J. Agrofor. Environ. 2 (2): 9-13, 2008 ISSN 1995-6983

Effect of planting density on morphological features and yield in 'baby' corn

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Abstract: A field experiment was carried out to investigate the effect of four planting densities (6, 8, 10 and 20 plants/m^2) on some important canopy structure and yield (husked fresh cob weight/ha) of 'baby' corn in two varieties (sweet corn and pop corn). Genetic variations existed for morphological characters and yield attributes in the two varieties with the sweet corn variety was shorter, thicker stem with larger cob and more yield in the sweet corn than in the pop corn. Irrespective of varieties, a density of 10 plants/m^2 produced greater and larger 'baby' corn. Results concludes that an optimum density of 10 plants/m^2 for baby corn yield (*c.* 7.0 t/ha) was observed in the both varieties under Mymensingh condition (24°75′N 90°50′E).

Key words: Spacing, canopy, young cob, vegetable, *Zea mays*

Introduction

Corn *(Zea mays L.)* belongs to the family Gramineae is the third most important cereal crop of the world after wheat and rice considering total area and production. `Baby' corn is an important vegetable and is produced from regular corn plants which are harvested early while the ears are very immature. Ears are ideal for baby corn if they are bite size, 4-5 inches long and 1-2 inches in diameter at the base. To meet these criteria, ears should be harvested between 8 and 12 days after silking (Bar-Zur and Saadi, 1990). Kernel colour of baby corn may be yellow, white, blue or even pink depending on the variety. Expected yield is approximately 8,500 pounds of unhusked baby corn ears per acre, or 1,140 pounds of husked baby corn (Miles and Shaffner, 1999). Baby corn is used primarily in Europe and America but production of this crop is highest in Asia. Countries known to export baby corn include Thailand, Srilanka, Taiwan, China, Zimbabwe, Zambia, Indonesia, South Africa, Nicaragua, Costa Rica, Guatemala, and Honduras. The importing countries are United States, United Kingdom, Denmark, Netherlands, Germany, France, Bahrain, Qatar etc. In Bangladesh, Maize is mainly grown for feed in many areas. Maize covers about 243 thousand acres of land and produces 522 tons of grains annually (BBS, 2006). Statistical information on baby corn production is limited because many countries neither report baby corn production nor include it within the sweet corn category. However, Thailand is estimated to account for 80% of the world's trade in baby corn. In 1990 (the latest year for which production statistics are available), Thailand produced 116,600 MTs of baby corn. Maize is a multipurpose Agroforestry species. It can be grown as sole, intercrop or border crop. Every part of this crop is used in one form or the other. Maize is used mainly for three purposes as staple food, raw materials for many industrial products and feed for livestock, Again 'baby' corn has many uses. Baby corn is mainly used as vegetables. It has a flavour and appealing in addition to salads, pasta, soups and other favourite dishes. Baby corn is rich in folate and Vitamin B. It is a good source of several other nutrients and provides 13 % potassium, 14% B-6 riboflavin, 17% vitamin-C and 11% fiber per four ounces (Anonymous, 1998). Currently corn plants are also being used for production of biofuel. Some research works were carried out abroad on morphological, yield and yield attributes of baby corn. Planting density significantly influences baby corn production (Thakur and Vinod, 2000). Sukanya *et al.* (1998) reported that wider spacing (45 x 30 cm) significantly promoted yield. Further. Sukanya *et al.* (1999) reported that a wider spacing of 45 x 30 cm increased all the growth parameters resulting the highest baby corn yield. Rashid (1997) observed that planting arrangement had significant influence on plant height, weight per cob, number of grain per cob, 100-grain weight and grain yield in maize. Waligora (1997) conducted experiments on hybrids of sweet corn and reported that a density of 8-11 plants/m^2 was optimum that produced corn yield of 6.21-6.24 t/ha in Poland. Although information is available at abroad there is only one report on baby corn in Bangladesh (Islam, 2007). The present experiment was carried out to investigate the effect of planting density on morphological features and yield attributes of baby corn in two varieties.

Materials and Methods

The research work was conducted at the Field Laboratory, Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, between March and May, 2007. Geographically the experimental field is located at 24°75'N latitude and 90°50'E longitude at the elevation of 18m above the sea level. Seeds of BARI sweet corn-1 (SC) and pop corn (PC) were collected from Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur. The soil was fertilized following the manual of BARC (2005). There were eight treatments (2 varieties x 4 densities). The four planting densities were 20 plants/m^2 (75 x 10 cm); 10 plants/m^2 (75 x 20 cm); 8 plants/m^2 (75 x 30 cm); and 6 plants/m^2 (75 x 40 cm). A distance of 5 cm on all the inner sides of lm x lm was considered as border. Seeds were hand sown at 3-5 cm depth on 1 April 2007. Eight treatments were laid out in a Randomized Complete Block Design (RCBD) with three replications. Block to block and plot to plot distance were l m and 0.75 m, respectively; while the unit plot size was 2.4 x 1.5m. The final harvest was done 10-12 days after silking (45-47 days after sowing). Data were recorded on randomly selected nine plants taking three plants/ replication. Morphological characters of stem, leaf, tassel, cob, yield and yield attributes were recorded. The yield/ha was estimated from the yield/plant. The data were analysed statistically to find out the statistical significance and the mean differences were evaluated by least significance difference (Gomez and Gomez, 1984).

Results

Morphological features of plant: Pop corn was longer (185.25 cm) than the sweet corn (164.78 cm) irrespective of density (Table 1). The stem height was increased with increasing planting density and was greater at 20 plants/m^2 (192.40 cm) than at 8 and 10 plants/m^2 (average of 174.87 cm), and 6 plants/m^2 (157.95 cm). Generally, stem height was increased with increasing planting density in both the varieties with the greater stem height was observed at 20 plants/m^2 in pop corn (198.77 cm) than sweet corn (186.03 cm) at the same density.

Generally, sweet corn had wider stem diameter (2.59 cm) than in the pop corn (1.99 cm) (Table 1). The stem diameter was progressively increased with decreasing planting density and it was greater at a density of 6 plants/m^2 and followed the following ranking: 6 plants/m^2 (2.71 cm) > 8 plants/m^2 (2.48 cm) > 10 plants/m^2 (2.77 cm) > 20 plants/m^2 (1.79 cm). The interaction effect of variety and density on stem diameter was also significant. At 6 plants/m^2, sweet corn had wider stem diameter (2.99 cm) than pop corn (2.44 cm).

The number of nodes/plant, generally, was greater in pop corn (13.41) than in the sweet corn (12.30) (Table 1). The density 10 and 20 plants/m^2 produced greater number of nodes (average of 13.99) than 6 and 8 plants/m^2 (average of 11.72). The interaction effect of variety and density on number of nodes/plant was also significant (Table 1). Both the varieties sweet corn and pop corn had similar and highest number of nodes/plant (14.44) at a density 20 plants/m^2. Again the variety sweet corn had fewest nodes/plant at the density 6 plants/m^2 (10.78), which is smaller than pop corn (12.55) at the same density.

Table 1. Effect of variety, planting density and their interaction on some important morphological features of `Baby' corn (var. sweet corn and pop corn)

Treatments	Stem height (cm)	Stem diameter (cm)	Nodes /plant (no.)	Green leaves/ plant (no.)	Dry leaves/ plant (no.)	Cob-leaf length (cm)	Cob-leaf breadth (cm)
Variety (V)							
Sweet corn (SC)	164.78	2.59	12.30	9.58	2.72	74.60	9.12
Pop corn (PC)	185.25	1.99	13.41	9.91	3.50	77.28	8.51
LSD $_{0.05}$	6.01	0.154	0.630	0.568	0.56	0.341	0.411
Density (D) (plants/m^2)							
20	192.40	1.79	14.44	10.11	4.34	75.89	8.96
10	177.27	2.17	13.55	9.83	3.71	76.67	8.80
8	172.50	2.48	11.77	9.39	2.39	76.50	8.74
6	157.89	2.71	11.66	9.66	2.00	74.69	8.76
LSD $_{0.05}$	8.498	0.218	0.891	0.823	0.179	3.842	0.482
VxD							
SC x 20	186.03	2.17	14.44	10.89	3.56	74.11	9.20
SCX 10	167.89	2.51	13.22	9.77	3.42	75.66	8.90
SC x 8	165.00	2.69	10.77	8.89	1.89	74.11	9.08
SC x 6	140.22	2.99	10.78	8.77	2.00	74.50	9.29
PC x 20	198.77	1.41	14.44	9.33	5.11	77.67	8.72
PCX 10	186.66	1.83	13.89	9.89	4.00	77.67	7.70
PC x 8	180.00	2.27	12.77	9.89	2.89	78.89	8.41
PC x 6	175.55	2.44	12.55	10.55	2.00	74.89	8.22
LSD $_{0.05}$	12.020	0.308	1.260	1.138	1.163	5.433	0.682

The effect of variety and density on the green leaf production was not significant and hence, was not ranked (Table 1). Combination of sweet corn x 20 plants/m^2 produced greater number of green leaves (10.89) while combination of sweet corn x 8 plants/m^2 and sweet corn x 6 plants/m^2 produced the lowest and similar number of leaves (average of 8.83). Pop corn produced statistically similar numbers of green leaves between the density 6 and 10 plants/m^2 (average of 10.11).

Number of dry leaves/plant was greater in pop corn (3.50) than in the sweet corn (2.72) (Table 1). Higher density, 10 and 20 plants/m^2, produced greater number of dry leaves (average of 4.02) than lower densities, 6 and 8 plants/m^2 (average of 2.19). The interaction effect of variety and density on the number of dry leaves was significant (Table 1). Variety pop corn produced greater number of dry leaves/plant at the densities of 10 and 20 plants/m^2 (average of 4.51) than in the sweet corn at the same densities (average of 3.49). The variety pop corn had greater cob leaf length (77.28 cm) than sweet corn (74.50 cm). In contrast, the sweet corn had greater cob leaf breadth (9.11 cm) than pop corn (8.16 cm). The interaction of density and variety on cob leaf breath was not significant.

Morphological features of cob: Variety sweet corn had greater cob-length (14.38 cm) than pop corn (13.01 cm) (Table 2). Densities 8 and 10 plants/m^2 had produced longer cob (average of 14.70 cm) than 6 (13.32 cm) and 20 plants/m^2 (12.08 cm). The interaction effect was not significant. Variety sweet corn had also greater cob-girth (5.72 cm) than pop corn (4.76 cm). The density 6 plants/m^2 had greater cob-girth (6.43 cm) than 8 and 10 plants/m^2 (average of 5.83 cm), and 20 plants/m^2 (4.17 cm). In both varieties cob-girth was greater 6 plants/m^2 (average of 6.15 cm) while the lowest was at 20 plants/m^2 (average of 4.17 cm). The densities 8 and 10 plants/m^2 had the greater number of seeds/line (30.94) than 6 and 20 plants/m^2 (average of 25.36) (Table 2). The sweet corn and pop corn produced increased number of seeds/line at 10 plants/m^2 (average of 33.44) while the fewest was observed at 20 plants/m^2 in the former variety (24.44) but 6 plants/m^2 in the latter (25.78).

Table 2 Effect of variety, planting density and their interaction on cob characteristics, yield attributes and yield of `baby' corn (var. sweet corn and pop corn)

Treatments	Cob-length (cm)	Cob-girth (cm)	Seeds/ line (no.)	1000-grain weight (fresh) (g)	Grain moisture (%)	Husked cob yield/plant (fresh) (g)	Total fresh wt./plant (g)	Husked cob yield/ha (fresh) (kg)	Green┼ fodder yield/ha (t)
Variety (V)									
Sweet corn (SC)	14.38	5.72	27.61	130.72	46.36	60.33	487.88	5852.50	49.22
Pop corn (PC)	13.01	4.76	28.69	128.39	45.96	57.45	476.97	5496.08	46.12
LSD $_{0.05}$	0.361	0.361	0.680	6.290	2.518	1.504	10.820	160.400	4.015
Density (D) (Plants/m^2)									
20	12.08	4.17	25.28	92.88	39.73	31.26	486.07	625 1.00	91.80
10	14.61	5.38	30.33	122.57	44.92	69.95	510.33	6995.00	43.53
8	14.79	5.49	31.56	142.45	48.22	70.82	467.11	5656.17	32.20
6	13.32	6.43	25.44	160.34	51.78	63.53	466.39	3795.00	23.15
LSD $_{0.05}$	1.043	0.513	3.054	9.161	3.18	2.780	15.180	260.800	5.450
V x D									
SC x 20	13.19	4.34	24.44	93.97	39.55	33.50	488.29	6700.00	92.65
SCX 10	14.41	5.62	27.33	123.36	44.74	70.57	518.36	7057.00	44.77
SC x 8	15.80	6.17	33.56	146.57	47.76	73.03	472.33	5823.00	33.94
SC x 6	14.14	6.74	25.11	159.00	53.40	64.23	472.55	3830.00	25.50
PC x 20	10.97	3.99	26.11	91.80	39.91	29.01	483.78	5802.00	90.95
PC x 10	14.81	5.14	33.33	121.78	45.09	69.33	502.31	6933.00	42.29
PC x 8	13.78	4.80	29.56	138.33	48.68	68.62	461.89	5489.33	30.46
PC x 6	12.50	6.12	25.78	161.67	50.17	62.83	459.89	3760.00	20.80
LSD 0.05	4.980	0.726	1.366	12.96	4.508	3.899	21.63	368.900	7.240

┼: Excluding cob weight.

Yield attributes and yield

1000-grain weight (fresh): Generally, the effect of varietal difference in 1000-grain fresh weight was little (Table 2). The effect of planting density on 1000-grain fresh weight was significant. The fresh grain weight was increased with decreasing density and was greater at the density of 6 plants/m^2 and followed the following ranking: 6 plants/m^2 (160.30 g) > 8 plants/m^2 (142.40 g) > 10 plants/m^2 (122.60 g) > 20 plants/m^2 (92.88 g). Irrespective of varieties, thousand grain weight was highest at 6 plants/m^2 (160.35 g) and lowest at 20 plants/m^2 (92.88 g) (Table 2). The moisture percentage progressively increased with decreasing planting density and followed following rank: 6 plants/m^2 (51.78%) > 8 plants/m^2 (48.22%) > 10 plants/m^2 (44.92%) > 20 plants/m^2 (39.73%). In both the varieties, moisture content was greater at 6 plants/m^2 (average of 51.79%). The grain moisture content was the lowest in both the varieties at 20 plants/m^2 (37.73%).

The variety sweet corn had greater fresh husked cob yield/plant (60.33 g) than pop corn (57.45g) (Table

2). The densities 8 and 10 plants/m^2, generally, produced the higher fresh husk cob yield/plant (average of 70.38 g) than 6 (63.53 g) and 20 plants/m^2 (31.26 g). The interaction effect of variety and density was significant on fresh cob-yield/plant (Table 2). For fresh cob weight/plant, sweet corn yielded greater (71.89 g) than pop corn (68.97 g) at the densities 8 and 10 plants/m^2. Both the varieties yielded lowest at a density 20 plants/m^2 (average of 20.50 g).

Greater total fresh weight/plant was observed in sweet corn (487.88 g) than pop corn (476.97 g). The densities 10 and 20 plants/m^2 produced greater fresh weight/plant (average of 498.20 g) than 6 and 8 plants/m^2 (average of 466.75 g). Both the varieties had higher fresh weight/plant at the density 10 plants/m^2 (average of 510 g) (Table 2).

Generally, sweet corn produced more cob yield (5496.08 kg) than pop corn (6251.00 kg). (Table 2). The density 10 plants/m^2 produced the greater yield (7695.00 kg) than the others and followed the following rank: 10 plants/m^2 (6995.00 kg) > 20 plants/m^2 (5903.00 kg) > 8 plants/m2 (5656.17 kg) > 6 plants/m^2 (3795.00 kg). In sweet corn, the yield was increased with increasing density, being higher at 10 and 20 plants/m^2 (average of 6878.50 kg/ha). In pop corn the yield was also increased with increasing density up to highest yield at 10 plants/m^2 (6933.00 kg/ha) followed by a decline at 20 plants/m^2 (5802.00 kg), 8 plants/m^2 (5489.33 kg) and 6 plants/m^2 (3760.00 kg). The green fodder yield/ha was progressively increased with increasing planting density and it was greater at a density of 20 plants/m^2 (91.08 t/ha) and followed the following ranks: 20 plants/m^2 (91.80 t) > 10 plants/m^2 (43.53 t) > 8 plants/m^2 (32.20 t) > 6 plants/m^2 (23.15 t). Both varieties yielded higher fodder at a density 20 plants/m^2 (average of 98.80 t) and the lowest at 6 plants/m^2 (average of 23.16 t).

Discussion

Density alters canopy structure, growth and yield in corn (Lee-Joung *et a1.*, 2005). Generally, high planting density decreases canopy components and results in smaller plants. In contrast, plants subject to wider spacing promotes growth and produces larger canopy. In the current research, there were four planting densities, *viz.*, 6, 8, 10 and 20 plants/m^2 and two varieties, sweet corn and pop corn. Genetic variations existed for different morphological and yield attributes. Generally, pop corn was taller, thinner with increased number of nodes and green leaves. Source leaf i.e. cob-leaf was longer but narrower in pop corn. However, cob-size was greater in sweet corn, therefore, produced more cob yield/ha in sweet corn (5.85 t/ha) than in the pop corn (5.50 t/ha). Cob yield is a function of cob size, number of lines/ cob, number of seeds/ line and seed size. Since there was little variation in above yield attributes, except cob size (length and girth), between the varieties, therefore, cob length and cob girth appeared to be the main determinant of baby corn yield. Such varietal differences were also observed by Turgut (2000), Sahoo and Mahapatra (2004) and Bian *et al.* (2004) in Corn. Irrespective of varieties, density produced typical effects on morphological features and yield attributes in the present research. For example, with increasing density, plants became taller and narrower with greater number of nodes and leaves/plant. However, cob size did not respond typically to density effect. For example, cob was longer at intermediate density (8 and 10 plants/m^2) but became wider and thicker at lower density (6 plants/m^2). Although thousand grain weight was heavier at lower density than at the higher densities, expected fresh cob yield/ha became maximum (6933 to 7057 kg/ha) at intermediate density 10 plants/m^2. This could be due to increased cob length and greater number of seeds/lines at these densities (8 and 10 plants/m^2) (Table 2). Kar *et al.* (2006) also reported that of the four spacings (45×30 cm, 45×20 cm, 60×30 cm and 60×20 cm) higher green grain yield of sweet corn (baby corn) was obtained at 60×20 cm (9.21 t/ha) due to increasing number of lines/cob, 1000-grain weight and length of cob. Generally, increasing density decreased yield/plant basis but increased yield/unit area. The interaction or compensation between decreased yield/plant and increased number of plants/unit area determines maximum yield and density at which such maximum yield was achieved, is called optimum density. In pop corn, fresh cob yield/plant was increased from 62.83 g at 6 plants/m^2 to a maximum 69.33 g at 10 plants/m^2 followed by a decreased to 29.01 g at 20 plants/m^2 and, therefore, maximum yield/ha would be obtained at 10 plants/m^2 (6.93 t/ha) (under Mymensingh condition). Such pattern was not followed in sweet corn and hence the interaction effect of variety and density on yield/ha was significant. In sweet corn, the highest yield/ha was achieved either at 10 or 20 plants/m^2 and the yield was similar between 10 and 20 plants/m^2 (average of 6.52 t/ha). In the current research optimum density for fresh cob yield was 10 plants/m^2. Since the plants were harvested earlier, between 10 and 12 days after silking, for baby corn, the stalk could be used as green fodder. Hence, considering the cost of seed and fodder value, the density 10 plants/m^2, could be useful both for baby corn and green fodder. However, the highest density, 20 plants/m^2 could be considered giving priorities to green fodder since maximum fresh fodder yield could be obtained (90-92 t/ha) at this density (Table 2). Sahoo and Panda (1999), March-a?-o *et al.* (2005) and Kar *et al*. (2006) also reported an optimum density between 7 and 10 plants/m^2 for matured kernel yield. The baby corn yield in the current research was lower (around 7 t/ha) than in the previous researchers (9-10 t/ha). This may be due difference in cultivar and growing conditions. The research was carried out in the 'Kharif' season when grain growth was rapid. Further investigation is needed for the same in the "Rabi' season. Moreover, in the current research cobs were harvested after pollination (silking) but yield and quality of baby corn without pollination and fertilization need to be investigated.

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