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Important morphological traits, nutrient composition and yield of baby corn as affected by planting density

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Abstract: The dehusked baby cob or baby corn is widely used as delicious vegetable in the world. Two factors field experiment with six treatments (2 genotypes and 3 densities) was conducted in Randomized Complete Block Design (RCBD) with three replications. The two Baby Corn varieties were Baby Star and BARI HYV Maize-7 and three planting densities were 8, 12 and 16 plants m^{-2}. The objective were to study the effect of planting density on some morphological characters, baby corn and biomass yields, and mineral compositions at the three planting densities during the Rabi season, 2015–2016. The result revealed that, plant height was increased with the increasing planting density. The highest fresh green fodder yield (6.94t ha^{-1}) was recorded at the highest density of 16 plants m^{-2}. The longer cob (6.72cm) was observed in BARI HYV Maize-7 at 8 plants m^{-2} than 16 plants m^{-2} (5.21 cm) in Baby star variety. Higher baby corn yield (shelled and fresh cob weight) was found at the higher plant densities in both the varieties. Genetic variation existed in mineral contents with total-N, P, Mg, Zn, Mn and Fe were higher in BARI HYV Maize-7 than in the Baby star variety while S and Ca contents were similar between the varieties (av. of 0.15 & 0.11% for S and C, respectively). Vitamin-C content, on the other hand, was significantly higher in Baby star (12.08 mg 100 g^{-1}) than in the BARI HYV Maize-7 (9 mg 100 g^{-1}). From the results, it might be concluded that optimum density for baby corn cultivation was not achieved but higher yield and yield attributes were recorded at higher plant population, and baby corn could be a good source of some macro- and micronutrient elements and vitamin C.
Key words: Baby corn, Mineral Composition, Morphological Traits, Planting Density.

Introduction

'Baby' corn (*Zea mays* L.) is dehusked maize ear, harvested young especially when the silk have either not emerged or just emerged and no fertilization has taken place (Pandey *et al*., 2000). Baby corn ear is light yellow in colour with regular row arrangement, 5 to 10 cm long and a 2-4 cm diameter (Golada *et al*., 2013). Baby corn is used primarily in Europe and America but production of this crop is the highest in Asia. Thailand is estimated to account for 80% of the world's production and trade in baby corn. In Bangladesh, there is no statistics for production and consumption of baby corn. However, recently baby corn is being grown through contact farmers and is sold fresh in the supermarket stack.

The dehusked baby cob can be used in various ways. Young cob (corn) has been used by Chinese as vegetable for generations and this practice has gained popularity to other Asian countries including Bangladesh (Fakir and Islam, 2008). It is used as ingredient in many food preparations like chewing the crunchy fresh cob, as salads, in pasta, parching, frying in oil, currying, stewing, or processed and canned for future uses. Baby corn is rich in folate and vitamin B. It is a good source of several other nutrients and provides potassium, B-6, riboflavin, vitamin-C and fiber (Anonymous, 1998). According to Rani *et al.*, (2017), baby corn contains protein 15–18%, Sugar 0.016–0.020%, Phosphorus 0.6–0.9%, Potassium 2–3%, Fibre 3–5%, Calcium 0.3–0.5%, Ascorbic acid 75–80 mg/100g. For diversification and value addition in food processing industries, baby corn has a great export potential in Bangladesh.

For each production system, there is a population that maximizes the utilization of available resources, allowing the expression of maximum attainable grain yield on that environment (Sangoi, 2001). Factors affecting baby corn production are varieties, location, densities (number of plants m^{-2}) and management practices (Farid *et al*., 2014). Optimization of population unit $area^{-1}$ remains the most important factor for baby corn to be elucidated in Bangladesh. A baby corn herb produces two to four cobs $plant^{-1}$. In sparse population, the size of the individual baby corn may be larger but total yield is decreased due to fewer plants unit $area^{-1}$ (BARI, 2008). In high density, the size of the baby corn is decreased due to intense competition but total yield is increased due to increased population (BARI, 2008). Prodhan *et al*. (2007) and Aravinth *et al*. (2011), recorded higher yields as a result of remarkable improvement in different growth and yield attributes when this crop was grown at wider spacing of 60 × 15 cm instead of other spacing. Silva *et al*. (2007) observed that planting arrangement had significant influence on plant height, ear height, stalk diameter, total number of ear, number of marketable husked ears, fresh biomass and dry biomass in baby corn.

Rahman *et al*. (2016) reported in sweet corn that, the highest number of cobs $plant^{-1}$, grain rows cob^{-1}, grains row^{-1}, grains cob^{-1}, 1000-grain weight, grain yield and harvest index were recorded at wider 75 cm × 25 cm spacing. In contrast, the closest spacing of 50 cm × 20 cm produced the fewest grain rows cob^{-1}, grains row^{-1}, grains cob^{-1}, 1000–grain weight and grain yield.

Asaduzzaman *et al*. (2014) reported that 45cm × 20cm planting geometry were observed optimum for yield (without husk) in four baby corn varieties (av. yield 1.5-2.0 t ha^{-1}). Hooda and Kawatra (2013) conducted an experiment to study nutritional composition of HM-4 variety of baby corn and indicated that baby corn is good source of various nutrients like crude fiber, carbohydrates and dietary fibers and its nutritional quality is at par or even superior to many other commonly used vegetables.

Although information is available at abroad there is little published research works in Bangladesh on baby corn especially on some important mineral elements of baby corn. On the contrary, this crop is highly suitable for cultivation utilizing residual moisture between Aman and Boro season in Bangladesh as the baby corn yield can be derived in 45-55 days only. As it is an emerging vegetable with bright future prospect, so the current investigation was conducted to investigate the effect of planting density on morphological features, yield and yield attributes of baby corn; and to determine some important macro- and micro-mineral elements (N, P, K, S, Ca, Mg, Zn, Mn and

Fe) in two baby corn varieties.

Materials and Methods

Planting materials: As planting materials, seeds of 'Baby Star' a commercial variety, were collected from Siddique Seed shop, Mirpur, Dhaka and another variety BARI HYV Maize-7 was collected from Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur.

Land preparation and experimentation: The field experiment was conducted at the Field Laboratory of the Department Crop Botany, Bangladesh Agricultural University and the laboratory analysis was done at the Plant Physiology Laboratory of the Department of Crop Botany, Bangladesh Agricultural University and Soil Science Laboratory of Bangladesh Institute of Nuclear Agriculture (BINA). The experimental field was medium to high land topography with silt loam in texture. The climate of the experimental site is sub-tropical, characterized by high temperature and heavy rainfall during kharif season (April to September) and gradual decrease of rainfall associated with moderately low temperature during rabi season (November to February). The land was well prepared by spading several times. The weeds and stubbles were removed as far as possible. Finally, the land was labeled and divided into blocks and plots maintaining the recommendation distance. The experimental plots were fertilized with the cow dung @ 8 tons/ha, Urea@ 300 kg/ha, TSP@ 200 kg/ha, MP@100 kg/ha and Gypsum @ 150 kg/ha and Boric acid @ 5 kg/ha. The cow dung was applied 5 days ahead of final land preparation. The entire amount of TSP, MP, and boric acid and one-third of urea were applied as basal dose at the time of final land preparation. The remaining one-third of urea was top dressed in splits at 20 days after sowing and the rest one-third urea was top dressed in splits at 35 days after sowing. The whole area was divided into 3 blocks. Each block was then sub-divided into 6 plots for six treatments (2 varieties × 3 densities). The seeds were hand sown in each whole in line. After 15 days of sowing, one plant in each whole was allowed. Intercultural operations such as weeding, pest management etc. was done when needed. Experimental plots were irrigated as and when necessary.

Experimental design and treatments: The experimental plots were laid out in the Randomized Complete Block Design (RCBD) with two factors and 3 replications. Factor A: varieties, two varieties of baby corn namely Baby Star and BARI HYV Maize-7 were used. Factor B: Three plant spacing were maintained as 50 cm × 25 cm, 40 cm × 20 cm and 25 cm × 25 cm which allowed a density of approximately 8, 12 and 16 plants m^{-2} respectively.

Data recording: Harvesting was done at 55 DAS when baby corn silk just came out from the top end of ears. Silk was whitish to pinkish in color. Five plants were randomly selected for hand picking from each plot for morphological characters such as plant height, diameter, total number of leaves per plant, number of green leaves per plant, source leaf size (length and diameter), number of cobs per plant, fresh green fodder (stem, leaves, unshelled baby corn) yield (t/ha) and total fresh biomass (t/ha). However, baby corn (shelled cob) size (length and diameter), green baby corn (unshelled fresh cob) yield were also recorded. Freshly harvested baby corns were shelled and number of rows per cob was counted. Fresh weight of shelled cob (baby corn yield) was obtained and the samples were oven dried at $(80\pm2)^0$C until constant weight was reached. Their corresponding dry weight of husk (sheath) and rachis were recorded after sun drying until constant weight.

Nutrient element analysis: Total-N by Kjeldahl Method (Kjeldahl, 1983), P by Vanadate- molybdate method (Suzanne, 2003), S by Turbidimetric method (Hart, 1961), K, Ca, Mg, Na by 1M NH_4OAC method (McKeague, 1978), and Zn, Fe, Mn by DTPA method (Soltanpour and Schwab, 1977) were determined.

Statistical analysis: The collected data were statistically analyzed by Analysis of Variance tests. The mean of different parameters were compared by MSTAT-C. The analysis of variance was performed by F test (variance ratio) and the significance of difference between pairs of treatments was evaluated by the least significance difference (LSD) test at the 5% levels of probability.

Results

Cob characteristics: Cob length, baby corn yield (shelled cob) and dry weight of cob $plant^{-1}$ was significantly different ($P \leq 0.05$) while the number of rows cob^{-1} showed non-significant differences (Table 1). In BARI HYV Maize-7, baby corn length was shorter at 16 plant m^{-2} density (5.21 cm) than 8 plant m^{-2} density (6.72 cm). Yield increased with increasing density with the highest cob weight was found in the highest plant density in both the varieties. In Baby star, the order of the fresh baby corn yield (t ha^{-1}) was as follows: 1.17>0.98>0.79 for 16, 12 and 8 plant m^{-2}, respectively (Table 1). Maximum fresh weight of shelled cob was observed in Baby star at 16 plant m^{-2} density (1.17 t ha^{-1}) and minimum was observed in BARI HYV Maize-7 at 12 plant m^{-2} density (0.61 t ha^{-1}). Dry cob weight followed a trend similar to that of the fresh cob weight. In case of Baby star, dry weight was increased gradually with increasing plant population where dry weight was statistically similar between densities in BARI HYV Maize-7 (average 0.24 t ha^{-1}). The maximum dry weight was found in Baby star at 16 plant m^{-2} density (0.84 t ha^{-1}) and the minimum in BARI HYV Maize-7 at 12 and 16 plant m^{-2} density (av. 0.23 t ha^{-1}).

Morphological attributes and biomass yield: Plant height, stem diameter (cm), number of green leaves $plant^{-1}$, source leaf size (cm), number of cobs $plant^{-1}$, stem yield, leaf biomass yield, green baby corn (unshelled cob) yield showed significant variation while total number of leaves $plant^{-1}$ was non-significant (Table 2). The increasing trend of plant height was observed with increasing density in the two varieties. The lowest plant height was recorded in sparse plant population (8 plant m^{-2}) and the highest was recorded at highest plant population (16 plant m^{-2}) in both varieties. On the other hand, descending order of stem diameter with increasing plant density was found in both varieties. The order of the stem diameter (cm) in Baby star was 6.45>6.31>5.57 for 8, 12 and 16 plant m^{-2} respectively. At the same time in BARI HYV Maize-7, stem diameter was greater at 8 plant m^{-2} density (6.33cm) than at 12 plant m^{-2} density (5.81cm) and at 16 plant m-

^{2}density (5.11cm). Eight plant m^{-2} density produced the thickest plant where 16 plant m^{-2} density produced the narrowest plant in both the varieties. Number of green leaves $plant^{-1}$ was decreased with increasing plant density in both the varieties. The maximum source leaf (leaf bearing cob) leaf length of 64.53 cm was observed at 12 plants per m^{-2} density in BARI HYV Maize-7 variety and the minimum leaf length of 49.53 cm was recorded at 16 plants m^{-2} in Baby star.

Table 1. Effect of planting density on morphological features and yield of cobs in two baby corn variety

Variety	Density (Plant m^{-2})	Baby corn size (cm)		Rows cob^{-1} (No.)	Baby corn yield (tha^{-1})		Husk+ rachis dry wt. (tha^{-1})
		Length	Diameter		Fresh wt.	Dry wt.	
BABY STAR	8	6.04 c	3.83	12.80	0.78 c	0.07 c	0.59 c
	12	5.37 d	3.88	13.87	0.98 b	0.09 b	0.68 b
	16	5.21 d	4.10	13.93	1.17 a	0.11 a	0.84 a
BARI HYV Maize-7	8	6.72 a	3.55	12.80	0.67 d	0.05 e	0.27 d
	12	6.51 ab	3.63	12.80	0.61e	0.04 f	0.23 d
	16	6.27 bc	3.87	13.60	0.79 c	0.06 d	0.23 d
$LSD_{0.05}$		0.263*	0.335^{NS}	0.805^{NS}	0.058**	0.009**	0.081**

** Indicates, significant at P≤ 0.01 level of probability, * indicates, significant at P≤0.05 level of probability and NS means non-significant.

The maximum number of cobs $plant^{-1}$ was produced by 12 plants m^{-2} density. Higher plant densities may have reduced the supply of water and nutrient for growing ears which consequently compelling the plants to undergo less reproductive growth. Yield of fresh stem mass (t ha^{-1}) increased with increasing planting densities in both the varieties. Yield (t ha^{-1}) for Baby star variety was 10.69, 17.74, 25.91 at 8, 12 and 16 plants m^{-2} where it was 7.03, 13.54, 20.45 at 8, 12 and 16 planting density, respectively in BARI HYV Maize-7. Fresh leaf biomass yield was increased with increasing plant density in both the variety. Eight plants m^{-2} density produced the lowest biomass yield of leaves where 16 plant m^{-2} density produced the highest biomass yield of leaves in both the varieties. In variety Baby star, the green baby corn yield was greater (6.94 t ha^{-1}) at 16 plants m^{-2} than 12 plants m^{-2} (6.32 t ha^{-1}) and 8 plants m^{-2} (3.69t ha^{-1}) (Table 2). At the same time, it was 1.76, 2.99 and 4.16 (t ha^{-1}) at 8, 12 and 16 plants m^{-2} planting density, respectively in BARI HYV Maize-7.

Table 2. Effect of planting density on morphological traits, baby corn yield and green fodder yield in two varieties of baby corn

Variety	Density (Plant m^{-2})	Plant height (cm)	Stem Diameter (cm)	Total leaf $plant^{-1}$	Green leaves $plant^{-1}$	Source leaf size (cm)		Cobs $plant^{-1}$	Fresh Green Fodder Yield (t ha^{-1})		
						Length	Breadth		Stem	Leaf biomass	Green baby corn
BABY STAR	8	120.66 d	6.45 a	14.73	11.67 a	51.95 d	7.96	1.60 c	10.69 e	5.77 cd	3.69 d
	12	139.85 c	6.31 a	13.87	10.60 b	56.95 c	7.33	2.00 a	17.74 c	8.24 b	6.32 b
	16	150.08 b	5.57 c	13.27	9.93 cd	49.53 e	7.09	1.80 b	25.91 a	10.0 a	6.94 a
BARI HYV Maize-7	8	124.82 d	6.33 a	12.80	10.07 c	59.61 b	6.69	1.07 e	7.03 f	4.48 e	1.76 f
	12	140.80 c	5.81 b	12.27	9.600 d	64.53 a	6.00	1.33 d	13.54 d	5.34 d	2.99 e
	16	168.76 a	5.11 d	11.93	8.87 e	53.70 d	5.68	1.00 e	20.45 b	6.32 c	4.16 c
$LSD_{0.05}$		6.699**	0.207*	0.739^{NS}	0.363*	1.97*	0.390^{NS}	0.141*	0.359**	0.853**	0.293**

** Indicates, significant at P≤ 0.01 level of probability, * indicates, significant at P≤0.05 level of probability and NS means non-significant.

Table 3. Analysis of some important nutrient elements and Vitamin-C of two baby corn varieties

Variety	Total-N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Vitamin-C (mg 100 g^{-1} fresh wt.)
Baby star	1.97 b	0.48 b	2.13 b	0.1 5	0.11	2522.85	38.55 b	4.45 b	34.74 b	12.08
BARI HYV Maize-7	2.37 a	0.58 a	2.31 a	0.15	0.11	2542.70	41.44 a	9.85 a	77.37 a	9.00
$LSD_{0.05}$	0.124**	0.072*	0.140*	0.501^{NS}	0.136^{NS}	112.55^{NS}	2.040**	1.220**	6.480**	2.140**

** Indicates, significant at P≤ 0.01 level of probability, * indicates, significant at P≤0.05 level of probability and NS means non-significant.

Nutritional composition of baby corn: Harvested baby corns were analyzed and the effects of variety on total-N, P, S, Ca, Mg, Zn, Mn, Fe and Vitamin C were significant among the varieties (Table 3).Total-N, P, Mg, Zn, Mn and Fe were higher in BARI HYV Maize-7 variety (2.37%, 0.58%, 2542.70 ppm, 41.44 ppm, 9.85 ppm and 77.37 ppm, respectively) than Baby star variety (1.97%, 0.48%, 2522.85 ppm, 38.55 ppm, 4.45 ppm and 34.74 ppm, respectively) while S and Ca content were similar (av. 0.15 and 0.11% for S and Ca, respectively) in Baby star and BARI HYV Maize-7 variety. Vitamin-C content was higher in Baby star (12.08 mg 100 g^{-1}) than BARI HYV Maize-7 (9 mg 100 g^{-1}). It revealed that, in baby corn, appreciable amount of some important nutrient elements (N, P, Mg, Zn, Mn and Fe) are present. As, it is a good source of Mg, Zn, Mn and Fe, use of baby corn as vegetable would expect to meet up the part of the daily requirements of these nutrients.

Discussion

Baby corn (*Zea mays*) is a delicious and nutritious vegetable crop with high market value both nationally and internationally (Hooda and Kawatra, 2012). Corn can be harvested and also consumed at three different maturity stages, such as baby corn (as vegetable), immature corn (for chewing as sweet corn) and mature corn (for grain/seed). Baby corn is harvested at the silking stage (Sarepoua *et al*., 2015). The nutritive value of baby corn is comparable to several high-priced vegetables like cauliflowers, cabbage, french beans, spinach, lady finger, brinjal, tomato, radish, etc. (Paroda, 2001). Apart from baby corn (unfertilized young ovule) Corn silk (collection of the stigmas, fine, soft, yellowish threads from the female flowers of the maize plant which) has the highly medicinal value and used traditionally as diuretic, antilithiasic, uricosuric and for curing cystitis, gout, kidney stones, nephritis and prostatitis (Thoudam *et al*., 2011). It has been investigated that, baby corn contained 90.03% moisture, 17.96% protein, 2.13% fat, 5.30% and 5.89% ash, total soluble sugars content was 23.43 g/100 g whereas reducing sugars was 1.96 g/100 g. They also revealed that it contained 8.10 g/100 g of cellulose, 5.41 g/100 g of lignin, 5.43 mg/100 g of ascorbic acid and 670 μg/100 g of β-carotene. Meanwhile, Calcium, magnesium and phosphorus content of baby corn was 95.00, 345.00 and 898.62 mg/100 g, respectively and contained 0.05μg/g methionine, 2.85μg/g isoleucine and 0.675μg/g of leucine (Hooda and Kawatra, 2012). The current investigation suggests that, baby corn is a highly nutritive and delicious valuable crop.

Baby corn as a new vegetable although not so popular yet, is an emerging potential crop among the progressive farmers around big cities. This study was taken to find out the optimum planting density to ensure the various morphological attributes, nutritional composition and biomass yield of two selected baby corn varieties.

From the study, it showed that, yield increased with increasing density with the highest cob weight was found in the highest plant density in both the varieties. In BARI HYV Maize-7, baby corn length was shorter at 16 plant m^{-2} density (5.21 cm) than 8 plant m^{-2} density (6.72 cm). This might be due to dense plant population. In case of Baby star, dry weight was increased gradually with increasing plant population whereas dry weight was statistically similar between densities in BARI HYV Maize-7 (average 0.24 t ha^{-1}). The maximum dry weight was found in Baby star at 16 plant m^{-2} density (0.84 t ha^{-1}) and the minimum in BARI HYV Maize-7 at 12 and 16 plant m^{-2} density (av. 0.23 t ha^{-1}). Lashkari *et al.* (2011) also found decreased cob length with increased plant density. In case of baby cob diameter, the effect of planting densities was non-significant. Similar trend was also observed by Rahmani *et al*. (2016) who also reported non-significant differences between plant densities in respect of cob diameter. The increasing trend of plant height was observed with increasing density in the both varieties. The lowest plant height was recorded in sparse plant population (8 plant m^{-2}) and the highest was recorded at highest plant population (16 plant m^{-2}) in both varieties. On the other hand, descending order of stem diameter with increasing plant density was found in both varieties. Srikanth *et al*. (2009) reported that plant height was markedly increased with increasing density due to competition for light. Lashkari *et al*. (2011) reported that stem diameter was smaller in high plant densities as a consequence of interplant competition. Similar effect of density on plant diameter was also reported by Konuskan (2000) and Sarjamei *et al*. (2011). Number of green leaves $plant^{-1}$ was decreased with increasing plant density in both the varieties. This may be due to acceleration of leaf senescence and decreased interception of solar radiation (Boyat *et al*., 2000).

On the other hand, lower densities may results in higher biomass production rather than reproductive organ production (Zamir *et al*., 2011). Several studies reported that plant population is a key factor for attaining the maximum grain yield (Narwal *et al*., 1989; Esechie, 1992; Akbar *et al.*, 2002). Sarjamei *et al.* (2011) also reported that green fodder yield was increased with increasing density. Fresh green plant biomass could be a good source for animal food or fodder. Rani *et al.* (2017) reported 50-60 tons ha^{-1} green fodder as bonus with baby corn cultivation. We found higher total-N, P, Mg, Zn, Mn and Fe in BARI HYV Maize-7 variety (2.37%, 0.58%, 2542.70 ppm, 41.44 ppm, 9.85 ppm and 77.37 ppm, respectively) than the Baby star variety (1.97%, 0.48%, 2522.85 ppm, 38.55 ppm, 4.45 ppm and 34.74 ppm, respectively). In this nutritional investigation, it is revealed that, baby corn is a highly nutritive. In South-east Asian countries including Bangladesh, nutrient elements like Ca, Zn, Fe and others appeared to be deficient in human diet (Akhtar *et al.*, 2013, Chaparro *et al.*, 2014). So, this study would help mitigation of some nutrient deficiency in the diet, when consumed.

Conclusion

Baby corn, being a very nutritious emerging vegetable in Bangladesh, yield attributes and nutritional compositions were studied in two varieties at different planting densities. Irrespective of varieties, plant became taller with the increasing planting density but stem thickness decreased with increasing planting density. The highest fresh green fodder yield (t ha^{-1}) was recorded at the density of 16 plants m^{-2}. Cob characteristics were also influenced by planting density. The longer cob (6.72cm) was found in BARI HYV Maize-7 at 8 plants m^{-2} than 16 plants m^{-2} (5.21 cm) in Baby star variety. Higher baby corn yield (shelled and fresh cob weight) was found in higher plant densities in both of the varieties. The maximum fresh and dry weight of shelled cob was also observed at 16 plants m^{-2} density. The mineral content analysis indicated that baby corn is highly nutritive. Vitamin-C content was higher in Baby star (12.08 mg 100 g^{-1}) than BARI HYV Maize-7 (9 mg 100 g^{-1}). From the results, it might be concluded that optimum density for baby corn cultivation was not achieved but higher yield and yield attributes were recorded at higher plant population (16 plants m^{-2}) and baby corn could be a good source of some micro- and macro nutrient elements.

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