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Influence of Plant Densities and Nitrogen Levels on the Performance of Popcorn Hybrid

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted at the Maize Research Centre, Agricultural Research Institute (ARI), Rajendranagar, Hyderabad during the rabid seasons (15 October to 15 January) for two years to study the effect of plant densities and nitrogen levels on growth parameters, yield characteristics, yield and economics of the newly published popcorn hybrid BPCH-6 by Professor Jayashankar Telangana State Agricultural University (Previously Acharya NG Ranga Agricultural University). 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 levels of nitrogen (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}) were taken in a randomised block configuration with three repeated factorial principles. Significantly higher plant height with a population of 1, 11,111 ha^{-1} (45x20 cm), significantly higher leaf area index with a population of 1, 11,111 ha^{-1} (60x15 cm) and significantly higher dry matter production (g $plant^{-1}$) with a population of 83,333 plants ha^{-1} (60x20 cm) was observed as per pooled mean over two years. Yield attributes like cob girth, number of rows cob^{-1}

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and 100 seed weight were not influenced significantly whereas cob length and number of seeds row^{-1} were significantly superior with optimum plant density of 83,333ha^{-1}. A plant density of 1, 11,111 ha^{-1} (60x15 cm). recorded significantly higher cob, grain fodder yields.
When a population of 1, 11,111 plants ha^{-1} (60x15 cm) was maintained, gross and net returns and profit cost ratios were higher. The use of 200 kg of nitrogen ha-1 resulted in slightly higher growth parameters, yield characteristics and yield, but it was equal to 160 kg of N ha^{-1} and both were greater than 120 and 80 kg of N ha^{-1}.. Application of 160 Kg N ha^{-1} recorded higher gross and net returns and benefit cost ratio compared to 200 Kg N ha^{-1}.

Keywords: Popcorn; rabi; plant densities; nitrogen levels; growth parameters; yield attributes; yield; economics.

1. INTRODUCTION

One of the essential cereals in India is maize (*Zea mays* L.). It is predominantly used in India as poultry feed (49%), animal feed (12%), and 25% as food in various types [1]. Popcorn (*Zea mays* variety everta) is a specialty type of maize that produces exceptional popping consistency, which when heated implies expansion in kernel volume. In many peri-urban areas, it is gaining importance as a popular nutritious snack food. There are currently four popcorn varieties available for commercial cultivation in India, such as Amber popcorn, VL popcorn, Jawahar popcorn and Pearl popcorn [2,3]. Maize Research Centre, Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, India, tried to grow hybrid in popcorn for the first time as the yield of hybrid is superior compared to varieties. Consequently, Professor Jayashankar Telangana State Agricultural University (formerly Acharya NG Ranga Agricultural University) published the first popcorn hybrid BPCH-6 at national level. Agronomic assessment must be done before the publication of any hybrid.. Among the various agronomic practices, plant density and fertilizer are the most important factors which greatly influence the potential yield realisation from any crop [4]. Popcorn yield is significantly influenced not only by genetic potential but also by different cultural practices as reported by Halluer [5], Babic and Pajic, [6] and Ziegler et al. [7]. Though plant density and fertiliser requirement of grain maize has been standardised by many authors the recommended plant density and nitrogen dose for the normal maize hybrids may not be applicable for the popcorn hybrid [8] and [9]. The current study on "Performance of popcorn hybrids at varying plant densities and nitrogen levels during rabies" was taken up at the Maize Research Centre, Agricultural. Research Institute (ARI), Rajendranagar, Hyderabad, Telangana, India, as part of agronomic assessment and also maintaining the significance of popcorn popularisation in a commercial way in peri-urban areas.

2. MATERIALS AND METHODS

The experiment was conducted at the Maize Research Centre, Agricultural Research Institute, Rajendranagar, Hyderabad for two years during *rabi* (From October 15th to January 15th). The altitude, latitude and longitude of the experimental site is 542.3 m above mean sea level, 17^{0} 19' N and 78^{0} 24' E respectively which is a part of Southern Telangana agro-climatic zone of Telangana (Previously part of Andhra Pradesh). The soil of the experimental field was clay loam, slightly alkaline (pH 7.8) with low organic carbon (0.38 %) and available nitrogen (195.3 kg ha^{-1}), medium in available phosphorous (30.23 kg ha^{-1}) and high in available potassium (156.7 kg ha^{-1}). The experiment was laid out in randomized block design in factorial with three replications. Treatments were three plant densities (P_1–1,11,111ha^{-1} (45 x 20 cm), P_2–1,11,111 ha^{-1} (60 x 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}.

BPCH-6 hybrid of Popcorn was used in the experiment. It is suitable for both *kharif* and *rabi* cultivation in Telangana (Previously part of Andhra Pradesh). The crop was sown on 20th October and harvested on 12th January. Seeds were dibbled at a depth of 3–4 cm to maintain the desired plant population. Irrigation was given to ensure proper and uniform germination. Thinning was performed within 15 days after germination to allow only one healthy seedling per hill. The nitrogen fertilizer was applied according to the treatments viz., 80, 120, 160 and 200 kg ha^{-1} in the form of solid fertilizer urea after calculating the proportion of nitrogen applied through solid fertilizer Diammonium Phosphate (DAP). Phosphorus @ 60 kg ha^{-1} as DAP and Potash @ 50 kg ha^{-1} as solid fertilizer Muriate of Potash (MOP) 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 days after sowing (DAS) and remaining $1/3^{rd}$ N at 60 DAS. Standard agronomic practices recommended by Professor Jayashankar Telangana State Agricultural University 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 to reduce the border effect of neighboring treatments. Fischer's method of analysis of variance technique by Gomez and Gomez [10] was adapted for interpretation of data. The levels of significance used in 'F' and 't' test were P-0.05 and 0.01 and critical values were calculated wherever the 'F' test was significant.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Growth parameters like plant height at harvest (cm), Leaf area index (LAI) at harvest and dry matter production (g) were influenced significantly by both plant densities and nitrogen levels in both the years. Pooled mean over two years indicated that, significant increase in plant height was observed with a plant population of 83,333 plants ha^{-1} (166 cm) compared to 1, 11,111 ha^{-1} (184 cm). Within the same plant population of 1, 11,111 plants ha^{-1} also, narrow row spacing of 45x20 cm recorded significantly higher plant height (184 cm) compared to wider row spacing of 60 x 15 cm (176 cm) (Table 1). Greater interplant competition at higher plant densities might have reduced the amount of light availability to the individual plant and hence the plant tended to grow taller in search of sunlight. Similar kind of results in popcorn were already reported by (Ülger, [11]; Konuskan, [12]; Gozubenli, et al. [13]; Konuskan and Gözübenli, [14]; Sener et al. [15]). Significant increase in LAI at harvest was recorded as the plant density increased from 83,333 ha^{-1} (4.1) to 1, 11,111 ha^{-1} (5.1) (Table 1). More number of leaves with greater number of plants per unit area might probably be the reason for higher LAI at higher plant population levels. The results are in accordance with Suryavanshi et al. [16]. Increase in plant density from 83,333 ha^{-1}(79.1 g $plant^{-1}$) to 1, 11,111 ha^{-1} (68.0 g $plant^{-1}$) decreased the dry matter production significantly. Within the same plant population of 1,11,111 plants ha^{-1}, wider row spacing of 60x15 cm recorded higher leaf area index (5.1) and dry matter production per plant (73.5 g) compared to narrow row spacing of 45 x 20 cm (4.5 and 68.0 g respectively) (Table 1). Wider space between rows might have increased the root spread which eventually utilized the resources like space, light, nutrients and moisture very effectively and in turn enhanced the leaf area index leading to higher photo-synthetic rate and more dry matter production per plant. Similar kind of response was noticed by Evans and Fischer, [17]; Long et al. [18]; Amthor, [19].

Plant height at harvest (cm), Leaf area index (LAI) at harvest and dry matter production (g) were influenced significantly by different nitrogen levels. Nitrogen at 200 kg ha^{-1} showed significantly higher plant height (185 cm), leaf area index (5.1) and dry matter production per plant (80.7 g) which was on par with 160 kg ha^{-1} (183 cm, 5.1 and 79.6 g respectively) and both were significantly superior over 120 and 80 kg N ha^{-1} (Table 1). As maize being an exhaustive crop, application of nitrogen at higher doses might have led to increased cell division, cell enlargement, cell differentiation and multiplication causing better vegetative growth of the plant. Similar kind of response was observed by Bindhani et al. [20], Sepat and Kumar [21] and Oktem et al. [22]. Positive effect of nitrogen on vegetative growth of popcorn was also noticed by Ülger [11], Gozubenli, et al. [23], Khalifa et al. [24] and Sezer and Yanbeyi [25].

Interaction effect showed that significantly higher plant height and leaf area index was with 1,11,111 plants ha^{-1} and at 200 kg N ha^{-1} but it was on par with 160 kg N ha^{-1} whereas significantly higher dry matter production was with 83,333 plants ha^{-1} and at 200 kg N ha^{-1} but it was on par with 160 kg N ha^{-1}.

3.2 Yield Attributes

Cob girth, number of rows cob^{-1} and 100 seed weight were not significantly influenced either by plant densities or nitrogen levels except with cob girth which was significantly influenced only by plant densities (Table 2). Most of them being genetic characters, external factors might not have shown the significant influence. Whereas, densities and nitrogen levels have showed significant influence on cob length and number of seeds row^{-1} (Table 3). Optimum plant density of 83,333 ha^{-1} with wider row spacing of 60x20 cm recorded significantly greater cob length (20.8 cm) and number of seeds row^{-1} (34.8) compared to high plant density of 1,11,111 ha^{-1} with narrow row spacing of 45x20 cm (19.0 cm and 31.0 respectively). The decrease in cob length and number of seeds row^{-1} with high plant population beyond optimum might be as a result of interplant competition for light, nutrients and water. Williams et al., [26] also reported that photosynthetic efficiency and growth in maize were strongly related to the effect of canopy architecture on the vertical distribution of light within the canopy. The results are in accordance with the findings of Sade and Çalis, [27] in popcorn.

Application of nitrogen at 200 kg ha^{-1} produced significantly higher cob length (20.4 cm) and number of seeds row^{-1} (33.8) but was on par with 160 kg ha^{-1} (20.6 cm and 33.6 respectively) and both were significantly superior over the rest of the treatments (Table 3). Nitrogen is a primary nutrient which shows significant influence on the plant productivity. Maize being an exhaustive crop, might have responded well to increased nitrogen application. And also, better vegetative growth in terms of greater plant height, LAI and dry matter production might have led to increased yield attributing characters. Similar kind of response in popcorn was reported by Sabri Gokmen et al. [28].

Interaction effect showed that significantly higher cob length and number of seeds row^{-1} were with 83,333 plants ha^{-1} and at 200 kg N ha^{-1} but were on par with 160 kg N ha^{-1}.

3.3 Yield

Cob, grain and fodder yields (t ha^{-1}) of popcorn were significantly influenced by both plant densities and nitrogen levels (Table 3). Pooled data over two years indicated that, a plant population of 1, 11,111 plants ha^{-1} (5.6 t ha^{-1}) showed significantly higher grain yield compared to 83,333 ha^{-1} (4.4 t ha^{-1}). Higher yield attributes in optimum plant population of 83,333 ha^{-1} did not record higher yield as loss of plants in lower plant density was not compensated by increased yield attributes whereas greater number of plants have compensated the reduction in yield attributes. Sahoo and Mahapatra [29] and Kumar [30] also reported similar results. Even with the same plant population of 1,11,111 plants ha^{-1}, wider row spacing of 60x15cm recorded significantly higher grain yield (5.6 t ha^{-1}) whereas narrow row spacing of 45 x 20 cm recorded significantly lower grain yield (4.9 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 21.4 and 12.5 respectively. Cob and fodder yield also followed similar trend (Table 3).

Fig. 1. Experimental site map

Table 1. Plant height (cm) at harvest, leaf area index (LAI) (%) 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 (LAI) (%) at harvest					Dry matter production (g $plant^{-1}$)				
	80 Kg N ha^{-1}	120 Kg N ha^{-1}	160 Kg N ha^{-1}	200 Kg N ha^{-1}	Mean	80 Kg N ha^{-1}	120 Kg N ha^{-1}	160 Kg N ha^{-1}	200 Kg N ha^{-1}	Mean	80 Kg N ha^{-1}	120 Kg N ha^{-1}	160 Kg N ha^{-1}	200 Kg N ha^{-1}	Mean
1,11,111 Plants ha^{-1} (45x20 cm)	169	176	195	197	184	3.6	4.4	5.0	5.0	4.5	60.6	65.1	72.1	74.3	68.0
1,11,111 Plants ha^{-1} (60x15 cm)	164	169	184	188	176	4.1	4.9	5.7	5.7	5.1	65.2	72.1	80.1	79.6	73.5
83,333 Plants ha^{-1} (60x20 cm)	161	167	169	170	166	3.5	3.9	4.5	4.1	4.1	67.0	74.3	86.7	88.2	79.1
Mean	165	171	183	185		3.7	4.4	5.1	5.1		64.3	69.6	79.6	80.7	
	S. Em ±	CD (P=0.05)				S. Em ±	CD (P=0.05)				S. Em ±	CD (P=0.05)			
P	2.5	6				0.02	0.04				2.5	7.1			
N	2.0	5				0.02	0.04				2.2	5.0			
P x N	4.0	11				0.03	0.08				3.1	10.2			

Table 2. Cob girth (cm), number of rows cob^{-1} and 100 seed weight (g) of popcorn hybrid as influenced by plant densities and nitrogen levels (pooled mean over 2 years)

Treatment	Cob girth (cm)	Number of rows cob^{-1}	100 Seed weight(g)
Plant densities (plants ha^{-1})			
1,11,111 (45x20 cm)	9.7	13.4	13.1
1,11,111 (60x15 cm)	10.1	13.4	13.3
83,333 (60x20 cm)	10.6	13.7	13.5
S. Em ±	0.1	0.3	0.2
CD (P=0.05)	0.3	NS	NS
Nitrogen levels (kg N ha^{-1})			
80	9.6	13.4	13.3
120	9.9	13.4	13.3
160	10.5	13.5	13.5
200	10.6	13.6	13.6
S. Em ±	0.1	0.2	0.2
CD (P=0.05)	NS	NS	NS
Interaction	NS	NS	NS

Table 3. Cob length (cm), number of seeds row^{-1}, cob yield (t ha^{-1}), grain yield (t ha^{-1}) and fodder yield (t ha^{-1}) of popcorn hybrid as influenced by plant densities and nitrogen levels

Treatments	Cob length (cm)					Number of seeds row^{-1}					Cob yield (t ha^{-1})					Grain yield (t ha^{-1})					Fodder yield (t ha^{-1})				
	80 Kg N ha^{-1}	120 Kg N ha^{-1}	160 Kg N ha^{-1}	200 Kg N ha^{-1}	Mean	80 Kg N ha^{-1}	120 Kg N ha^{-1}	160 Kg N ha^{-1}	200 Kg N ha^{-1}	Mean	80 Kg N ha^{-1}	120 Kg N ha^{-1}	160 Kg N ha^{-1}	200 Kg N ha^{-1}	Mean	80 Kg N ha^{-1}	120 Kg N ha^{-1}	160 Kg N ha^{-1}	200 Kg N ha^{-1}	Mean	80 Kg N ha^{-1}	120 Kg N ha^{-1}	160 Kg N ha^{-1}	200 Kg N ha^{-1}	Mean
1,11,111 Plants ha^{-1} (45x20 cm)	18.5	18.6	19.5	19.5	19.0	29.8	30.1	31.6	31.7	31.0	4.5	4.8	5.9	6.0	5.3	4.1	4.7	5.3	5.4	4.9	4.8	5.3	6.4	6.5	5.8
1,11,111 Plants ha^{-1} (60x15 cm)	19.5	19.7	20.8	20.4	20.1	32.0	32.8	33.4	33.9	33.0	5.3	5.8	6.9	6.9	6.2	5.0	5.3	6.0	6.0	5.6	6.1	6.5	7.4	7.3	6.9
83,333 Plants ha^{-1} (60x20 cm)	20.0	20.2	21.6	21.3	20.8	33.6	33.9	35.7	35.8	34.8	4.1	4.6	5.1	5.0	4.7	3.4	4.2	5.1	4.9	4.4	4.5	4.9	5.5	5.6	5.1
Mean	19.3	19.5	20.6	20.4		31.8	32.3	33.6	33.8		4.6	5.1	6.0	6.0		4.2	4.7	5.5	5.4		5.1	5.6	6.4	6.5	

	Cob length S. Em ±	Cob length CD (P=0.05)	Seeds row^{-1} S. Em ±	Seeds row^{-1} CD (P=0.05)	Cob yield S. Em ±	Cob yield CD (P=0.05)	Grain yield S. Em ±	Grain yield CD (P=0.05)	Fodder yield S. Em ±	Fodder yield CD (P=0.05)
P	0.3	0.6	0.4	1.2	0.1	0.3	0.2	0.4	0.2	0.4
N	0.3	0.7	0.3	1.0	0.2	0.4	0.2	0.4	0.3	0.5
P x N	0.5	1.1	0.8	3.0	0.2	0.6	0.2	0.5	0.3	0.5

Table 4. Cost of cultivation (₹ ha^{-1}), gross returns (₹ ha^{-1}), net returns (₹ ha^{-1}) and benefit cost ratio of popcorn hybrid as influenced by plant densities and nitrogen levels (mean over 2 years)

Treatment	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
Plant densities (plants ha^{-1})				
1,11,111 (45x20 cm)	42,832	1,47,150	1,04,318	2.44
1,11,111 (60x15 cm)	42,832	1,71,550	1,28,718	3.01
83,333 (60x20 cm)	40,832	1,31,850	91,018	2.23
Nitrogen levels (kg N ha^{-1})				
80	40,694	1,28,850	88,156	2.17
120	41,676	1,44,050	1,02,374	2.46
160	42,656	1,68,350	1,25,694	2.95
200	43,638	1,65,450	1,21,812	2.79

Cost of grain/kg = ₹ 30/-
Cost of fodder/kg = ₹ 0.5/-

Application of nitrogen at 200 kg N ha^{-1} recorded significantly higher cob (6.0 t ha^{-1}), grain (5.4 t ha^{-1}) and fodder yields (6.5 t ha^{-1}) and it was on par with 160 kg N ha^{-1} (6.0, 5.5 and 6.4 t ha^{-1} respectively) and both were superior over rest of the nitrogen treatments (Table 3). The per cent increase in grain yield with 160 kg N ha^{-1} over 80 and 120 kg N ha^{-1} was 23.6 and 14.5 respectively. Favorable growth and yield attributing characters with higher level of nitrogen application might be the reason for higher yields. Kumar et al. [31] and Singh et al. [32] also reported similar response. However, grain yield increased up to 160 kg N ha^{-1} and beyond that it was not significant. Grain yield of any crop to applied nitrogen depends on different factors like weather, water supply, soil characteristics and finally the type of cultivated variety. The grain yield of maize grown on soils low in fertility has been found to increase with increments of Nitrogen until it reaches a peak, and additional N has either not affected it or decreased it [33].

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).

3.4 Economics

Both plant densities and nitrogen levels influenced the cost of cultivation, gross and net returns and benefit cost ratio (Table 4).

Population of 1,11,111 plants ha^{-1} recorded higher gross returns (₹ 1,71,550 ha^{-1}), net returns (₹ 1,28,718 ha^{-1}) and benefit cost ratio (3.01) compared to lower gross returns (₹ 1,31,850 ha^{-1}), net returns (₹ 91,018 ha^{-1}) and benefit cost ratio (2.23) with a population of 83,333 ha^{-1}.

Among the nitrogen levels, application of 160 kg ha^{-1} resulted in higher gross returns (₹ 1,68,350 ha^{-1}), net returns (₹ 1,25,694 ha^{-1}) and benefit ratio of 2.95 compared to 200 kg ha^{-1} (₹ 1,65,450 ha^{-1}, ₹ 1,21,812 ha^{-1} and 2.80 respectively).

4. CONCLUSION

From the results, it can be concluded that, both Plant density and Nitrogen had major impact on performance of Popcorn. In the Southern Telangana Agroclimatic Zone of Telangana, India, a plant density of 1, 11,11 plants ha-1 (60x15 cm) with 160 kg N ha-1 is considered optimal for obtaining higher yields and net income for the Popcorn hybrid to be produced.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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