kharif* 2016 and 2017, respectively.

The treatments comprised of two varieties of maize, viz. Double dekalb and Mansar with six planting densities, viz. 40 cm × 15 cm, 40 cm × 20 cm, 50 cm × 15 cm, 50 cm × 20 cm, 60 cm × 15 cm and 60 cm × 20 cm which were studied using factorial randomized block design with a plot size of 6 × 4 m. Maize crop was sown at onset of *monsoon* and harvested at the physiological maturity. Urea, diammonium phosphate, and muriate of potash were used as a source of nitrogen, phosphorus and potassium, respectively. Economics of maize crop was computed on the basis of prevailing market prices of inputs and crop produce.

RESULTS AND DISCUSSION

Growth parametres: Among the varieties, Mansar produced significantly superior plant height of 116.1 and 183.6 cm than Double dekalb with 107.1 and 174.1 cm plant height at 60 DAS and harvest, respectively. Among the various plant densities studied, statistically higher plant height of maize plants was recorded with spacing 40 cm × 15 cm (118.9 and 192.5 cm) and the least value of height (105.1 and 171.1 cm) was observed with 50 cm × 20 cm spacing which was at par with the values obtained with 60 cm × 20 cm and 60 cm × 15 cm spacing in the year 2016 (Table 1). The values obtained in year 2017 were however lower than that of 2016 but a similar trend was observed. Increased mutual shading and internodal extension may have occurred due to higher plant densities which results in better vegetative development and increased plant height. This trend explains that as the number of plants increased in a given area the competition among the plants for nutrients and sunlight interception also increased. Increase in plant height may also be due to prolonged vegetative growth. Similar results had been also reported by Sharifi and Namwar (2016).

Both varieties of maize and different plant spacings followed more or less similar pattern of dry matter accumulation. Generally higher plant densities increased total dry matter production in both the varieties. Hence, a close relationship was observed between plant spacing and dry matter production. Significantly higher dry matter values were recorded in Double dekalb (53.7, 79.0 and 46.2, 67.9 q/ha) than Mansar at 60 DAS and at harvest during both the years under study. The closest plant density 40 cm × 15 cm observed significantly higher values of dry matter accumulation at 60 DAS and harvest (53.68, 78.94 and 46.17, 67.89 q/ha), respectively during both the years followed by the statistically similar values obtained with spacing 50 cm × 15 cm (52.69, 77.49 and 45.22, 66.50 q/ha), respectively. Statistically lowest dry matter accumulation to the tune of 50.09, 73.66 and 44.09, 64.84 q/ha, respectively at 60 DAS and harvest were recorded with spacing 60 cm × 20 cm and the values were at par with the dry matter values obtained with spacing 50 cm × 20 cm (Table 1). Increase in planting density might have favoured the photosynthetic activity which resulted in production of higher biomass, thus dry matter is directly related to plant density. Jeffrey *et al.* (2005) also reported similar findings.

Among the varieties, relatively higher leaf area index was recorded in Double dekalb than Mansar at 60 DAS and harvest. The treatment having planting density of 40 cm × 15 cm produced significantly higher LAI of 3.35, 1.71 and 3.18, 1.78 at 60 DAS and harvest, respectively, Valadabadi and Farahani (2010) stated that leaf area is influenced by genotype, plant population, climate, and soil fertility. The lowest values of LAI (2.87, 1.41 and 2.72, 1.52) were observed in plant density 60 × 20 cm at 60 DAS and

Table 1 Effect of varieties and spacing on growth parameters of maize under rainfed conditions

Treatment	Plant height (cm)				Dry matter accumulation (q/ha)				Leaf Area Index			
	2016		2017		2016		2017		2016		2017	
	60	At Har	60	At Har	60	At Har	60	At Har	60	At Har	60	At Har
Varieties (V)												
Double dekalb (V1)	107.1	174.1	111.1	177.6	53.73	79.01	46.20	67.95	3.26	1.66	3.10	1.73
Mansar (V2)	116.1	183.6	120.6	187.5	50.06	73.61	43.34	63.74	3.03	1.52	2.88	1.61
CD (P=0.05)	4.90	3.99	4.85	4.57	1.41	2.08	1.50	2.21	0.15	0.11	0.14	0.08
Plant Spacing (S)												
40 cm × 15 cm	118.9	192.5	123.5	195.5	53.68	78.94	46.17	67.89	3.35	1.71	3.18	1.78
40 cm × 20 cm	112.2	179.6	116.7	183.4	51.73	76.07	44.72	65.77	3.23	1.65	3.06	1.72
50 cm × 15 cm	116.1	185.1	120.6	188.1	52.69	77.49	45.22	66.50	3.27	1.67	3.10	1.74
50 cm × 20 cm	105.1	171.1	110.9	176.2	51.67	75.99	44.20	65.01	3.02	1.48	2.87	1.61
60 cm × 15 cm	111.2	176.2	115.7	179.2	51.50	75.73	44.23	65.05	3.15	1.62	2.99	1.68
60 cm × 20 cm	106.4	168.5	107.9	172.8	50.09	73.66	44.09	64.84	2.87	1.41	2.72	1.52
CD (P=0.05)	8.49	6.92	8.37	7.90	3.88	4.14	2.44	3.11	0.26	0.19	0.24	0.14
V × S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2 Effect of varieties and spacing on yield and yield attributes of maize under rainfed conditions

Treatment	Yield attributes									
	Cob length (cm)		Cob girth (cm)		No. of grain rows/ cob		No. of grains/cob row		No. of grains/cob	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Varieties (V)										
Double dekalb (V1)	14.52	13.07	12.67	11.40	12.07	10.86	27.23	24.51	329.68	267.04
Mansar (V2)	13.95	12.55	11.73	10.56	11.82	10.64	24.18	21.77	285.72	231.43
CD (P=0.05)	0.32	0.28	0.14	0.13	0.23	0.20	1.25	1.13	16.79	13.60
Plant Spacing (S)										
40 cm × 15 cm	13.86	12.47	11.93	10.73	11.50	10.35	23.75	21.38	273.08	221.19
40 cm × 20 cm	14.61	13.15	12.08	10.87	11.80	10.62	24.35	21.92	287.25	232.68
50 cm × 15 cm	13.93	12.53	12.44	11.19	12.10	10.89	26.90	24.21	326.95	264.83
50 cm × 20 cm	14.74	13.26	12.46	11.21	12.35	11.12	29.05	26.15	359.37	291.09
60 cm × 15 cm	14.27	12.84	12.09	10.88	11.90	10.71	24.70	22.23	293.83	238.01
60 cm × 20 cm	14.00	12.60	12.23	11.00	12.00	10.80	25.50	22.95	305.71	247.63
CD (P=0.05)	0.55	0.49	0.24	0.22	0.39	0.35	2.17	1.96	29.08	23.55
V × S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

harvest, respectively (Table 1). The higher plant densities tend to occupy more green canopy of plants per unit area; thus an increase in LAI was observed on account of more area. On the other hand, increasing leaf area index is one of the way of increasing the capture of solar radiation within the canopy and accumulation of dry matter. Responses of dry matter accumulation and leaf area index were similar when plant density was increased or intra-row spacing was decreased (Sharifi and Namvar 2016). The results are also in agreement with Shafi *et al.* (2012) who reported that LAI increases with higher plant population.

Yield and yield attributes: In case of varieties, yield attributes like cob length, cob girth, number of grain rows/ cob, number of grains/cob row and number of grains/cob (14.52 cm, 12.67 cm, 12.07, 27.23 and 329.68, respectively (Table 2) were significantly higher in Double dekalb than Mansar in the year 2016. The results also revealed that planting density had a significant effect on all the yield attributes. The values of attributes increased when the spacing was reduced, but the positive response was noticed up to 50 cm × 20 cm spacing, thereafter a decline in values was observed. However, the values of yield attributes like cob length (14.74 cm), cob girth (12.46 cm) and grains/row (12.35) in 50 cm × 20 cm spacing were statistically similar with the values obtained in spacing 60 cm × 20 (14.0 cm, 12.23 cm and 12.0), respectively in the year 2016. Almost a similar trend was observed in the year 2017 with respect to varieties and plant density. The lowest values of yield attributes were recorded in the closest plant density (40 cm × 15 cm). The plant spacing 50 cm × 20 cm also observed

Table 3 Effect of varieties and spacing on grain and stover yield of maize under rainfed conditions

Treatment	Grain yield (q/ha)		Stover yield (q/ha)		Net returns (₹/ha)		B:C ratio	
	2016	2017	2016	2017	2016	2017	2016	2017
Varieties (V)								
Double dekalb (V1)	24.05	21.65	55.08	46.30	25938	23176	1.30	1.16
Mansar (V2)	22.11	19.91	51.30	43.82	22662	19999	1.14	1.00
CD (P=0.05)	0.94	0.85	2.03	2.12				
Plant Spacing (S)								
40 cm × 15 cm	21.43	19.12	56.07	46.66	22330	19453	1.12	0.98
40 cm × 20 cm	21.79	19.49	54.28	45.35	22501	19715	1.13	0.99
50 cm × 15 cm	24.29	21.82	54.64	46.07	26206	23384	1.31	1.17
50 cm × 20 cm	24.95	22.42	51.04	44.06	26435	23844	1.33	1.20
60 cm × 15 cm	23.10	20.72	52.96	44.29	24145	21309	1.21	1.07
60 cm × 20 cm	23.52	21.11	50.14	43.94	24182	21820	1.21	1.09
CD (P=0.05)	1.62	1.47	3.52	3.69				
V × S	NS	NS	NS	NS				

Table 4 Effect of varieties and spacing on nutrient uptake (kg/ha) by grain and stover of maize

Treatments	Grain 2016			Stover			Grain 2017			Stover		
	N	P	K	N	P	K	N	P	K	N	P	K
Varieties												
Double dekalb (V1)	39.42	8.65	12.65	33.76	10.02	54.60	34.99	7.55	11.84	27.70	8.31	53.27
Mansar (V2)	36.06	7.63	11.99	30.88	9.13	60.82	31.91	6.69	10.28	23.97	7.45	50.52
CD (P=0.05)	1.79	0.72	0.64	1.22	0.24	1.34	1.43	0.32	0.55	0.89	0.17	1.43
Plant Spacing (S)												
40 cm × 15 cm	34.43	6.91	11.43	33.46	9.88	37.63	30.27	6.16	9.92	24.95	7.59	49.38
40 cm × 20 cm	35.24	7.29	11.29	32.20	9.42	61.29	31.36	6.53	10.13	24.92	7.77	52.02
50 cm × 15 cm	39.66	8.56	11.47	33.68	9.79	61.79	35.19	7.60	11.88	26.76	7.95	52.56
50 cm × 20 cm	41.20	9.01	13.24	31.11	9.78	62.50	36.51	7.97	12.27	27.51	8.26	53.79
60 cm × 15 cm	37.62	8.18	14.02	31.16	9.34	62.54	33.29	7.27	11.03	25.19	7.78	51.97
60 cm × 20 cm	38.29	8.89	12.51	30.28	9.24	60.00	34.10	7.18	11.13	25.69	7.93	51.65
CD (P=0.05)	3.09	1.25	1.12	2.12	0.42	2.32	2.49	0.55	0.95	1.55	0.29	2.48
V × S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

significantly higher yield attributes like number of grains/cob row and number of grains/cob to the tune of 29.05 and 359.4; followed by the values with 50 cm × 15 cm plant spacing (26.90 and 326.95), respectively. However, the lowest values (23.75 and 273.08) were recorded with the most dense spacing (40 cm × 15 cm), respectively. Highest plant population had a negative impact on yield attributes as their values were comparatively lower when compared with other treatments. This may be due to the fact that available nutrients, moisture, space and light become limited in high plant population due to high competition of soil resources between plants. Ultimately plants produced relatively fewer number of grains/cob, grain rows, smaller length/girth of cobs. Similar results were reported by Shafi *et al.* 2012. Also, in narrow plant spacing there was more competition for available resources and hence plants produced weaker characteristics of yield attributes. Hassan (2000) also observed that ear length decreased with increase in plant population. Manan *et al.* (2016) and Zamir *et al.* (2011) also found the similar results.

Statistically significant variations were observed in grain and stover yield of maize crop due to varieties and densities. Double dekalb was statistically superior to Mansar with regard to grain and stover yields (24.05 and 55.08 q/ha), respectively (Table 3). Among the various plant spacing, 50 cm × 20 cm significantly enhanced the grain yield (24.95 q/ha), followed by 60 cm × 20 cm spacing (23.52 q/ha). The spacing (50 cm × 20 cm) may be optimum under rainfed conditions and grain may have become a dominant sink at their maturity stage and the entire photoassimilate deposited in the grains as compared to other parts of the plant (Shafi *et al.* 2012). The reason of increased grain yield and positive relationship between grain yield and plant density may be due to higher numbers of yield attributing characters and plants per unit area in this spacing. However, on further reduction in plant spacing, the grain yield significantly reduced due to weaker plants, increased stem lodging and reduced number of yield attributes. The statistically lowest grain yield to the tune of 21.43 q/ha was recorded in 40 cm × 15 cm spacing. Under high plant densities, the rate of yield reduction was in response to decreasing light, moisture, nutrient and other environmental resources available to each plant. Similar findings were also reported by Dawadi and Sah, 2012.

Economics: Variety Double dekalb accrued maximum net returns (₹ 25938 and 23176/ha) and B:C ratio values of (1.30 and 1.16) than the other variety Mansar, respectively during both the years under study. Among the various spacings, 50 cm × 20 cm registered highest values of net returns (₹ 26435 and 23844/ha), whereas the recommended plant spacing 60 cm × 20 cm registered net returns to the tune of ₹ 24182 and 21820/ha during the *kharif* seasons of 2016 and 2017, respectively. However, the B:C ratio values of 1.33, 1.20 and 1.21, 1.09 for the plant spacing 50 cm × 20 and 60 cm × 20 cm, respectively were obtained during both the years under study.

Nutrient uptake: Significant variation in N, P and K uptake by grain and stover of maize crop was noticed due to varieties and varying plant densities during both the years under study (Table 4). The variety Double dekalb recorded statistically higher values of N, P and K uptake in grain (39.42, 8.65 and 12.65 kg/ha) and stover (33.76, 10.02 and 54.60 kg/ha), respectively than Mansar in the year 2016. In case of plant spacings, significantly higher N, P and K uptake in grain and stover was recorded in 50 cm× 20 cm spacing to the tune of 41.20, 9.01, 13.24 and 31.11, 9.78, 62.50 kg/ha, respectively. The lowest values of N, P and K uptake was observed in the closest spacing of 40 cm × 15 cm. A more or less similar trend was observed during the *kharif* season of 2017.

The plant spacing of 50 cm × 20 cm produced significantly higher grain yield with Double dekalb variety

of maize, owing to better growth and development, nutrient uptake and superior yield attributes besides recording higher net returns and benefit: cost ratio . Hence, the planting density of 50 cm × 20 cm could be safely recommended for enhancing rainfed maize productivity in the sub-tropical foot-hills of Jammu region.

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