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PLANT GROWTH, FRUIT YIELD, AND QUALITY OF CAPSICUM (*CAPSICUM ANNUM* L.) AS AFFECTED BY NITROGEN LEVELS IN THE COASTAL SOIL OF BANGLADESH

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Abstract

Though capsicum (*Capsicum annum* L.) is a high-value crop in Bangladesh, limited cultivation is reported in the coastal zone of Khulna. Moreover, the nitrogen (N) requirement of capsicum for this zone needs to be evaluated. An experiment was administered at the Agrotechnology Field Laboratory of Khulna University, Bangladesh, from 1st December 2020 to 25th March 2021 with the variety 'California Wonder' to evaluate the effect of nitrogen on plant growth, fruit yield, and the quality attributes of capsicum. The experiment was fixed following Randomized Complete Block statistical design with five levels of nitrogen (0, 58, 87, 116, and 145 kg N ha^{-1}) and replicated four times. The recommended dose (116 kg N) and the highest dose (145 kg) of N resulted in statistically similar stem diameter, leaf number, leaf chlorophyll index (SPAD readings), yield, fruit diameter and length, vitamin C, and total soluble solid (TSS). Only plant height was statistically higher with the highest N level compared to the recommended level of N. However, numerically higher leaf number, chlorophyll index, yield and vitamin C content were recorded from the recommended dose of N and importantly, the recommended level of N resulted in 12% higher yield compared to the highest dose of N. Therefore, the application of 116 kg N ha^{-1} can achieve the optimum yield of capsicum in the Khulna region, and excessive N application did not increase the yield of bell pepper. However, more experiments should be conducted to recommend the optimal nitrogen dose for capsicum cultivation in the Khulna region of Bangladesh.

Keywords: Urea, Capsicum, Yield, Quality, N-deficient soil

Introduction

Capsicum (*Capsicum annum* L.), a member of Solanaceae, is a lucrative vegetable crop with high market value and a promising horticultural crop in Bangladesh (Saha et al., 2010, Haque et al., 2019). Sporadic cultivation of Capsicum has been reported in Bangladesh in the nineties of the last century. Initially, cultivation started on a small scale and was confined to the peri-urban area of Dhaka, the capital of Bangladesh, to supply the Dhaka-based super shops. Due to a lack of information about cultivation techniques, large-scale capsicum production has not yet started (Das et al., 2015); however, small-scale commercial (Sattar et al., 2016) cultivation has recently been started in different parts of the country. Capsicum is rich in vitamin A, vitamin C, vitamin E, and folate (Phillips et al. 2006; Wahyuni et al. 2011), and also phenolic compounds and fibers. It also contains a trace amount of omega-3 and omega-6 fatty acids. Every 100 g edible flesh of capsicum has 1.3 g, 4.3 g, and 0.3 g protein, carbohydrate, and fat, respectively, along with 24 kcal of energy (Haque et al., 2019) and it is also rich in vitamins A and C (Aminifard et al., 2012). It could be an excellent addition to the diet in Bangladesh.

Nitrogen (N) stimulates dry matter accumulation in plants. Capsicum requires a high amount of N, which makes the plant tall with more lateral stems and a higher leaf chlorophyll index (Bhuvaneswari, 2014). Adequate N enhances the growth and development, encourages flower development, and improves yield and quality (fruit size, color, taste, keeping quality) attributes of capsicum (Aminifard, 2018; Shukla and Naik, 1993; Kinet et al., 1985). Nitrogen forms also affected capsicum flowering, fruit set, fruit ripening time, and yield (Xu et al., 2001). Higher

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dose of N invigorated a higher uptake of potassium and phosphorus synergistically in capsicum (Qawasmi et al., 1999). However, excessive application of N is discouraged as it causes adverse effects on plant growth, fruit yield, and quality (Leghari, 2016) and can decrease the vitamin C content of fruits and vegetables (Mozafar, 1993). Excessive N application overstimulated plant growth, delayed flowering, increased blossom-end rot incidence and decreased the fruit yield and quality in pepper (Aliyu, 2002). Bangladesh uses mainly urea to supply N to the plants for crop production. However, urea is costly, and Bangladesh imports urea to meet local needs. Bangladesh imported 60000 tons of urea (granular) at Tk. 251 crore from Qatar and Saudi Arabia on 22nd November 2023 (The Daily Star, 2023).

The soil of Khulna region – the southern coastal belt of Bangladesh – is characterized by very low to low N content. According to the Soil Resources and Development Institute (SRDI), the total N content ranges between 0.027 % and 0.121 % in this area. Previous reports showed that the total N content of the experimental field varies from 0.07% to 0.125%, and the critical value is 0.12% (Biswas et al., 2022; Saha et al., 2019). The Bangladesh Agricultural Research Institute (BARI) generally recommends 116 kg ha^{-1} N (250 kg ha^{-1} urea) for capsicum cultivation. As the soil of the coastal area contains very low N, we aimed to evaluate the performance of capsicum regarding growth, yield, and quality attributes based on various N levels in the southern coastal soil of Bangladesh.

Materials and Method

Experimental site, design and treatments

The experiment was performed from December 2020 to March 2021 at the Agrotechnology Field Laboratory of Khulna University in Bangladesh with the capsicum variety 'California Wonder' – a mild season, open-pollinated, high-yielding variety and quasi-familiar in Bangladesh with very little commercial cultivation. Mature fruit is 7.5-10 cm long with thick flesh, 3 or 4 lobed, mild, and sweet flavored, having an average weight of 170 g. The land was plowed three times to get the fine tilt. The final land preparation was completed on 8 December 2020. Though there was a general fertilizer recommendation for this Agro Ecological Zone (AEZ), there is a lack of specific fertilizer recommendations for capsicum, which is a newly introduced crop for this area. Therefore, the fertilizers were applied according to the existing recommendations except nitrogen (N). The recommended doses of organic matter (cow dung), phosphorus (in the form of triple super phosphate, TSP), potassium (muriate of potash, MP), and zinc (ZnO) were applied during the final land preparation.

The treatment consists of five N levels in the form of urea: N_0= 0 kg N (0 kg urea)/ha, N_1= 58 kg N (125 urea)/ha, N_2= 87 kg N (188 urea)/ha, N_3= 116 kg N (250 kg urea; recommended dose)/ha, N_4= 145 kg N (313 kg urea)/ha. Fertilizer treatments were replicated 4 times following a randomized complete block design. The cow dung was applied 4 days before the final land preparation. The full dose of TSP and zinc oxide and 1/3rd of urea (according to the treatments) and MP were applied at final land preparation for each treatment. The rest of the urea and MP were divided into two halves and top dressed at 25 and 50 days after transplanting (DAT), respectively. Healthy and uniform-sized 25-day-old seedlings were transplanted on 12 December with a spacing of 90 cm for row-row and 20 cm for plant-plant in a plot area of 1.2 m x 1.2 m. Gaps filling, weeding, irrigation, and pest management were done as per requirement.

Plant growth

Plant height, stem diameter, and leaf number were measured on different days after transplanting (DAT). Similarly, leaf chlorophyll was estimated from two leaves per plant at different DAT with a SPAD chlorophyll meter (Chlorophyll Meter SPAD-502; Konica Minolta Sensing Americas, Inc., Ramsey, NJ, USA).

Fruit yield

Mature green marketable-sized fruit was harvested twice during the season, counted and weighed to calculate fruit yield. Fruit diameter and length were measured using digital slide micrometers, and the ratio between fruit diameter and length is expressed as fruit shape index (Kabir et al., 2023).

Determination of vitamin C, total soluble solids, and pH

Vitamin C content in the green fruit was determined in the laboratory following the titration method with the indicator dye 2, 6-dichloroindophenol (Nielsen, 2017). Briefly, 20 g crushed sample was mixed vigorously with 50 ml of metaphosphoric acid in a 100 ml flask, made the ultimate volume 100 ml by adding more metaphosphoric acid, and homogenized. Then, 10 ml aliquot was pipetted into the Erlenmeyer flask along with 5 ml metaphosphoric acid

and titrated with dye (2,6-dichloroindophenol) to get the stable pink color. The titration was repeated three times for each treatment and each harvest, and an average value was reported. Total soluble solids (TSS) was measured with a Kruss refractometer (Model HR 900, SN 1200793, brix range 0%-90% at 20 °C, Germany) and pH with a pH meter (Delta 320, Mettler, Shanghai) following a recognized protocol (Rahman et al., 2014).

Data Analysis

The data were analyzed using Statistix 10.0 (Analytical Software 2105 Miller Landing Rd, Tallahassee, FL 32312, USA), and the means were separated by Tukey's HSD Test at a 5% level of significance.

Results

Soil and climate of the experimental field

The soil analysis of the experimental field reported that the soil contains 1.27% organic matter with a pH of 7.1 and EC 4.2 (ds/m). The soil contains only 0.078% N which is low and P, K, S, and Zn levels are 2.61 ppm, 0.71 ppm, 9.68 ppm, and 0.90 ppm, respectively (Table 1). During the experimental period, the minimal temperatures range between 9 and 26.8 °C with an average of 16.7 °C and the maximal temperatures ranges from 22-38.2 °C with an average of 29 °C. The minimum RH was 40%, and the maximum was 93%, with an average of 62.5%. During the entire growing season, it rains only 3 mm on 8 February 2021 and the rest of the period remains rainless (Figure 1).

Table 1. Soil characteristics of the study field

PH	EC (ds/m)	Organic matter (%)	N (%)	P (ppm)	K (ppm)	S (ppm)	Zn (ppm)
7.1	4.2	1.27	0.078	2.61	0.71	9.68	0.90

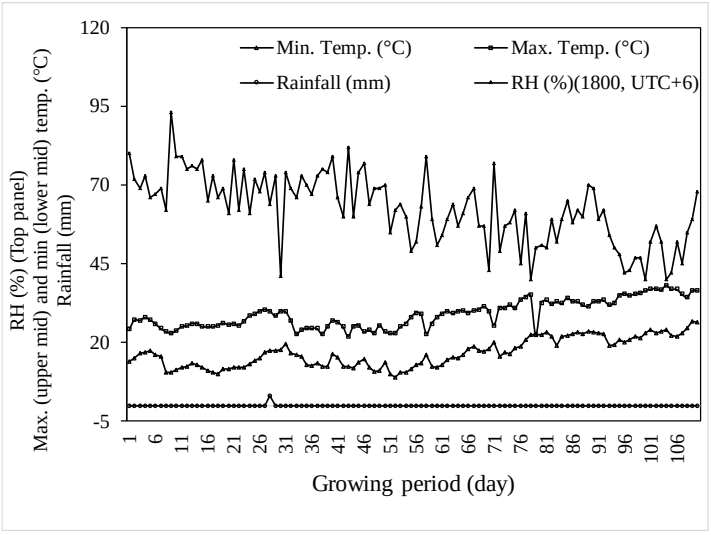

Figure 1. The daily rainfall (mm) (bottom panel), minimal and maximal air temperatures (°C) (lower and upper middle panels, respectively), and relative humidity (RH) (top panel, %) at 6:0 pm (UTC+6) of the experimental field from 2 December 2020 to 31 March 2021. The data were obtained from Khulna Meteorological Station, which is within 50 m of the study field.

Plant Growth

Plant height of capsicum varied due to the rate of N application on different days after transplanting (DAT). At 75 DAT, the tallest plant (30.89 cm) was measured from 145 kg N ha^{-1} and the plant height decreased as the amount of N decreased. A similar trend was found for other DATs (Table 2). Stem diameter also varied due to N application, and the highest diameter was recorded from higher doses of N (116 kg or 145 kg) and the lowest from the control.

Statistically similar diameters were measured for the N rates @ 116 kg or 145 kg per ha at 65 DAT and 75 DAT (Table 3). The leaf number of bell pepper plants also differed significantly among the levels of N, and the higher leaf number was counted for 116 kg or 145 kg N treatments and lower from the control. However, leaf number was statistically similar between 116 kg and 145 kg N treatments for all DATs (Table 4). Leaf chlorophyll content index (CCI) (SPAD value) of capsicum was different statistically at all DATs except 35 DAT, and statistically similar CCI was estimated for higher levels of N treatments (87, 116, 145 kg/ha) at 45, 55, 65, and 75 DATs (Table 5).

Table 2. Effects of N on bell pepper plant height during the growing season

N (kg/ha)	Plant height (cm)*				
	35DAT	45DAT	55DAT	65DAT	75DAT
0	9.08e	11.08e	12.68d	11.88e	12.36e
58	12.50d	14.99d	16.99c	17.91d	18.21d
87	18.30c	21.33c	22.74b	22.83c	23.12c
116	19.13b	22.91b	23.99b	25.08b	25.70b
145	24.25a	28.75a	31.83a	29.66a	30.89a
P	0.01	0.02	0.001	0.01	0.01

*DAT= days after transplanting. * Different letter (s) in a column indicates significant differences among the means following Tukey's HSD test at a 5% probability.*

Table 3. Stem diameter of capsicum as affected by N levels

N (kg/ha)	Stem diameter (mm)*				
	35DAT	45DAT	55DAT	65DAT	75DAT
0	2.48d	4.43d	5.08e	8.30d	11.49d
58	3.64c	5.99c	9.06d	12.42c	17.11c
87	3.78bc	7.58b	10.33c	15.82b	21.55b
116	4.21b	9.51a	13.57b	19.29a	24.15a
145	4.92a	9.35a	14.88a	19.82a	24.41a
P	0.01	0.01	0.02	0.02	0.01

*DAT= Days after transplanting. * Different letter (s) in a column indicates significant differences among the means following Tukey's HSD test at a 5% probability.*

Table 4. Effect of N on the leaf number in capsicum

N (kg/ha)	Leaf no. plant^{-1}*				
	35DAT	45DAT	55DAT	65DAT	75DAT
0	11.74c	14.58c	17.41d	20.74c	21.99c
58	12.99bc	17.99b	19.91c	26.66b	27.91b
87	14.99ab	21.33a	22.91b	28.24ab	28.41b
116	16.99a	22.74a	23.99ab	31.41a	32.22a
145	17.91a	22.83a	25.08a	28.99ab	30.41ab
P	0.03	0.01	0.02	0.01	0.01

*DAT= Days after transplanting. * Different letter (s) in a column indicates significant differences among the means following Tukey's HSD test at a 5% probability.*

Table 5. Leaf chlorophyll index (SPAD value) as affected by N levels during the growing season in capsicum

N (kg/ha)	Leaf chlorophyll index*				
	35DAT	45DAT	55DAT	65DAT	75DAT
0	50.12	45.76c	45.54b	47.88c	45.80b
58	46.49	51.92b	46.38b	52.84bc	46.81ab
87	43.40	53.46ab	51.30a	54.48ab	50.58ab
116	52.91	57.15a	51.12a	59.47a	51.25ab
145	46.75	57.13a	47.33ab	58.68ab	52.57a
P	0.86	0.02	0.01	0.01	0.01

*DAT= Days after transplanting. * Different letter (s) in a column indicates significant differences among the means following Tukey's HSD test at a 5% probability.*

Fruit Yield and physical attributes

Different levels of N resulted in fruit yield differences in bell pepper significantly (Table 6). The highest yield (12102 kg/ha) was recorded from 116 kg N and was statistically similar to 145 kg N (10582 kg/ha), and the lowest yield (2011 kg/ha) was estimated from the control treatment (no N). Fruit diameter and length differed significantly between the control and the rest of the treatments (Table 6). Though the treatments 116 kg N and 145 kg N resulted in statistically similar diameter and length, the treatment 116 kg N resulted in numerically higher diameter (78.16 mm) and length (78.67 mm) compared to145 kg N (76.84 mm diameter, 76.84 mm length). The fruit shape index (diameter: length) did not differ among the treatments.

Table 6. Effect of N levels on yield and fruit physical attributes of capsicum

N (kg/ha)	Fruit yield (kg ha^{-1})	Fruit diameter (mm)	Fruit length (mm)	Fruit shape index
0	2011d	49.08b	46.62b	1.05
58	5051c	67.25a	67.25a	1
87	7471bc	73.57a	73.57a	1
116	12102a	78.16a	78.67a	0.99
145	10592ab	76.84a	76.84a	1
P	0.001	0.01	0.01	0.58

Different letter (s) in a column indicates significant differences among the means following Tukey's HSD test at a 5% probability.

Fruit Quality

The pH of capsicum fruit was lowest at the control and varied statistically from the rest of the treatments (Table 7). Statistically similar vitamin C and TSS were measured for 116 kg and 145 kg of N and differed significantly from the control (Table 7). The control treatment resulted in the lowest content of vitamin C and TSS.

Table 7. Effect of N levels on capsicum fruit pH, vitamin C, and TSS

N (kg/ha)	pH	Vitamin C (mg/100 g)	TSS (%)
0	5.19b	130.21c	3.82d
58	5.83a	131.82 b	4.77c
87	5.95a	132.40 ab	5.27b
116	6.03a	132.97a	5.65ab
145	6.29a	132.52ab	6.07a
P	0.01	0.01	0.01

TSS = Total soluble solids, Different letter (s) in a column indicates significant differences among the means following Tukey's HSD test at a 5% probability.

Discussion

Soil and climatic condition

The soil analysis indicated a very low fertility status of the studied field (total N content 0.078%). Very similar results (0.07% N) were reported from another study conducted in the same experimental field (Biswas et al., 2022). However, another study showed that the total N content is 0.125%. Whatever the report says, the main point is that the N content of the coastal soil of Bangladesh is very low. The high average of low (16.7 °C) and high (29 °C) temperatures along with high average RH (63%) indicated that Bangladesh is a warm and humid country. Only one-day 3 mm rainfall in the entire growing season (December – March) is proof of existence of the dry season in Bangladesh.

Plant Growth

Higher doses of N increased the plant height and stem diameter of capsicum due to the increased supply of N. Similar results were reported from several studies in capsicum (Bar-tal et al., 2001; Pervez et al., 2004; Aminifard et al., 2012; Aminifard et al., 2018; Ekwu and Okporie, 2002; Kumar et al., 2018; Bhuvaneswari et al., 2014). N also increased leaf number and leaf chlorophyll content, as was reported by other authors (Bhuvaneswari et al., 2014; Bowen and Frey, 2002). N is required for every part of a cell – cell wall, plasma membrane, chloroplast, nucleus, mitochondria, ribosome, rough and smooth endoplasmic reticulum, vacuoles, and organelle membranes – as a structural component, and it is also part of structural and non-structural (enzymes) protein. N alone accounts 40%

to 50% dry matter of protoplasm. Therefore, N is badly needed for the growth and development of plants. However, excess N makes the plant vulnerable to diseases and pests through growth stimulation (Aliyu, 2002).

Fruit yield and quality attributes

The optimum dose of N promoted capsicum fruit yield and quality attributes. High dose of N increases fruit (number) plant^{-1}, individual fruit weight, fruit diameter and length, and finally, yield of capsicum (Chaudhary and Singh, 2006; Jan et al., 2006; Aman et al., 2002; Gare et al., 2000; Khan et al., 2010; Roy et al., 2011; Leghari et al., 2016). However, excessive N reduces capsicum yield significantly (Aliyu, 2002). Numerically higher yield was obtained from 116 kg N compared to 145 kg in the present study, which was in agreement with other reports (Tumbare et al., 2004; Fernández-Luqueño et al., 2010).

High N dose also increases the TSS and vitamin C content of pepper (Lodhi et al., 2019). However, a report claimed that N has both positive and negative effects on vitamin C contents in fruits (Mozafar, 1993). Increased N rate also increases vitamin C in pumpkin (Biesiada et al., 2009). Though vitamin C and TSS were lowest from the control treatment (no N) in the present study, the highest N dose (145 kg N) did not increase those parameters compared to recommended dose (116 kg).

Conclusion

The recommended dose of N (116 kg N ha^{-1}) resulted in statistically similar stem diameter, leaf number, and leaf chlorophyll index with the highest dose of N (145 kg N ha^{-1}; 125% of recommended dose). Though the fruit yield, fruit diameter, and fruit length were statistically similar between the recommended and the highest dose of N, the yield was 12% higher for the recommended dose. Fruit chemical attributes like vitamin C and TSS were also similar between the two levels of N. Overall, 116 kg N ha^{-1} performed well regarding capsicum plant growth, fruit yield and quality attributes. Therefore, this N dose that has been suggested by BARI is satisfactory for capsicum production in the coastal saline soil of Bangladesh.

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Competing Interest

The authors report there are no competing interests to declare.

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