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Productivity, economics and nitrogen-use efficiency of specialty corn (*Zea mays*) as influenced by planting density and nitrogen fertilization

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ABSTRACT

A field experiment to study the effect of planting density and N level on pop corn and sweet corn (*Zea mays* L.) was conducted during rainy season 2005 and 2006 at New Delhi. An increase in planting density recorded taller plants with reduced values of yield attributes of both pop corn and sweet corn. However, in sweet corn the number of cobs/ha increased with the increase in planting density. The planting density of 66,666 and 83,333 plants/ha recorded 23.5 and 40.0% higher grain yield of pop corn compared with that of 55,555 plants/ha respectively. The cob and kernel yields of sweet corn however, improved significantly by 19.4 and 15.2% at a planting density of 83,333 over that of 66,666 plants/ha respectively, but further increase in planting density to 1,11,111 plants/ha decreased both the cob and the kernel yields in comparison with 83,333 plants/ha. The net returns, net returns/Re invested, N uptake and N-use efficiency also showed a similar trend. The increase in N level up to 120 kg/ha resulted in taller plants with higher values of yield attributes of pop corn as well as sweet corn, which consequently resulted in higher yields and returns. The highest N uptake and residual soil N content were recorded at 120 kg N/ha level. The N-use efficiency was the highest at 40 kg N/ha, and an increase in N level reduced the N-use efficiency. The results show that for getting higher yield and net return, pop corn and sweet corn should be planted at 83,333 plants/ha planting density and fertilized with 120 kg N/ha.

Key words: Economics, Growth, N-use efficiency, Planting density, Pop corn, Sweet corn

Pop corn and sweet corn are the two important specialty corns (*Zea mays* L.), which are most popular as snack food in many parts of the world. The kernels of pop corn are composed of hard starch; when heated to about 170°C they swell and burst, turning inside out. The sweet corn grains, however, have higher sugar content (14-20%) and are more delicious. At present the cultivation of specialty corn is concentrated in the outskirts of big cities and metropolis. The productivity levels of these crops are very low due to non-availability of suitable production technology. Owing to non-availability of appropriate agro-techniques and lack of awareness regarding their trade potential among the farmers and policy-makers, the cultivation of specialty corn has not been extended in other areas of the country. Planting density is an important non-monetary input for corn to achieve high yield. Like normal corn, specialty corn also has poor capability of adjustment to a thinner stand compared with other cereals. The planting density for normal corn has been optimized, but the recommended plant density for hybrid and composites of normal corn may not be applicable for the specialty corn because of differences in their growth and development pattern. N is a very important nutrient for corn, as it responds to N levels up to 120 kg (Sepat and Kumar, 2007) or even more (Singh *et al.*, 2003) depending on the cultivars and soil-fertility status. In India much work has not been done so far on the production technology, specifically on plant density and N requirement of specialty corn, which need an urgent attention. In view this; two experiments were undertaken to study the effect of planting density and N level on pop corn and sweet corn.

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MATERIALS AND METHODS

Two field experiments on specialty corn were carried out at Indian Agricultural Research Institute, New Delhi having three planting densities for each pop corn (55,555, 66,666 and 83,333 plants/ha) and sweet corn (66,666, 83,333 and 1,11,111 plants/ha) with four N levels (0, 40, 80, and 120 kg N/ha). Factorial randomized block design was adapted, replicated thrice during rainy (*kharif*) season 2005 and 2006. The soil of was low in organic carbon (0.37%) and available N (167.0 kg/ha); and medium in available P (11.6 kg P/ha) and K (178.7 kg/ha) with sandy loam texture and pH 7.6. After applying a pre-planting irrigation, 'Amber'

pop corn and 'Madhuri' sweet corn were dibbled at a depth of 5-6 cm in rows 60 cm apart as per the requirement for different planting densities. The crops were planted on 29 June 2005 and 10 July 2006, respectively. At 15 days crop stage, planting densities of 55,555, 66,666, 83,333 and 1,11,111 plants/ha as per treatment were maintained by keeping respectively 30, 25, 20 and 15 cm spacing between the plants. Pop corn was harvested on 4 and 9 October, whereas green cobs of sweet corn were harvested during the third and fourth weeks of September during 2005 and 2006 respectively. N as per treatment was applied into three splits, i.e. one-third each as basal at each knee-high and silking stages. However, P, K and Zn were applied uniformly @ 26.1, 33.2 and 5 kg/ha respectively as basal. In addition to pre-sowing irrigation, four post-sowing irrigations were applied to both the crops. The plant height and yield attributes were observed from five plants sampled randomly from each plot at maturity. Net return and benefit : cost ratio were calculated on the basis of prevailing market prices of different inputs and produce. N uptake was calculated on the basis of N concentration and yields of the crops. Available N content in 30 cm deep soil samples at maturity was analysed as per the standard method. The agronomic N use efficiency (ANUE) and physiological N use efficiency (PNUE) were worked out by using the standard formulae.

RESULTS AND DISCUSSION

Growth and yield attributes

Plant height and all the yield attributes of pop corn and sweet corn except cob girth of pop corn varied significantly due to different planting densities (Table 1). Taller plants of pop corn and sweet corn were found with successive increase in planting densities from 55,555 to 83,333 plants/ha and from 66,666 to 1,11,111 plants/ha respectively. However, cob length, grains/cob and shelling (%) of popcorn showed declining trend with each increase in planting density from 55,555 to 83,333 plants/ha except between 5,5,555 and 66,666 plants/ha, where cob length and shelling percentage remained at par. Similarly, green-cob weight, number of kernels/cob, 1,000-kernel weight and kernel recovery of sweet corn also decreased with the increase in planting density from 66,666 to 1,11,111 plants/ha, but values of these yield attributes did not vary statistically between the plant densities of 66,666 and 83,333 plants/ha. More severe competition for light and higher intra-row competition for nutrients and water due to overcrowding of plants might be responsible for increasing the plant height and declining the values of yield attributes respectively at higher planting densities. Our results confirm the findings of Meena (1993) and Sahoo and Mahapatra (2007). The Increase in planting density from 66,666 to 1,11,111 plants/ha recorded higher number of sweet corn cobs/ha.

Each successive increase in N level from 0 to 120 kg/ha gave taller plants of both pop corn and sweet corn with increasing values of yield attributes of sweet corn, viz. number of cobs/ha, weight of green cob, number of kernels/cob, kernel recovery and 1,000-fresh kernel weight (Table 1). However, yield attributes of pop corn, viz. girth and length of cobs, grains/cob and shelling percentage markedly improved up to 80 kg N/ha. The increased levels of N might have resulted in easy and greater availability of N to the crop plants, which consequently improved the plant height and yield attributes of corn. These findings are in close conformity with those of Bindhani *et al.* (2007) and Sahoo and Mahapatra (2007).

Yield

In general, planting densities of 66,666 and 83,333 plants/ha recorded 23.5 and 40.0% higher grain, and 8.1 and 21.1 % higher stover yield of pop corn compared with that of 55,555 plants/ha (Table 2). The improvement in both grain and stover yields of pop corn with increase in planting densities from 55,555 to 66,666 and 66,666 to 83,333 was significant. At higher planting densities, more number of cobs might have compensated the poor values of yield attributes, which consequently improved the grain yield. In sweet corn also the planting densities significantly influenced the yields of green cobs, fresh kernel and green fodder (Table 2). Significant improvement of 19.4 and 15.2% in cobs and kernel yield of sweet corn was found with the planting density of 83,333 over 66,666 plants/ha respectively. Lower yield at 66,666 plants/ha was due to lower number of cobs. When the planting density was further increased from 83,333 to 1,11,111 plants/ha, the cob and kernel yields decreased considerably to 21.9 and 29.4% respectively. At higher planting density, greater competition for different resources reduced the values of different yield attributes, which consequently decreased the yield. The results are in close conformity with those of Sahoo and Mahapatra (2007). The increasing planting density contributed significantly towards the green fodder yield of sweet corn, being maximum at 1,11,111 plants/ha (Table 2). Linear increase in green fodder yield with increasing planting densities was also noticed by Widdicombe and Thelen (2002).

Marked improvement in the grain and stover yields of pop corn and in green cobs, fodder and fresh kernel yields of sweet corn was found with each successive increase in N level from 0 to 120 kg N/ha. In general, pop corn showed 38.2, 64.9 and 82.2% increase in grain yield and sweet corn showed 122.7, 190.9 and 212.3% increase in green cob yield with the application of 40, 80 and 120 kg

Table 1. Influence of planting density and N level on growth and yield attributes of specialty corn (pooled data of 2 years)

Treatment	Pop corn: Plant height (cm)	Pop corn: Dry weight (g/plant)	Pop corn: Days to 50% silking	Pop corn: Cob length (cm)	Pop corn: Cob girth (cm)	Pop corn: Grains / ear	Pop corn: Shelling (%)	Sweet corn: Plant height (cm)	Sweet corn: Dry weight (g/plant)	Sweet corn: Number of Cobs (000'/ha)	Sweet corn: Number of kernels/ Cobs	Sweet corn: Fresh kernel weight (g/1000 seed)	Sweet corn: Green cob weight (g)	Sweet corn: Kernel recovery (%)	Sweet corn: Barren-ness (%)
Plant population (plants/ha)															
55,555	98.3	48.1	65	13.7	9.5	316	76.5								
66,666	103.7	46.2	67	13.3	9.5	311	75.5	96.3	72.5	62.94	321	276.3	153.2	62.0	6.6
83,333	107.6	44.6	68	12.3	9.3	308	73.9	102.0	66.8	76.59	311	264.4	151.0	60.4	9.0
1,11,111								105.1	60.6	93.99	289	251.6	110.7	53.8	15.2
SEm±	0.6	0.3	0.4	0.2	0.02	1.0	0.5	0.6	1.6	2.22	5	4.0	2.8	1.1	1.1
CD (P=0.05)	1.9	1.0	NS	0.6	NS	2.9	1.4	1.8	4.8	6.67	15	12.3	5.4	3.3	3.3
Nitrogen (kg/ha)															
0	95.3	42.2	63	12.2	9.3	302	73.4	94.7	36.8	57.15	163	166.3	86.0	49.8	16.2
40	102.0	46.0	66	12.4	9.4	311	74.9	100.2	60.2	74.0	302	245.8	128.7	60.8	10.2
80	107.4	47.8	68	13.5	9.5	316	76.2	103.3	79.9	85.73	370	305.0	159.6	62.0	8.4
120	109.7	49.2	69	13.8	9.5	318	76.6	106.9	88.7	94.46	395	340.1	179.1	62.4	6.1
SEm±	0.7	0.4	0.4	0.2	0.03	1.1	0.6	1.0	1.8	2.25	8	4.8	3.6	1.2	1.5
CD (P=0.05)	2.2	1.2	1.4	0.5	0.1	3.0	1.5	2.9	5.4	6.78	24	14.5	7.1	3.6	4.5

N/ha over the control, respectively (Table 2). The cumulative beneficial effect of N on yield attributes was finally reflected in grain yield of maize. Bindhani *et al.* (2007) and Sepat and Kumar (2007) also reported similar findings for baby corn and maize respectively.

N uptake and use-efficiency

In general, sweet corn showed higher values of N uptake, agronomic N-use efficiency (ANUE) and physiological-use efficiency (PNUE) than pop corn due to its higher yield level (Table 2). All these values of both the crops improved significantly with each increase in planting density up to 83,333 plants/ha. However, sweet corn recorded their lower values at 1,11,111 plants/ha due to reduction in yield.

Nitrogen application improved the N uptake by both the types of corn with each increase in N up to 120 kg N/ha. But N-use efficiencies showed the reverse trend, and the maximum values of ANUE and PNUE by both the crops were noticed at 40 kg N/ha. An increase in N level up to its highest dose significantly reduced the ANUE of both pop corn and sweet corn, but decreased PNUE of N in sweet corn only. No significant variation was found in PNUE of pop corn. Our result confirms the findings of Kumar and Ahlawat (2004) and Bindhani (2007).

Economics

Different planting densities and N levels showed significant variation in net return and net return/Re invested (Table 2). In general, sweet corn gave higher net return than pop corn due to its higher productivity. The net returns and net returns/Re invested varied from Rs 18,350 to 41,590 and Rs 1.57 to 3.23 in pop corn; and Rs 8,050 to 49,420/ha and Rs 0.64 to 3.55 in sweet corn respectively. Both these values improved in pop corn as well as sweet corn with increase in planting density up to 83,333 plants/ha. However, in sweet corn further increase in plant density over 83,333 plants/ha considerably reduced net return and net return/Re invested. Sahoo and Mahapatra (2007) also reported similar findings.

There was marked improvement in net return by both pop corn and sweet corn with each successive increase in N level from 0 to 120 kg N/ha (Table 2). The highest net return of Rs 41,590/ ha and Rs 49,420/ha by pop corn and sweet corn was found at 120 kg N/ha, which were 126.6, 41.6 and 12.9%; and 513.9, 53.33 and 8.9% higher than 0, 40 and 80 kg N/ha respectively. Similarly, net return/Re invested was also maximum (pop corn, Rs. 3.23 and sweet corn, Rs. 3.55) at 120 kg N/ha. But net return/Re invested at 80 kg N/ha by both the crops was statistically similar to that of 120 kg N/ha. Higher yields directly contributed to the returns at higher N level. This finding confirms that of Sepat and Kumar (2007).

Table 2. Influence of planting density and N levels on yield, net returns, N-use efficiency, N uptake and residual N in soil after specialty corn (pooled data of 2 years)

Treatment	Yield (t/ha) Pop corn Grain	Pop corn Stover	Sweet corn Green cobs	Sweet corn Green fodder	Sweet corn Fresh kernel	Net returns ($x10^3$ Rs/ha) Pop corn	Net returns Sweet corn	Net returns/Re invested (Rs) Pop corn	Net returns/Re invested Sweet corn	Agronomic efficiency Pop corn (kg grain/ kg N applied)	Agronomic efficiency Sweet corn kg (cob/ kg N applied)	Physiological efficiency Pop corn (kg grain/ kg N uptake)	Physiological efficiency Sweet corn (kg cob/ kg N uptake)	Nitrogen uptake (kg N/ha) Pop corn	Nitrogen uptake Sweet corn	Residual soil N (kg/ha) Pop corn	Residual soil N Sweet corn
Plant population (plants/ha)																	
55,555	2.30	3.61				23.96		1.94		15.0		56.4		53.3		162.3	
66,666	2.84	3.90	9.58	12.06	5.84	32.20	31.05	2.61	2.34	15.7	102.4	58.0	89.5	61.8	94.6	153.1	175.5
83,333	3.22	4.37	11.44	14.56	6.73	38.07	39.74	3.09	2.99	16.2	110.5	58.8	92.9	68.1	109.2	147.1	166.8
1,11,111			8.93	16.00	4.75		30.45		2.30		98.8		82.8		97.9		190.1
SEm±	0.07	0.09	0.12	0.28	0.12	0.99	1.10	0.09	0.15	0.2	2.5	0.2	1.3	2.2	3.1		
CD (P=0.05)	0.19	0.27	0.37	0.85	0.35	3.00	3.29	0.28	0.46	0.6	7.6	0.6	3.9	6.5	9.1		
Nitrogen (kg/ha)																	
0	1.91	2.85	4.31	6.95	2.19	18.35	8.05	1.57	0.64					39.5	39.6	139.4	157.4
40	2.64	3.84	9.60	13.59	5.71	29.38	32.23	2.42	2.46	18.3	132.4	58.4	95.2	57.9	95.2	150.9	175.5
80	3.15	4.41	12.54	17.33	7.34	36.82	45.35	2.91	3.36	15.5	102.9	57.4	86.7	70.5	134.6	158.0	182.5
120	3.48	4.75	13.46	18.97	7.85	41.59	49.42	3.23	3.55	13.1	76.3	57.1	83.4	78.9	149.4	168.6	187.8
SEm±	0.07	0.10	0.17	0.33	0.14	1.07	1.10	0.10	0.19	0.4	2.7	0.6	1.5	2.7	3.3		5.5
CD(P=0.05)	0.21	0.30	0.50	1.00	0.43	3.20	3.32	0.30	0.57	1.1	8.2	NS	4.5	8.0	10.0		16.5

Residual soil N content

Minimum content of N in the soil was observed at 83,333 plants/ha due to greater N uptake by both pop corn and sweet corn (Table 2). But the highest residual soil-N content was found at 55,555 and 1,11,111 plants/ha in pop corn and sweet corn respectively. The residual soil-N content increased with increase in N level, being the highest at 120 kg N/ha and the lowest at 0 kg N/ha. This finding confirms that of Mundra *et al*. (2002).

It was concluded that for getting higher yield and net return, the specialty corn should be grown at planting density of 83,333 plants/ha and fertilized with 120 kg N/ha.

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