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Rainfed Popcorn Productivity as Influenced by Plant Densities and Nitrogen Levels

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ABSTRACT: A field experiment was conducted during *kharif* seasons of 2011 and 2012 at Maize Research Centre, ARI, Rajendranagar, Hyderabad to study the influence of varying plant densities and nitrogen levels on growth parameters, yield attributes, yield and economics of first popcorn hybrid BPCH-6. The experiment was laid out in randomized block design with factorial concept with three plant densities {P_1-1,11,111/ha (60 x 15 cm), P_2-1,11,111/ha (45 x 20 cm) and P_3-83,333/ha (60 x 20 cm)} and four nitrogen levels (N_1-80 kg/ha, N_2-120 kg/ha, N_3-160 kg/ha and N_4-200 kg/ha) and replicated thrice. Mean data over 2 years indicated that plant height and leaf area index were significantly higher with high plant density of 1, 11,111/ha whereas dry matter production (g/plant) was significantly higher with 83,333/ha. Yield attributes like cob length, cob girth, number of rows per cob and number of seeds per row was significantly superior with low plant density of 83,333/ha. Hundred seed weight was not significantly influenced either by plant densities or nitrogen levels. On the contrary pooled data over 2 years revealed that cob, grain and fodder yields were significantly higher with a plant density of 1,11,111/ha. Gross returns, net returns and benefit-cost ratio were higher when a population of 1,11,111 plants/ha was maintained. Application of 200 kg nitrogen/ha had significantly higher growth parameters, yield attributes, yield and gross returns but it was on par with 160 kg N/ha and both were significantly superior over 120 and 80 kg N/ha whereas net returns and benefit-cost ratio were higher with 160 kg N/ha. Therefore, it is profitable to grow popcorn hybrid at a plant density of 1,11,111/ha (60 x 15 cm) with 160 kg N/ha in peri urban areas.

Key words: Popcorn, *kharif*, plant densities, nitrogen levels, yield and economics

Maize (*Zea mays* L.) is an important cereal in India, which has registered continuous increase in productivity over years. Because of its uniqueness for diverse uses as well as responsiveness to inputs, maize has tremendous potentiality in ensuring sustainability and food security in India. Popcorn (*Zea mays var. everta*) is one type of maize which is popular as a snack food in many parts of the world. So far only popcorn varieties like Amber popcorn, VL popcorn and Pearl popcorn are available for commercial cultivation in India. Recently, first popcorn hybrid BPCH-6 was released by ANGRAU at national level. Because of unavailability of appropriate agro-techniques and lack of awareness among the farmers and policy makers regarding the trade potential, its cultivation has not picked up in the country.

Among the various agronomic inputs, plant density and fertilizers in particular nitrogen are the most important factors which greatly influence the potential yield realisation from any crop in general and maize in particular. The optimum plant density is an important factor for intercepting sunlight for photosynthesis besides efficient use of plant nutrients and soil moisture. Nitrogen is universally deficient in majority of Indian soils and has beneficial effect on growth, yield attributing characters and yield of maize (Thind *et al*., 2002). Escalating prices of nitrogen fertilisers coupled with reduction in subsidy on fertilisers have forced crop growers to use fertilisers efficiently. Being an exhaustive crop, maize respond up to 120 kg N/ha application (Sepat and Kumar, 2007) and even at higher than this nitrogen level (Singh *et al*., 2003). Correlating these functions to produce the highest possible yields with the greatest efficiency has been the main objective of this study. Therefore, matching optimum plant density with nitrogen is essential to achieve the targeted yields.

Though spacing and fertiliser requirement of grain maize has been standardised by the recommended plant density and nitrogen dose for the normal maize hybrids may not be applicable for the popcorn hybrid. However, no systematic research has been conducted to develop site and situation specific production technology for this crop; hence there is a need to establish a relationship between plant density and nitrogen level. Keeping in view of the above considerations, the present study was undertaken to study the effect of plant densities and nitrogen on the popcorn hybrid.

Materials and Methods

The present investigation was carried out at the Maize Research Centre, Agricultural Research Institute, Rajendranagar, Hyderabad during *kharif*, 2011 and 2012. The farm is geographically situated at an altitude of 542.3 m above mean sea level at 17^0 19’ N latitude and 78^0 28’ E longitude and falls under the southern agro-climatic zone of Telangana State. Based on soil analysis, the soil of the experimental site was classified as clay loam, slightly alkaline (pH 7.8) with low organic carbon and available nitrogen, medium in available phosphorous and high in available potassium. The experiment was laid out in randomized block design with factorial concept with three plant densities P_1-1,11,111/ha (45 x 20 cm), P_2-1,11,111/ha (60 x 15 cm) and P_3-83,333/ha (60 x 20 cm) and four nitrogen levels (N_1-80 kg/ha, N_2-120 kg/ha, N_3-160 kg/ha and N_4-200 kg/ha) and replicated thrice.

Popcorn hybrid, BPCH-6 was used in the present study and it is suitable for both *kharif* and *rabi* cultivation in Telangana State. Two to three seeds per hill were dibbled at a depth of 3-4 cms in a conventionally tilled soil to get desired plant population, followed by irrigation to ensure proper and uniform germination. The thinning operation was done leaving one healthy seedling per hill. The nitrogen fertilizer was supplied as per treatment *viz.,* 80, 120, 160 and 200 kg/ha in the form of urea after calculating the proportion of nitrogen supplied through DAP. Phosphorus @ 60 kg/ha in the form of DAP and potash @ 50 kg/ha in the form of muriate of potash were applied. Entire phosphorus and potash were applied as basal. Nitrogen fertilizer was applied in three splits as per schedule i.e., 1/3rd N as basal, 1/3rd N at 30 DAS and remaining 1/3rd N at 60 DAS. Standard agronomic practices were followed to raise a healthy and uniform crop. The rainfall received during 2011 was 447.1 mm in 29 rainy days and during 2012 it was 618.4 mm in 36 rainy days. The cobs from border rows of each plot were harvested separately and later the cobs from the net plot were harvested. Five plants were marked at random in the net plot in each treatment to record periodical observations on growth characters and yield attributes of the crop.

Results and Discussion

Growth parameters

The varying plant densities and nitrogen levels have showed significant influence on plant height, leaf area index and dry matter production at harvest. Mean over 2 years showed that as the plant density increased from 83,333/ha (158 cm) to 1, 11,111/ha (187 cm), the plant height also increased (Table 1). This clearly indicates that increase in number of plants per unit area beyond optimum level certainly reduced the amount of light availability to the individual plant, especially to lower leaves due to shading. As the intensity of shading increased due to high population densities, the plants attained higher height. Such increase in height of the plant at high population densities was reported by Ashok Kumar (2009). Even at same plant density of 1, 11,111/ha, the row spacing of 45 x 20 cm recorded significantly higher plant height (187 cm) compared to 60 x 15 cm row spacing (174 cm). Leaf area index at harvest also increased as the plant density increased from 83,333/ha (4.47) to 1,11,111/ha (5.71) (Table 1). The increase in leaf area index with increase in plant density was due to more number of plants per unit area. The research findings of Suryavanshi *et al*. (2008) also indicated the fact that high plant density recorded more LAI as compared to low plant density. As the plant density increased from 83,333/ha (73.0 g/plant) to 1, 11,111/ha (60.5 g/plant), the dry matter production decreased significantly (Table 1). It was evident from the results that increased dry matter production at the density of 83,333/ha might be due to less interplant competition for space, light, nutrients and moisture and better utilization of the available resources. With the same plant density of 1,11,111/ha wider row spacing of 60 x 15 cm recorded higher leaf area index (5.71) and dry matter production per plant (66.7 g) compared to narrow spacing of 45 x 20 cm (5.41 and 60.5 g, respectively) (Table 1). Wider space availability between rows and closer intra-rows might have increased the root spread which eventually utilized the resources such as water, nutrients, space and light very effectively. Better utilization of available resources might have increased the functional leaves and in turn enhanced the leaf area index leading to higher photosynthetic rate which leads to more dry matter production per plant. Increased leaf area index due to closure intra-row spacing was also observed by Abo-Shetaia (2002).

Application of nitrogen at 200 kg/ha recorded significantly higher plant height (186 cm), leaf area index (5.56) and dry matter production per plant (71.9 g) but it was on par with 160 kg/ha (182 cm, 5.54 and 69.4 g, respectively) and both were significantly superior over rest of the nitrogen treatments (Table 1). Increase in nitrogen rate might have increased the photosynthate formation and partitioning to stems that might have favorable impact on plant height of maize (Amanullah *et al*., 2009). The influence of phytochromes in promotion

Table 1 : Plant height (cm) at harvest, leaf area index at harvest and dry matter production (g/plant) of popcorn hybrid as influenced by plant densities and nitrogen levels

Treatment	Plant height (cm) at harvest			Leaf area index at harvest			Dry matter production (g/plant)		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Plant densities (plants/ha)									
1,11,111 (45 x 20 cm)	180	193	187	5.36	5.45	5.41	55.5	65.4	60.5
1,11,111 (60 x 15 cm)	168	179	174	5.50	5.91	5.71	61.1	72.3	66.7
83,333 (60 x 20 cm)	153	162	158	4.23	4.71	4.47	64.4	81.6	73.0
CD (P=0.05)	10.0	13.0		0.02	0.03		5.1	6.0	
Nitrogen levels (kg N/ha)									
80	151	161	156	4.56	4.80	4.68	53.2	69.1	61.2
120	160	173	167	4.80	5.21	5.01	57.2	71.7	64.5
160	176	188	182	5.38	5.70	5.54	64.6	74.2	69.4
200	181	190	186	5.39	5.72	5.56	66.4	77.3	71.9
CD (P=0.05)	11.0	13.0		0.02	0.03		5.0	6.0	
Interaction	NS	14.0		0.04	0.06		8.0	7.0	

NS = Not Significant

of cell division, cell enlargement, cell differentiation and multiplication under higher nitrogen level resulted in consistent and statistically significant increase in leaf area index (Rao and Padmaja, 1994). As maize hybrids are highly responsive to applied inputs, nitrogen at higher rate promoted better growth and resulted in higher uptake of nitrogen, phosphorus and potassium as compared to lower levels. These nutrients triggered the vigorous growth of plants; there by achieving more LAI, this further enhanced the dry matter production. Similar response of growth parameters to applied nitrogen levels was reported by Abdullah Oktem *et al*. (2010).

Yield attributes

The varying plant densities and nitrogen levels have showed significant influence on cob length, cob girth, number of rows per cob and number of seeds per row, whereas 100 seed weight was not significantly influenced either by plant densities or nitrogen levels (Table 2). The low plant density of 83,333/ha under wider spacing of 60 x 20 cm produced longest (18.3 cm) and thicker cobs (10 cm), more number of rows per cob (13.7) and seeds per row (31.5) compared to high plant density of 1,11,111/ha under narrow spacing of 45 x 20 cm (15.2 cm, 8.9 cm, 13.3 and 26.9, respectively). This clearly indicates that plants at lower density made use of the natural resources efficiently, besides responding to externally applied inputs and expressed its maximum potential compared to plants at higher density where the competition would be high. Higher values for these yield attributes could be attributed to stress free environment under low plant densities compared to high plant densities. Abdullah Oktem (2005) also reported that shorter ears were obtained from higher plant density of 1, 02,040/ha while longer ears were found at lower plant density of 47,620/ha. The plant population of 83,333/ha produced shorter cobs than with the plant population of 66,666 and 53,333/ha (Sahoo and Mahapatra, 2007).

Application of nitrogen at 200 kg/ha produced significantly higher cob length (18.4 cm), cob girth (10.2 cm), number of rows per cob (13.8) and seeds per row (31.3) but was on par with 160 kg/ha (18.3 cm, 10.1 cm ,13.7 and 30.5, respectively) and both were significantly superior over other two nitrogen levels (Table 2). This might be due to increased physiological process in crop plants at higher fertility doses leading to higher growth and increased photosynthates to silk. Increased availability of nitrogen to crop at higher levels might have resulted in production of longer cobs accompanied by increased grain filling that gave more rows per cob and seeds per row. Similar results were reported by Sahoo and Mahapatra (2007).

Yield

The varying plant densities showed significant effect on cob, grain and fodder yields (t/ha) of popcorn (Table 3). Pooled data over 2 years indicated that significantly higher grain yield was obtained with a plant density of 1,11,111/ha (4.8 t/ha) whereas significantly lower grain yield was obtained with 83,333/ha (3.4 t/ha). Though the values of yield attributes were poor with high plant density, more number of plants/ha under high plant density might have compensated reduction in yield attributes. Sahoo

Table 2 : Cob length (cm), cob girth (cm), number of rows/cob, number of seeds/row and 100 seed weight (g) of popcorn hybrid as influenced by plant densities and nitrogen levels

Treatment	Cob length (cm)			Cob girth (cm)			Number of rows/cob			Number of seeds/row			100 Seed weight (g)		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Plant densities (plants/ha)															
1,11,111 (45 x 20 cm)	12.4	18.1	15.2	8.4	9.5	8.9	12.8	13.8	13.3	25.2	28.6	26.9	12.3	13.0	12.7
1,11,111 (60 x 15 cm)	14.4	19.6	17.0	9.2	9.8	9.5	13.0	13.9	13.5	26.9	30.4	28.7	12.5	13.1	12.8
83,333(60 x 20 cm)	15.8	20.7	18.3	9.9	10.1	10.0	13.4	13.9	13.7	29.8	33.2	31.5	12.5	13.3	12.9
CD (P=0.05)	0.6	0.8		0.2	0.2		0.3	NS		2.0	3.0		NS	NS	
Nitrogen levels (kg N/ha)															
80	11.5	18.3	14.9	7.9	9.3	8.6	12.5	13.7	13.1	24.8	27.9	26.4	12.2	13.0	12.6
120	12.9	19.2	16.1	8.6	9.6	9.1	12.8	13.9	13.4	26.2	29.3	27.8	12.4	13.0	12.7
160	16.2	20.3	18.3	10.0	10.1	10.1	13.4	14.0	13.7	28.6	32.4	30.5	12.5	13.2	12.9
200	16.4	20.3	18.4	10.1	10.2	10.2	13.6	14.0	13.8	29.5	33.1	31.3	12.6	13.3	13.0
CD (P=0.05)	0.6	0.9		0.3	0.2		0.3	NS		2.0	3.0		NS	NS	
Interaction	0.9	NS		0.5	0.3		NS	NS		4.0	6.0		NS	NS	

NS = Not Significant

and Mahapatra (2007) also reported similar results. Within the same plant density of 1,11,111/ha wider row spacing of 60 x 15 cm recorded higher grain yield (4.8 t/ha) compared to narrow row spacing of 45 x 20 cm (4.2 t/ha) (Table 3). Pooled mean over two years indicated that the per cent increase in grain yield at 1,11,111 plants/ha (60 x 15 cm and 45 x 20 cm) over 83,333 plants/ha (60 x 20 cm) was 41.2 and 23.5, respectively. The positive and significant correlation of leaf area index and dry matter production per plant can be related with enhanced grain yield under wider row spacing. The results are in confirmation with the findings of Maddoni *et al*. (2006). Similar situation was observed in case of cob and fodder yields (Table 3).

Significantly higher cob (5.5 t/ha), grain (4.7 t/ha) and fodder yields (6.7 t/ha) were obtained with 200 kg N/ha but it was on par with 160 kg N/ha (5.4, 4.6 and 6.5 t/ha, respectively) and both were superior over other two nitrogen levels (Table 3). The per cent increase in grain yield with 160 kg N/ha over 80 and 120 kg N/ha was 35.3 and 17.9, respectively. Singh *et al*. (2010) also reported higher cob, grain and fodder yields with increase in fertilizer levels which could be attributed to adequate nutrient supply, which in turn improved the growth and yield attributing characters. However, grain yield increased up to 160 kg N ha^{-1} and beyond that it was not significant. Maize yield increased with an increase in rate of nitrogen fertilizer until it reached a plateau and there after N application did not affect corn yield (Schmidt *et al.,* 2002).

Interaction effect of plant densities and nitrogen levels on grain yield showed that grain yield (5.4 t/ha) at a plant density of 1,11,111/ha with 200 kg N/ha was on par with 160 kg N/ha at same plant density whereas significantly lower grain yield (2.8 t/ha) was with a plant density of 83,333/ha at 80 kg N/ha but it was on par with 120 kg N/ha at the same plant density (Table 4).

Table 3 : Cob yield (t/ha), grain yield (t/ha) and fodder yield (t/ha) of popcorn hybrid as influenced by plant densities and nitrogen levels

Treatment	Cob yield (t/ha)			Grain yield (t/ha)			Fodder yield (t/ha)		
	2011	2012	Mean	2011	2012	Pooled mean	2011	2012	Mean
(Plant densities (plants/ha)									
1,11,111 (45 x 20 cm)	4.9	5.2	5.1	4.1	4.3	4.2	5.7	6.2	6.0
1,11,111 (60 x 15 cm)	5.7	5.9	5.8	4.7	4.9	4.8	6.6	6.8	6.7
83,333 (60 x 20 cm)	3.9	4.4	4.2	3.1	3.6	3.4	5.1	5.7	5.4
CD (P=0.05)	0.5	0.4		0.4	0.3	0.4	0.4	0.5	
(Nitrogen levels (kg N/ha)									
80	4.0	4.6	4.3	3.0	3.7	3.4	5.0	5.4	5.2
120	4.5	5.0	4.8	3.7	4.1	3.9	5.5	6.0	5.8
160	5.2	5.5	5.4	4.5	4.6	4.6	6.2	6.7	6.5
200	5.4	5.6	5.5	4.6	4.8	4.7	6.5	6.8	6.7
CD (P=0.05)	0.6	0.4		0.5	0.3	0.4	0.4	0.5	
Interaction	0.5	0.3		0.5	0.4	0.6	0.6	0.6	

Table 4 : Interaction effect of plant densities and nitrogen levels on grain yield (t/ha) of popcorn hybrid (pooled mean over 2 years)

	Nitrogen levels (kg N/ha)				
Plant densities (plants/ha)	80	120	160	200	Mean
1,11,111 (45 x 20 cm)	3.5	3.9	4.6	4.7	4.2
1,11,111 (60 x 15 cm)	4.0	4.7	5.3	5.4	4.8
83,333 (60 x 20 cm)	2.8	3.1	3.8	3.9	3.4
Mean	3.4	3.9	4.6	4.7	
CD (P=0.05)	0.6				

Economics

There was a positive response of the plant densities and nitrogen levels on per hectare total cost of cultivation, gross and net returns and benefit-cost ratio (Table 5). Higher gross returns (₹ 1,47,350/ha), net returns (₹ 1,05,418/ha) and benefit-cost ratio (3.51) were accrued when the popcorn hybrid was grown with a population of 1,11,111 plants/ha (60 x 15 cm) as compared to lower gross returns (₹ 1,04,700/ha), net returns (₹ 64,768/ha) and benefit-cost ratio (2.62) with a population of 83,333/ha. The benefit-cost ratio (3.51) indicates that on every rupee investment made on the production of popcorn hybrid gave a dividend of ₹ 3.51.

Among the nitrogen levels, application of 200 kg/ha found to result in higher gross returns (₹ 1,41, 350/ha) followed by 160 kg/ha (₹ 1,41,250/ha) whereas net returns (₹ 99,494/ha) and benefit-cost ratio (3.38) were higher with 160 kg/ha compared to 200 kg/ha (₹ 98,612/ha and 3.31, respectively). Kar *et al*. (2006) reported that an increase in application of nitrogen from 0 to 80 kg/ha gave significantly higher net returns (₹ 32,086 to 61,532 per ha) and benefit-cost ratio (1.73 to 3.76) of sweet corn during *kharif* season.

Table 5 : Total cost of cultivation (₹/ha), gross returns (₹/ha), net returns (₹/ha) and benefit-cost ratio of popcorn hybrid as influenced by plant densities and nitrogen levels (mean over 2 years)

Treatment	Total cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B-C ratio
Plant densities (plants/ha)				
1,11,111 (45 x 20 cm)	41,932	1,29,000	87,068	3.08
1,11,111 (60 x 15 cm)	41,932	1,47,350	1,05,418	3.51
83,333 (60 x 20 cm)	39,932	1,04,700	64,768	2.62
Nitrogen levels (kg N/ha)				
80	39,794	1,04,600	64,806	2.63
120	40,776	1,19,900	79,124	2.94
160	41,756	1,41,250	99,494	3.38
200	42,738	1,41,350	98,612	3.31

Cost of grain (per kg) = ₹ 30/-

Cost of fodder (per kg) = ₹ 0.5/-

Conclusion

The findings of the present experiment clearly suggest that growth parameters, yield and yield attributes in popcorn hybrid were influenced by plant densities and N fertilizers as similar to normal corn hybrids. Therefore, it is recommended to grow popcorn hybrid at a plant density of 1,11,111/ha (60 x 15 cm) with 160 kg N/ha in peri urban areas.

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