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RESEARCH ARTICLE :

Growth and yield of *Rabi* popcorn hybrid at varied plant densities and nitrogen levels

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SUMMARY : A field experiment was conducted during *Rabi* seasons of 2011-12 and 2012-13 at Maize Research Centre, ARI, Rajendranagar, Hyderabad to study the influence of varying plant densities and nitrogen levels on growth parameters and yield of BPCH-6, the first popcorn hybrid released by PJTSAU at national level. The experiment was laid out in Randomized Block Design with factorial concept with three plant densities (P_1-1,11,111 ha^{-1} (60 x 15 cm), P_2-1,11,111 ha^{-1} (45 x 20 cm) and P_3-83,333 ha^{-1} (60 x 20 cm) and four nitrogen levels (N_1-80 kg ha^{-1}, N_2- 120 kg ha^{-1}, N_3-160 kg ha^{-1} and N_4-200 kg ha^{-1}) and replicated thrice. Mean data over 2 years indicated that plant height was significantly higher with high plant density of 1,11,111 ha^{-1} (45x20 cm) and leaf area index was significantly higher with plant density of 1,11,111 ha^{-1} (60x15 cm) whereas dry matter production (g plant^{-1}) was significantly higher with 83,333 ha^{-1} (60x20 cm). Cob, grain and fodder yields were significantly higher with a plant density of 1,11,111 ha^{-1} (60x15 cm). Application of 200 kg nitrogen ha^{-1} gave significantly higher growth parameters and yield but it was on par with 160 kg N ha^{-1} and both were superior over 120 and 80 kg N ha^{-1}. Interaction effect of plant densities and nitrogen levels on grain yield showed that significantly higher grain yield (6.0 t ha^{-1}) was obtained at a plant density of 1,11,111 ha^{-1} (60x15 cm) with 200 kg N ha^{-1} but it was on par with 160 kg N ha^{-1} with the same plant density.

KEY WORDS :
Popcorn, *Rabi*, Plant densities, Nitrogen levels, Growth parameters, Yield

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BACKGROUND AND OBJECTIVES

Maize (*Zea mays* L.) is an important cereal in India, which has exhibited continuous increase in productivity. 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 PJTSAU 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 been popularised in our 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. The optimum plant density is an important factor for intercepting sun light for photo synthesis 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. 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 responded upto 120 kg N ha^{-1} application (Sepat and Kumar, 2007) and even at higher of this nitrogen level. Moreover the enhanced plant population of maize increased its nitrogen requirement. Correlating these functions to produce the highest possible yields with the greatest efficiency has been the aim of this research. Therefore, matching optimum plant density with nitrogen is essential to achieve the targeted yields.

Though spacing and fertilizer 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 at the study center 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. Keeping in view the above considerations, the present study was undertaken to study the effect of plant densities and nitrogen on the popcorn hybrid.

RESOURCES AND METHODS

The present investigation was carried out at the Maize Research Centre, Agricultural Research Institute, Rajendranagar, Hyderabad during *Rabi*, 2011-12 and 2012-13. 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 Telangana agro climatic zone of Andhra Pradesh. 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 phosphorus 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^{-1} (45 x 20 cm), P_2-1,11,111 ha^{-1} (60x 15 cm) and P_3-83,333 ha^{-1} (60 x 20 cm) and four nitrogen levels (N_1-80 kg ha^{-1}, N_2-120 kg ha^{-1}, N_3-160 kg ha^{-1} and N_4-200 kg ha^{-1}) and replicated thrice.

Popcorn hybrid, BPCH-6 was used in the present study. It is suitable for both *Kharif* and *Rabi* cultivation in Andhra Pradesh. 2-3 seeds $hill^{-1}$ were dibbled at a depth of 3-4 cm 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^{-1} in the form of urea after calculating the proportion of nitrogen supplied through DAP. Phosphorus @ 60 kg ha^{-1} in the form of DAP and potash @ 50 kg ha^{-1} 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.*, $1/3^{rd}$ N as basal, $1/3^{rd}$ N at 30 DAS and remaining $1/3^{rd}$ N at 60 DAS. Standard agronomic practices were followed to raise a healthy and uniform crop. 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 of the crop.

OBSERVATIONS AND ANALYSIS

The results obtained from the present study as well as discussions have been summarized under following heads:

Growth parameters :

The varying plant densities and nitrogen levels have showed significant influence on plant height at harvest, leaf area index at harvest and dry matter production. Mean over 2 years indicated that as the plant density increases from 83,333 ha^{-1} (171 cm) to 1,11,111 ha^{-1} (197 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 increases due to high population densities, the plant tends to grow taller. Such increase in height of the plant at high population densities was reported by Gozubenli *et al*. (2006); Muniswamy *et al.* (2007); Suryavanshi *et al.*

(2008) and Kumar (2009). Even with the same plant density of 1,11,111 ha^{-1} narrow row spacing of 45x20 cm recorded significantly higher plant height (197 cm) compared to 60 x 15 cm (185 cm) spacing (Table 1). Leaf area index at harvest also increases as the plant density increases from 83,333 ha^{-1} (4.25) to 1,11,111 ha^{-1} (5.53) (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 increases from 83,333 ha^{-1} (85.1 g plant^{-1}) to 1,11,111 ha^{-1} (67.5 g plant^{-1}) the dry matter production decreased significantly (Table 1). Dry matter accumulation (DMA) is one of the important parameters reflecting the growth of a crop. The optimum accumulation of dry matter, followed by adequate partitioning of assimilates to the sink leads to higher grain yield. It was evident from the results that increased dry matter production at the density of 83,333 ha^{-1} 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^{-1} wider row spacing of 60x15 cm recorded higher leaf area index (5.53) and dry matter production per plant (73.0 g) compared to narrow spacing of 45 x 20 cm (5.18 and 67.5 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 photo synthetic rate which leads to more dry matter production per plant.

Application of nitrogen at 200 kg ha^{-1} recorded significantly higher plant height (196 cm), leaf area index (5.30) and dry matter production per plant (80.2 g) but it was on par with 160 kg ha^{-1}(192 cm, 5.26 and 78.5 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 of cell division, cell enlargement, cell differentiation and multiplication under higher nitrogen level resulted in consistent and statistically significant increase in leaf area index. 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 Bindhani *et al*. (2007); Sepat and Kumar (2007) and Abdullah *et al*. (2010).

Yield :

The varying plant densities showed significant effect on cob, grain and fodder yields (t ha^{-1}) of popcorn (Table

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

Treatments	Plant height (cm) at harvest			Leaf area index (%) at harvest			Dry matter production (g plant^{-1})		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Plant densities (plants ha^{-1})									
1,11,111 (45x20 cm)	192	202	197	5.10	5.26	5.18	65.8	69.2	67.5
1,11,111 (60x15 cm)	180	189	185	5.34	5.72	5.53	71.3	74.6	73.0
83,333(60x20 cm)	167	174	171	4.06	4.44	4.25	83.8	86.3	85.1
C.D. (P=0.05)	11	9		0.04	0.04		4.5	5.0	
Nitrogen levels (kg N ha^{-1})									
80	169	173	171	4.23	4.81	4.52	68.0	70.7	69.4
120	174	183	179	4.70	5.03	4.86	71.3	73.9	72.6
160	187	197	192	5.18	5.35	5.26	76.7	80.3	78.5
200	191	200	196	5.22	5.38	5.30	78.4	82.0	80.2
C.D. (P=0.05)	11	9		0.05	0.04		4.5	5.5	
Interaction	13	12		0.08	0.07		6.0	7.0	

Table 2 : Cob, grain and fodder yield (t ha^{-1}) of popcorn hybrid as influenced by plant densities and nitrogen levels

Treatments	Cob yield(t ha^{-1})			Grain yield (t ha^{-1})			Fodder yield(t ha^{-1})		
	2011	2012	Mean	2011	2012	Pooled mean	2011	2012	Mean
Plant densities (plants ha^{-1})									
1,11,111 (45x20 cm)	5.9	6.1	6.0	4.6	5.0	4.8	6.2	6.4	6.3
1,11,111 (60x15 cm)	6.6	7.0	6.8	5.6	5.5	5.6	6.9	7.2	7.1
83,333(60x20 cm)	5.5	5.5	5.5	4.2	4.4	4.3	5.6	5.8	5.7
C.D. (P=0.05)	0.3	0.5		0.3	0.4	0.4	0.4	0.4	
Nitrogen levels (kg N ha^{-1})									
80	5.2	5.4	5.3	4.1	4.2	4.2	5.5	5.9	5.7
120	5.8	6.0	5.9	4.6	4.8	4.7	6.0	6.2	6.1
160	6.4	6.6	6.5	5.3	5.6	5.5	6.5	6.8	6.7
200	6.6	6.7	6.7	5.3	5.5	5.4	6.8	6.9	6.9
C.D. (P=0.05)	0.4	0.5		0.4	0.4	0.4	0.4	0.5	
Interaction	0.4	0.6		0.4	0.6	0.5	0.6	0.5	

Table 3 : Interaction effect of plant densities and nitrogen levels on grain yield (kg ha^{-1}) of popcorn hybrid (pooled mean over 2 years)

Nitrogen levels (kg N ha^{-1})					
Plant densities (Plants ha^{-1})	80	120	160	200	Mean
1,11,111 (45x20 cm)	4.1	4.7	5.3	5.4	4.9
1,11,111 (60x15 cm)	5.0	5.3	6.0	6.0	5.6
83,333 (60x20 cm)	3.4	4.2	5.1	4.9	4.4
Mean	4.2	4.7	5.5	5.4	
C.D. (P=0.05)			0.5		

2). Pooled data over 2 years indicated that significantly higher grain yield was observed with a plant density of 1,11,111 ha^{-1} (5.6 t ha^{-1}) whereas significantly lower grain yield was obtained with 83,333 ha^{-1} (4.3 t ha^{-1}). More number of plants ha^{-1} under high plant density with higher dry matter production might have contributed for higher grain yield. Sahoo and Mahapatra (2007) and Kumar (2008) also reported similar results. Within the same plant density of 1,11,111 ha^{-1} wider row spacing of 60x15cm recorded higher grain yield (5.6 t ha^{-1}) compared to narrow row spacing of 45x20 cm (4.8 t ha^{-1}) (Table 3). Pooled mean over two years indicated that the per cent increase in grain yield at 1,11,111 plants ha^{-1} (60x15 cm) over 83,333 plants ha^{-1} (60x20 cm) and 1,11,111 plants ha^{-1} (45x20 cm) was 30.2 and 16.7, 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 accordance with Maddonni *et al.* (2006). Cob and fodder yields also followed similar trend (Table 3).

Significantly higher cob (6.7 t ha^{-1}), and fodder yields (6.9 t ha^{-1}) were obtained with 200 kg N ha^{-1} but were on par with 160 kg N ha^{-1} (6.5 and 6.7 t ha $^{-1}$, respectively) and both were superior over other two nitrogen levels (Table 3) whereas application of 160 kg N ha^{-1} recorded higher grain yield (5.5 t ha^{-1}) compared to 200 kg N ha^{-1} (5.4 t ha^{-1}). The per cent increase in grain yield with 160 kg N ha^{-1} over 80 and 120 kg N ha^{-1} was 30.9 and 17.0, respectively. Arun Kumar *et al*. (2007) and 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 characters. However grain yield increased upto 160 kg N ha^{-1} and beyond that it was not significant. Maize yield increases with an increase in rate of nitrogen fertilizer until it reaches 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 significantly higher grain yield (6.0 t ha^{-1}) was at a plant density of 1,11,111 ha^{-1} with 200 kg N ha^{-1} but it was on par with 160 kg N ha^{-1} at same plant density whereas significantly lower grain yield (3.4 t ha^{-1}) was with a plant density of 83,333 ha^{-1} at 80 kg N ha^{-1} (Table 3).

The findings of the present experiment clearly

suggest that growth parameters and yield in popcorn hybrid have been very much influenced by the plant densities and N fertilizers as much as that in normal corn hybrids. Therefore it is recommended to grow popcorn hybrid at a plant density of 1,11,111 ha^{-1} (60x15 cm) with 160 kg N ha^{-1} in peri urban areas, so that farmers can get maximum benefit in terms of net income.

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