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Effects of micronutrients and their application efficiency on Capsicum production

B. M. Mahmudul Hasan[1*], Md. Hanjala Pipil[1], Md. Nurul Alam[2], Shumsun Nahar[2], Md. Hasib[3], Anju Man Ara[3], Tamanna Akter Moon[4], Ramjan Ali[5], Antu Chandra Karmokar[5], Tayaba Khanam Hridita[1], Jannatul Ferdoush[6]

[1]*Department of Biochemistry and Molecular Biology, Trust University, Barishal, Bangladesh*
[2]*Department of Crop Science and Technology, University of Rajshahi, Rajshahi, Bangladesh*
[3]*Department of Food Science and Technology, University of Rajshahi, Rajshahi, Bangladesh*
[4]*Department of Biochemistry and Biotechnology, University of Barishal, Bangladesh*
[5]*Department of Public Health Nutrition, Primeasia University, Dhaka, Bangladesh*
[6]*Department of Zoology, National University, Dhaka, Bangladesh*

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ABSTRACT

A field experiment was conducted over two consecutive Rabi seasons (2023–2025) in Daharnangi, Rajshahi (AEZ-11), Bangladesh, to investigate the interactive effects of micronutrients (boron and zinc), application efficiency, and varietal response on the growth, yield, and nutritional quality of chili (Capsicum annuum L.). The study followed a split-split plot design with three replications and tested three chili varieties—Sikarpuri (V1), Sakata-653 (V2), and Picnic (V3)—under three fertilizer application methods: broadcast (E1), foliar spray (E2), and combined method (E3: 50% broadcast + 50% spray), and four micronutrient treatments: control (M0), boron (2 kg/ha, M1), zinc (4 kg/ha, M2), and combined boron + zinc (M3). The soil was silty clay loam with high pH and low micronutrient availability. The results revealed that the combined application of boron and zinc (M3) using the E3 method significantly improved plant height, fruit set, total yield, and biochemical parameters such as protein, carbohydrate, chlorophyll, calcium, and vitamin C content. The Picnic variety (V3) showed the highest performance in both years, with the maximum fresh fruit yields of 10.614 t/ha and 10.663 t/ha, along with superior values in fruit weight, seed weight, and nutritional quality. Sikarpuri performed better in terms of flavor and beta-carotene content, while Sakata showed lower overall performance. The findings demonstrate that the integrated application of boron and zinc through combined methods is effective in enhancing chili productivity and quality, especially in calcareous soils. The combined treatment of V3E3M3 (Picnic + 50% broadcast + 50% foliar + B+Zn) is recommended for commercial chili production in similar agro-ecological zones.

***Corresponding author:** B. M. Mahmudul Hasan ✉ jewelgono@gmail.com

INTRODUCTION

Chili (*Capsicum annuum* L.) is one of the most important spice crops in Bangladesh, widely cultivated year-round and valued for its pungency, color, and nutritional qualities. Originating from South America, it belongs to the Solanaceae family and plays a significant role in both cuisine and the agro-economy of Bangladesh. Despite favorable climatic conditions and increasing demand, chili productivity in Bangladesh remains low (700-800 kg/ha) compared to neighboring countries (1000-1200 kg/ha), primarily due to limited arable land, poor adoption of improved varieties, and inefficient agronomic practices.

The increasing domestic and industrial demand for chili highlights the need for enhanced per-hectare yield. However, constraints such as biotic and abiotic stresses, poor seed quality, inadequate irrigation, and unbalanced soil fertility-particularly deficiencies in micronutrients like zinc (Zn) and boron (B)-limit production. These deficiencies are exacerbated in calcareous soils, common in the High Ganges River Floodplain (AEZ-11), where high pH reduces micronutrient availability. Zn and B are essential for chili growth, affecting fruit set, quality, and overall yield. Studies have shown that combined applications of these micronutrients significantly enhance yield and quality in chili and related crops. Moreover, foliar application of micronutrients presents an effective method of nutrient delivery, enhancing plant uptake and minimizing nutrient fixation, particularly in high-pH soils typical of calcareous regions. While the benefits of foliar fertilization and micronutrient supplementation are well-documented globally, limited research has been conducted on their combined effects on indigenous chili cultivars in Bangladesh. Recognizing this gap, the present study was designed with four specific objectives: to investigate the individual effects of zinc (Zn) and boron (B) on chili growth and yield; to evaluate the synergistic impact of their combined application on yield performance; to assess their influence on the nutritional quality of chili; and to determine the most efficient fertilizer application method for optimizing chili production under local soil and environmental conditions.

MATERIALS AND METHODS

The present research work was carried out at farmer's field of Daharnangi, Nimghutu, Damkura, Rajshahi, Bangladesh during the period from September, 2023 to April, 2025 for two seasons to study the growth and development of chili as affected by different variety and different micronutrient levels and fertilizer application efficiency.

Soil

Soil texture of the experimental area was silty loam belonging to the High Ganges River Floodplains Tract under AEZ-11 (FAO-UNDP, 1988). The selected experimental site was well drained medium high land.

Chemical properties

The nutrient status of soil sample collected from the experimental area was estimated in Soil Resource Development Institute (SRDI), Rajshahi Regional Research Laboratory, (Lab. No.14727, Ministry of Agriculture, and Bangladesh). From soil analysis it was shown-

i. The pH of the soil sample = 8.12
ii. The amount of nitrogen (N) = were 0.11%,
iii. Phosphorus (p) = 16.60 ppm
iv. Potassium (K) = 0.14 cmol/kg
v. Sulphere (S) = 17.05 ppm
vi. Zinc (Zn) = 0.39 ppm
vii. Boron (B) = 0.23 ppm
viii. Organic carbon (C) – 1.59% per 100 g of soil respectively.

Soil analysis data have been presented in Appendix-III.

Experimental treatments

The experiment was conducted applying the following three main treatments i.e. Factors A, B and C.

Characteristics of experimental Chili cultivars

Land preparation

The experimental plot was thoroughly prepared by ploughing for several times with a power tiller followed by laddering. Weeds and stubbles were collected and removed from the land.

The clods were broken into friable soil and the surface was leveled until the desired tilth was obtained. Finally, irrigation and drainage channels were prepared around the plot. The land was prepared a month before transplanting of seedlings.

Manuring and fertilization

Organic manure and different inorganic fertilizer were applied to the experimental field owing to the requirements of the research work. Cow dung, urea, TSP and MP were added to the soil 7 days before planting at final land preparation.

All micro-nutrient fertilizers were applied as various distributions to soil and to the chili plant before and after transplanting in each plot as per requirements of the research work. The tabulated doses of manures and fertilizers were applied to the plots at final land preparation for fruit production.

Plant protection

Insect pests

Miral 3G @ 16.8 kg/ha was applied during the final land preparation as preventive measure against the soil pests.

Diseases

Some of the plants were attacked by Leaf curl disease of chili caused by *Bemisia tabaci* fly. It was controlled by spraying Malathion @ 2 mL/L and sprayed for 3 times at 2 weeks' interval.

Harvesting

Fresh ripened chili fruits of every variety were harvested when maturity showing 85-95% maturity.

Generally, the maturity symptom was indicated by the change of color approaching green to red.

The fruits were picked with the help of hand. Care was taken so that no fruits were injured during picking. Finally, these were kept in a cool dry place.

Data collection (Chili)

Growth parameters

Out of 6 plants in each unit plot 3 plants were selected at random. The following parameters were recorded and their mean values were calculated from the sample plants during the course of experiment.

a) Plant height (cm)

Plant height was measured from 3 randomly selected plants in each plot from the ground level to the tip of the plant at 20 days' interval starting from 30 days of planting up to 120 days to observe the growth rate of the plant.

b) Number of leaves per plant

The number of leaves from 3 randomly selected plants was counted at 20 days' interval starting from 30 days of planting up to 120 days to observe the growth rate of leaves. Mean of total number of leaves per plant was calculated from the representative of three plants.

(c) Number of branches per plant

The number of branches per plant was recorded from the average of 3 selected plants from each plot at 25, 50, 75 days' interval.

(d) First day of flowering

The day of first flowering of each variety of chili from 3 randomly selected plants of each plot was recorded at different days after transplanting.

(f) Number of flowers per plant

The number of flowers per plant was counted from 3 randomly selected plants of each plot was recorded for three times at 7 days' interval starting from the day of first flowering.

Yield attributes

(a) Number of fruit per plant

The total number of fruits from 3 randomly selected plants were counted at different days' interval starting from first appearances of mature fruits up to harvesting (3 times). Mean of total number of fruits per plant was calculated from the representative of the three plants.

(b) Damaged fruit per plant

The damaged fruits per plant of each variety of chili from 3 randomly selected plants of each plot were recorded at the day of final harvesting.

(c) Fruit length (cm)

Fruits length was measured from the neck node to the apex of the fruit of each variety of chili from 3 randomly selected plants of each plot were recorded.

(d) Fruit diameter (cm)

Fruit diameter measurements were carried out when the fruits were mature. Measurements were made using calipers at the middle of the mature selected fruit.

(e) Fresh fruit weight (g)

An electric balance was used to take the weight of chili fruit. After removing mature fruits from the selected plant of a plot, weight of twelve fruits randomly from 3 selected plants were taken and their average were calculated as individual fruit weight.

(f) Dry weight of fruit per plant

Every 100 g of ripen fruits was taken from 3 randomly selected plants in each experimental unit plot.

This 100 g ripen fruits were dried under scorching sunlight and kept in an oven at 65°C for drying until the constant weight reached at a certain point.

(g) Seed number

Presence of seeds in the mature ripened fruit of each variety from 3 randomly selected plants in each experimental unit plot were considered and total number of seeds per fruit was counted. Later on, mean of 5 fruits of each variety was calculated.

(h) Seed weight (g)

One hundred seeds were counted separately in each and every variety from 3 randomly selected plants in each experimental plot dried properly and weighed by using an electric balance.

(i) Fresh fruit yield per plant

All mature fruits were taken from 3 randomly selected plants in each experimental unit plot then weighed by using balance and mean of the weight of fruits of in each experimental plot was calculated. Finally, the values were expressed in gm.

(j) Yield of Fresh fruit (t ha^{-1})

Fruit yields were determined by harvesting crops grown one square meter area of each plot. The harvested samples were then weighed by using balance and finally the values were expressed in t ha^{-1}.

Determination of Trace Elements

Iron, Copper, Manganese, Zinc and Boron

Atomic Absorption Spectrophotormetric method (Krishna and Ranjan. 1991).

Principle

The technique involves determination of concentration of a substance by the measurement of absorption of the characteristic radiation by the atomic vapour of an element. When radiation characteristics of a particular element passes through an atomic vapor of the same element, absorption of radiation occurs in proportion to the concentration of atoms in the light path. The séance of characteristic radiation is hollow cathode lamp being made of the element destined to be estimated.

Reagents

Tri acid mixture concentrated nitric acid-perchloric acid concentrated sulphuric acid (3:2:1).

Procedure

1. 5g of the dry sample was weighed and 25ml of 3:2:1 tri acid mixture was added and left aside for 3-4 hours in a fume cupboard.
2. It was then heated for 30 minutes until the initial vigorous reaction was subsided.
3. It was heated more strongly for 4 hours until the nitrous fumes were removed and white fames of perchloric acid were evolved.

The content were allowed to cool and transferred with 3-4 washing of de-ionized water to a 50ml volumetric flask and made up to the mark with water. Aliquots of the sample were taken for the estimation of heavy metals in an atomic absorption spectrophotometer.

Chemical analysis (Chili)

Chlorophyll test (mg/g)

Chlorophyll is the green pigments universally present in all photosynthetic tissues. Chlorophyll-a and Chlorophyll-b occur in higher plant.

Total chlorophyll, chlorophyll-a, and chlorophyll-b were calculated on a basis of fresh weight following the formulae described by Mahadevan and Sridhar, 1982). One (1) g of mature chili fruit was cut into

small pieces and homogenized well with excess acetone in a mortar pestle and then filtered the extract through Buchner funnel using Whatmann no. 42 filter paper. Then 80% of acetone was added and repeated the extraction. The content from extraction was transferred to Buchner funnel and washed with 80% acetone until colorless. The filters were pulled and made the volume up to 100ml in a volumetric flask with 80% acetone. The absorbance of the extract was measured at 645nm and 663nm for determination of Chlorophyll-a and Chlorophyll-b respectively. The Chlorophyll content were calculated on fresh weight basis employing the following formula as describe Mahadevan and Sridhar, 1982, using the specific absorbance coefficients for Chlorophyll-a and Chlorophyll-b at 663nm and 645 nm in 80% acetone respectively.

Calculation

$$\text{Total chlorophyll (mg g}^{-1}) = \frac{20.2\ A_{645} + 8.02\ A_{663}}{a \times 1000 \times w} \times v$$

$$\text{Total chlorophyll-a (mg g}^{-1}) = \frac{12.7\ A_{663} - 2.69\ A_{645}}{a \times 1000 \times w} \times v$$

$$\text{Chlorophyll-b (mg g}^{-1}) = \frac{22.9\ A_{645} - 4.68\ A_{663}}{a \times 1000 \times w} \times v$$

Where,

A = Optical density in each sample,

a = Length of light path in the cell (usually l cm),

v = Volume of the extract in ml and

w = Fresh weight of sample in 'g'.

Determination of carbohydrate

Total soluble carbohydrates were estimated by following the phenol sulfuric acid method (Dubois *et al.* 1956). 1ml prepared sample placed in a test tube and then 1ml p phenol solution added. The procedure was followed by adding 5ml of sulfuric acid and well shaken. The yellow-orange color was pipette off and wave length was read in 490 nm by spectrophotometer.

Calculation

The amount of carbohydrates was calculated from the standard curve of glucose. Finally, the percentage of total soluble carbohydrate present in the fresh ripened chili was determined using the formula given below.

$$\text{Percentage of total soluble carbohydrate content (g 100 g}^{-1}\text{ of fresh ripened chili)} = \frac{\text{Weight of total soluble carbohydrate obtained}}{\text{Weight of fresh ripened chili}} \times 100$$

Determination of ash contents

Ash content was determined by following the method of AOAC, (1980).

About 10g of ripened chili were weighed in a porcelain crucible which was previously cleaned and heated to about 100 ^{o}C for an hour, cooled and weighed. The crucible was placed in a muffle furnace for about six hours at 600 ^{o}C.

It was then cooled in desiccators and weighed. To ensure completion of ash the crucible was again heated in the muffle furnace for half an hour, then cooled and weighed again. This was repeated till two consecutive weights were the same and the ash was almost white in color.

Calculation

$$\text{Percent of ash content (g 100 g}^{-1}\text{ of ripened chili)} = \frac{\text{Weight of the ash obtained}}{\text{Weight of the sample (ripened chili)}} \times 100$$

Determination of pH Content

The p^{H} of fresh ripened chili of three different varieties was determined by the conventional procedure using a pH meter.

The electrode assembled of the p^{H} meter was dipped into the standard buffer solution of p^{H} 7.0 taken in a clean and dry beaker. The temperature correction knob was set to 28^{o}C and the fine adjustment was

made by asymmetry potentially knob to p^H 7.0. After washing with distilled water the electrode assembly was then dipped into a solution of standard p^H 4.0 and adjusted to the required p^H by the asymmetry potentially knob. The electrode assembly was raised, washed twice with distilled water, rinsed with powder extract and then dipped into the fresh ripened chili solution for recording the p^H of the extract.

Determination of β-carotene

β-carotene content in fresh ripened chili was determined using atomic absorption spectrophotometer following the method of Masayasu *et al.* (1994). β-carotene in sample are extracted with acetone-hexane (4:6) at once, then optical density of the supernatant at 663 nm, 645nm, 505 nm and 453 nm are measured by spectrophotometer at the same time. From these values, the content of β-carotene was measured.

Determination of zinc

Zinc content in fresh ripened chili was determined using atomic absorption spectrophotometer following the method of Jackson (1973).

Calculation

The amount of zinc in the stock solution of fresh ripened chili was calculated from the standard curve of zinc. Finally, the amount of zinc present in the fresh ripened chili was determined using the formula given below:

Amount of zinc (mg/100 g of fresh ripened chili) =

$$= \frac{\text{Weight of zinc obtained}}{\text{Weight of fresh ripened chili}} \times 100$$

Determination of calcium

Calcium content of fresh mature chili was determined by Colorimetric method following Stern, J. and Lewis, W.H.P. (1957).

Calculation

The amount of calcium content in the stock solution of fresh mature chili was calculated by using the standard curve of calcium.

Finally, the amount of calcium present in the grain was determined using the formula given below:

Amount of calcium (mg 100 g^{-1} of fresh mature chili)

$$= \frac{\text{Weight of calcium obtained}}{\text{Weight of fresh mature chili}} \times 100$$

Determination of vitamin C

Vitamin-C content in chili was determined by the titrimetric method (Bessy and King, 1933).

Calculation

Estimation of the vitamin -C content of the extract by using the following formula:

$$\text{Ascorbic acid/ 100g of chili (mg)} = \frac{I \times S \times D \times 100}{A \times W}$$

Where,

I = ml of indophenol reagent in the titration

S = mg of Ascorbic acid reacting with 1ml of the reagent

D= Total volume of the extract in ml

A = the liquid titrates in ml (in titration used extract)

W = the weight of sample in g

Determination of total soluble sugar

The total soluble sugar content in fresh ripened chili was determined calorimetrically by the Anthrone method (Morse, E.E. 1947).

Calculation

Percentage of soluble sugar content (g/100 g of fresh ripened chili) =

$$= \frac{\text{Amount of soluble sugar obtained}}{\text{Weight of fresh ripened chili}} \times 100$$

Determination of total soluble protein

Soluble protein content in fresh ripened chili was determined following the method of Lowry *et al.* (1951).

Calculation

Percentage of soluble protein content (g 100 g^{-1} of fresh ripened chili) =

$$= \frac{\text{Amount of soluble protein obtained}}{\text{Weight of fresh ripened chili}} \times 100$$

Statistical data analysis technique

Data regarding various characteristics under study were analyzed statistically to find out the statistical significant difference of the experimental results by using statistical package program MSTAT-C (Russel, 1986). The significance of the difference among the treatments means were estimated by the Duncan's Multiple Range Test (DMRT) at 1% and 5% level of probability (Gomez and Gomez 1984). The means for all the treatments were calculated and analyses of variance for most of the characters were performed using F-test.

The significance of the differences between pairs of means was evaluated by least significant difference test (LSD) [Gomez and Gomez, 1984].

RESULTS AND DISCUSSION

The highest plant height (33.303cm) was found in Picnic (Metal) variety which was statistically identical and the lowest (24.517 cm) was found in Sikarpuri variety at 75 DAT. The maximum plant height 46.559 cm and 48.633 cm found in Sakata variety at 100 DAT and 125 DAT.

Effects of variety on Growth parameters of chili Plant height

Plant height was recorded at different days after planting (Fig.1). It was observed that the effect of different types of variety was found significant on plant height at different days after transplanting (DAT) in the year of 2023-2024 while there was no significant effect in the year of 2024-2025. At 25 DAT and 50 DAT the highest plant height 13.171 cm and 18.547 cm were found in Sakata variety and the lowest 12.353 cm and 17.106 cm was found in Sikarpuri variety which wasn't significant.

Plant heights increased with the advancements of growing time from 25 DAT. The effect of variety on plant height was found significantly differences at 75 DAT, 100 DAT and 125 DAT.

Table 1.

Variety name / Characteristics	Shikarpuri (Local Variety)	Sakata – 653 (HYV) (Japan)	Picnic (HYV) (Metal Company ltd.)
Cultivation	Rabi	Rabi	Rabi & Kharif
Plant Height	60-90 cm	45-55 cm	40-50 cm
Number of fruits per plant	300-400	350-400	350-500
Yield of fruits per plant	400-600 g	450-550 g	500-750 g

The highest plant height (33.303cm) was found in Picnic (Metal) variety which was statistically identical and the lowest (24.517 cm) was found in Sikarpuri variety at 75 DAT. The maximum plant height 46.559 cm and 48.633 cm found in Sakata variety at 100 DAT and 125 DAT. On the other hand, the lowest reading 35.419 cm from Sikarpuri at 100 DAT and 37.889 from Picnic variety at 125 DAT. In the year of 2015-2016, the highest plant height (14.719 cm, 19.372 cm, 28.512 cm, 43.538 cm and 46.958 cm) were observed in Sakata-653 variety which was statistically identical and the lowest (12.853 cm, 17.268 cm, 25.418 cm, 33.374 cm and 35.309 cm) were found in Sikarpuri variety at 25 DAT, 50 DAT, 75 DAT, 100 DAT and 125 DAT respectively. Similar finding was observed by Gogoi *et al.* (2002). This result was agreement with the findings of Sreelathakumary *et al.* (2004), Smitha *et al.* (2006) observed significant differences among the genotypes with respect to both quantitative and qualitative characters.

Table 2. Dose of Basal Application of NPKS Fertilizer.

Dose / Manure/Fertilizers	Amount
Cowdung	5 t/ha
N as Urea	120 kg/ha
P as Triple super phosphate (TSP)	60 kg/ha
K as Muriate of potash (MP)	80 kg/ha
S as Gypsum	20 kg/ha

Days of first flowering

Days of first flowering had no significant effect among varieties in both the years. In respect of variety, the highest value of Days of first flowering were (67.57 in 1st year and 64.91 in 2nd year) found in Sakata (V_2) and the lowest value 41.38 in 1st year and 41.02 in 2nd year were founded in Sikarpuri (V_1) in both the years. Gogoi *et al.*, 2002 recorded similar findings.

Numbers of flowers per plant

Total number of flowers plant^{-1} varied significantly due to varietal effect in both the years at 45 DAT in 1st year and 15 DAT in 2nd year. An increasing trend on production of number of total flowers plant^{-1} was noticed in different variety. In the year of 2014-2015, the highest number of total flowers plant^{-1} (8.70 and 13.66) were found in Metal variety (V_3) at 15 and 45 DAT respectively and also highest number of total flower plant^{-1} was 32.02 in Sikarpuri at 30 DAT.

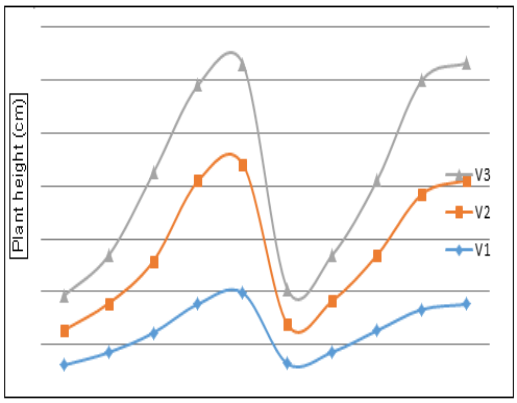

Fig. 1. Effect of variety on plant height of chili at different days after transplanting.

The lowest numbers of total flower plant-1 (6.92 at 15 DAT and 11.72 at 45 DAT) were recorded in Picnic (V_3) and (9.29) in Sakata at 30DAT. Similar results were reported by Gogoi *et al.* (2002).

Chowdhury *et al.* (2015) showed wide differences in genotypic constituents reflected by morphological status in case of varietal effect. Mehraj *et al.* (2014) found maximum number of flowers due to varietal effect.

On the other hand, lowest number of total flower plant^{-1} (7.892) was found in Sikarpuri at 15 DAT and 30.10 at 30 DAT and 11.14 at 45 DAT shown in Sakata variety (V_2). In 2nd year, the highest number of total flower plant^{-1} (8.65 at 15 DAT and 16.39 at 45 DAT) was noticed in Sikarpuri variety (V_1).

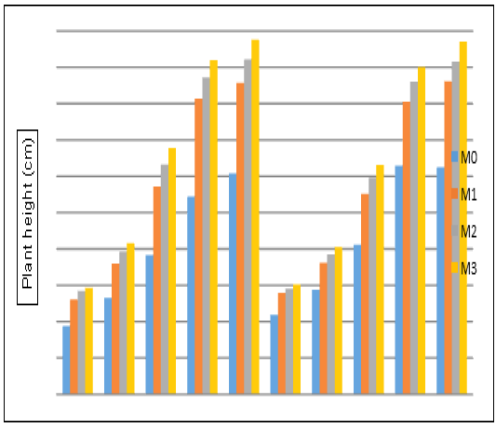

Fig. 2. Effect of fertilizer application efficiency on plant height of chili at different days after transplanting.

Number of fruits per plant

Variety had significant effect on number of fruits per plant at 45 DAT in the 1st year and in the 2nd year at 15 DAT, 30 DAT and 45 DAT. Picnic (V_3) variety showed the highest number of fruits 10.02, 12.46, 32.23 at 15 DAT, 30 DAT and 45 DAT in the first year. The Sikarpuri variety (V_1) showed the lowest number of fruits per plant at 15 DAT and 45 DAT. Minimum value (12.25) also revealed in Sakata at 30 DAT. In the 2nd year, variety had significant effect on number

of fruits per plant at 15 DAT, 30 DAT and 45 DAT. Highest number of fruits (6.58, 13.35 and 29.88) were observed in Metal (V_3) and the lowest number of fruits 5.81 noticed in Sakata at 15 DAT and 11.58 and 24.99 in Sikarpuri variety at 30 DAT and 45 DAT. This result was supported by Gogoi *et al.* (2002) and also Chowdhury *et al.* (2015) noted similar result due to varietal effect.

Total number of fruits per plant

Varieties had no significant effect on total number of fresh or marketable fruits per plant. Metal (V_3) variety showed the highest total number of fresh fruits per plant (32.235 in 1st year and 29.881 in 2nd years) and the lowest numbers of fresh fruits (28.44 in 1st year and 27.963 in 2nd years) were observed in Sikarpuri (V_1) variety. Gogoi *et al.* (2002) and Mehraj *et al.* (2014) reported similar observation.

Fresh fruit weight per plant

Significant effects on fresh fruit weight per plant were shown among different varieties in both of the years. Metal (V_3) variety showed the highest fresh fruit weight per plant 187.552 g in the year of 2014-2015 and 167.472 g in the year of 2015-2016 and Sikarpuri (V_1) variety showed the lowest fresh fruit weight per plant (164.684 g) in the 1st year and in the year of 2015-2016 (2nd year) Sakata variety (V_2) showed the minimum yield (134.981g) which was statistically significant. Gogoi *et al.* (2002) supported the findings.

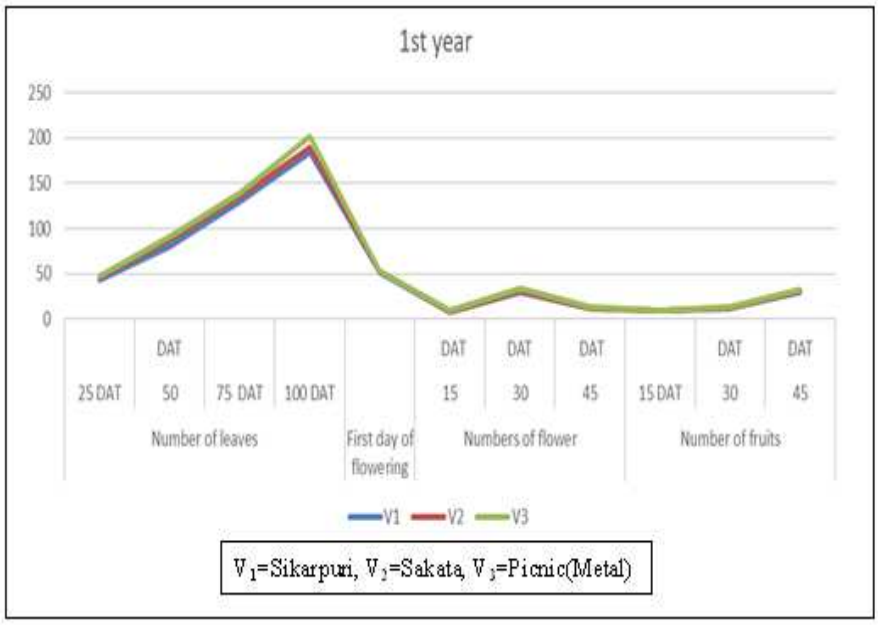

Fig. 3. Effect of fertilizer application efficiency on number of leaves, first day of flowering, number of flowers and number of fruits of chili at different days after transplanting (1st year).

Damaged fruits per plant

There were no significant effects on damaged fruit per plant in both of the year. In the year of 2014-2015, Sikarpuri (V_1) variety showed the highest number of damaged fruits per plant (4.343) whereas Sakata (V_2) variety showed the lowest number of damaged fruits per plant (3.688). In the year of 2015-2016, the highest number of damaged fruits per plant (3.988) as observed in Sikarpuri variety (V_1) and the lowest (3.658) was in Sakata variety (V_2). Similar results were reported by Gogoi *et al.* (2002).

Fresh weight per fruit

Different varieties of chili influenced on fresh weight of their fruits. Variety had significant effect on average fresh fruit weight in both of the years. The highest fresh weight of chili fruit (5.00 g) was performed by Sikarpuri variety (V_1) and the lowest (4.643 g) was in Sakata (V_2) in the 1st year. But in the 2nd year, Metal variety (V_3) gave the maximum value (6.064 g) and minimum value (5.00g) revealed from Sakata variety (V_2). Barche *et al.* (2014) found high significant difference due to genotypes for all the

traits including fresh weight of fruits indicating sufficient genetic variability among the genotypes. Similar result was reported by Mehraj *et al.* (2014) and Mehaj *et al.* (2014).

pH

P^{H} was recorded from fresh ripened chili. It was found that, different types of variety showed insignificant effect on p^{H} at the maturation stage of chili in first year but there was significant effect in second year. The highest pH value 5.667 was found in Metal variety (V_3) and the lowest 5.407 found in Sikarpuri (V_1) variety. The effect of variety on pH was found significantly differences in second year whereas the maximum pH (5.658) value was found in Sakata variety (V_2) which was statistically identical and the lowest (5.563) was found in Metal variety (V_3).

Vitamin-C

Variety had significant effect on vitamin-C of fresh chili. Metal (V_3) variety showed the maximum value whereas Sakata (V_2) variety showed the lowest value of vitamin-C of fresh chili in both years.

In first year, the highest value (96.101mg/g) was observed in Metal (V_3) and the lowest (74.642 mg/g) was in Sakata (Fig. 6). In second year, Metal variety (V_3) gave the maximum result (94.316 mg/g) and the lowest (72.401 mg/g) found in Sakata (V_2). Improvement in ascorbic acid content through fertigation was reported by Ramachandrappa *et al.* (2010) and Mehraj *et al.* (2014) in chili.

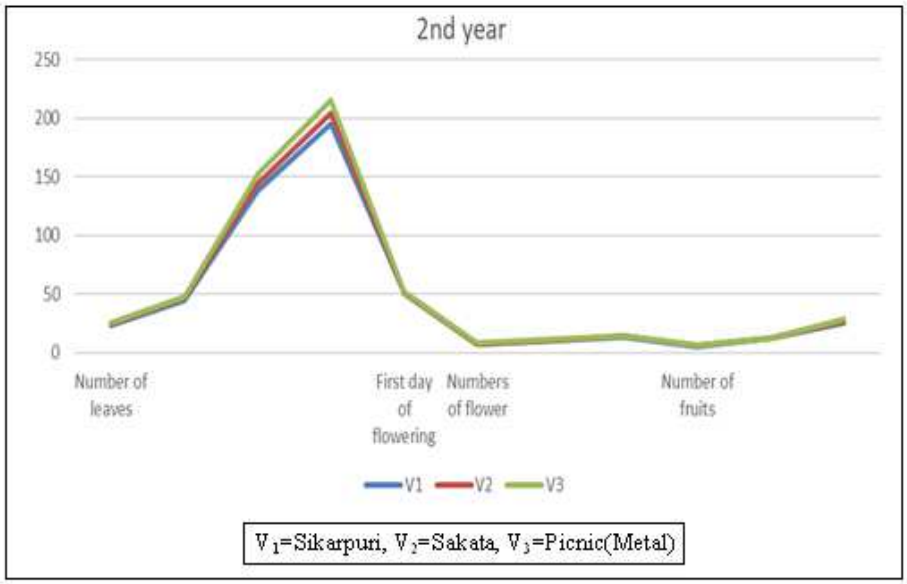

Fig. 4. Effect of fertilizer application efficiency on number of leaves, first day of flowering, number of flowers and number of fruits of chili at different days after transplanting (2nd year).

Sugar

The result indicates that, sugar content in chili differs significantly due to the effect of variety in both of the years. Metal (V_3) variety showed the highest sugar level (1.582% in 1st year and 1.624% in 2nd year) and Sikarpuri (V_1) variety showed the lowest sugar content (1.071% in 1st year and 1.096% in 2nd year) which was statistically significant.

Carbohydrate

Different variety exhibited significant variation in respect of carbohydrate. The maximum value of carbohydrate was produced in Picnic variety (V_3) compare to other variety of the two-year experiments.

The highest value (4.025%) observed in Picnic (Metal) variety (V_3) and the lowest value (3.305%) found in Sikarpuri (V_1) in first year which was not significant. The maximum number (3.938%) found in Metal variety (V_3) and the minimum value (3.163%) recorded from Sikarpuri (V_1) in second year which was statistically significant.

Chlorophyll

The increase of chlorophyll content in chili was significantly affected by variety. In 1st year, Metal (V_3) variety showed the highest value of (4.663mg/g in 1st year and 4.835mg/g in 2nd year) and Sakata variety (V_2) showed the lowest sugar content (3.853mg/g in 1st year and 3.743mg/g in 2nd year) which was statistically significant. Mehraj *et al.* (2014) founded same observation in chili.

Calcium

The varietal effect on calcium status of chili found highly significant in both of the years. Metal (V_3) variety showed the maximum result (0.924mg in 1st year and 0.910mg in 2nd years) and the lowest value (0.658mg in 1st year and 0.666mg in 2nd years) were observed in Sakata (V_2) variety.

Zinc

Variety had significant effect on zinc (Zn) content in chili. The highest value of zinc content in (6.869g/ml in 1st year and 6.871 g/ml in 2nd year) were found in Sakata variety (V_2) whereas the lowest value of zinc 3.602 g/ml in 1st year and 3.644 g/ml in 2nd year were recorded in Metal variety (V_3) in both the years.

Beta Carotene

The influence of variety on beta-carotene level of chili was found to be statistically significant in both of the year. In 1st year, the maximum result of beta carotene in chili 3.611 µg was observed in Sikarpuri variety (V_1) and the lowest value of chili 2.912 µg was found in Sakata (V_2) variety. In 2nd year, the maximum value 3.696 µg was noticed in Sikarpuri variety (V_1) and the lowest result 2.778 µg was found in Sakata variety.

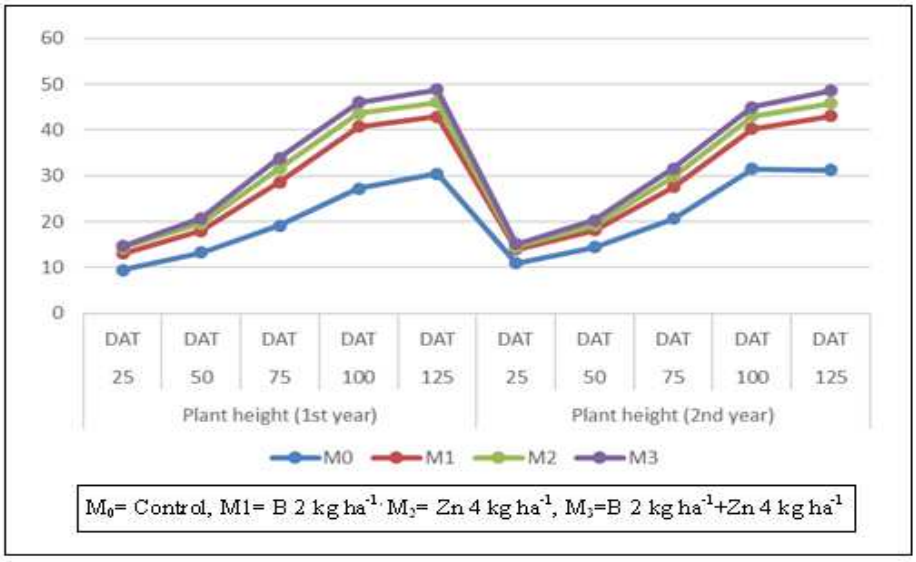

Fig. 5. Effect of Micronutrient on plant height of chili at different days after transplanting.

Ash

The total amount of ash varied significantly due to varietal effect in 2nd year only. In 1st year, the highest result 1.525% in 1st year and 1.569% in 2nd year were found in Metal variety (V_3). On the other hand, lowest number of ash content 1.449% found in Sakata (V_2) in 1st year and in 2nd year, minimum value 1.494% observed in Sikarpuri variety (V_1).

Protein

Protein had significant effect by varieties in both the years. In respect of variety, the highest value of protein 1.014% in 1st year and 0.994% in 2nd year were found in Metal variety (V_3) whereas the lowest value of protein 0.775% in 1st year and 0.776% in 2nd year were recorded in Sakata (V_2) in both the years.

Effect of fertilizer application efficiency on the growth and yield of chili

Plant height

Plant height was recorded at different days after planting (Fig. 2). It was noticed that the effect of

fertilizer application efficiency was not found significant on plant height at different days after planting (DAT) in both years. In 1st year, at 25 DAT, 50 DAT, 75DAT, 100DAT and 125 DAT the highest plant height 13.105cm, 18.467cm, 29.556 cm, 40.076 cm and 43.019 cm were found in (E_3) and the lowest 12.576 cm, 17.466 cm, 27.104 cm, 38.772 cm and 41.043 cm were found in (E_1).

In 2nd year, at 25 DAT, 50 DAT, 75 DAT, 100 DAT and 125 DAT lowest plant height 13.876 cm, 18.369 cm, 28.486 cm, 40.942 cm and 43.575 cm were found in E_3 and the lowest 13.474 cm, 17.642 cm, 26.396 cm, 39.099cm and 41.174 cm were found in E_1 at 25 DAT, 50 DAT, 75DAT, 100DAT and 125 DAT. Hatwar *et al.* (2003) carried out an experiment and found similar results.

Total number of fruits per plant

Fertilizer application efficiency had no significant effect on total number of fresh or marketable fruits per plant. E_3 showed the highest total number of fresh fruits per plant 30.981 in the 1st year and 32.304 in the 2nd year and the lowest numbers of fresh fruits 28.616 (Fig. 3 & 4) in the 1st year and 29.103 in the 2nd year were observed in E_1 variety.

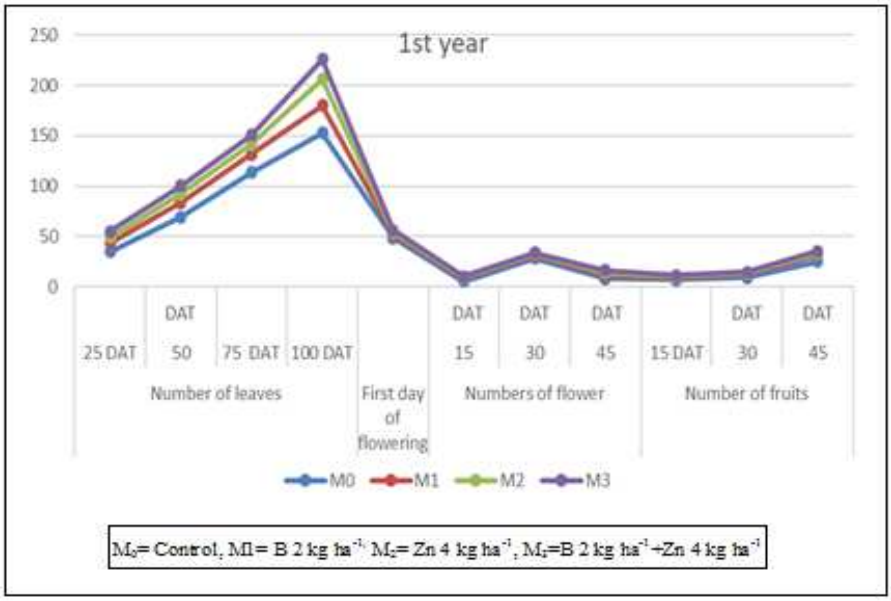

Fig. 6. Effect of Micronutrient on number of leaves, first day of flowering, number of flowers and number of fruits of chili at different days after transplanting (1st year).

Result revealed that the pH value had no significant effect due to fertilizer application efficiency in both the years in chili. In 1st year, the maximum pH value 5.593 was found in E_3 and the minimum result 5.546 found in E_1 variety. In second year whereas the highest pH 5.626 value was found in E_3 and the lowest 5.582 was found in E_1 variety (Fig. 6).

Vitamin-C

Results showed that fertilizer application efficiency had significant effect on vitamin-C of fresh chili in second year. E_3 variety showed the maximum value whereas E_1 variety showed the lowest value of vitamin-C of fresh ripened chili in both years. In first year, the maximum value 86.872mg/g were observed in E_3 and the lowest 83.098 mg/g was in E_1 (Fig. 6). In second year, E_3 gave the maximum result 84.934 mg/g and the lowest 81.649 mg/g found in E_1.

Sugar

The result indicates that, sugar content in chili was not significantly influenced due to the effect of fertilizer application efficiency in both of the years. V_3 variety showed the highest sugar level 1.414% in 1st year and 1.469% in 2nd year and V_1 variety showed the lowest sugar content 1.392% in 1st year and 1.430% in 2nd year (Fig. 6).

Carbohydrate

It was observed that, fertilizer application efficiency exhibited significant variation in respect of carbohydrate in 2nd year. The highest value 3.788% observed in E_3 and the lowest value 3.660 % (Fig. 6) found in E_1 in first year which was not significant. The maximum results 3.703% found in E_2 and the minimum number 3.558% observed in E_1 in second year which was statistically significant.

Chlorophyll

Results showed that, the increase of chlorophyll content in chili was significantly affected by fertilizer application efficiency in second year. In first year, the maximum value 4.372 mg/g was observed in E_3 and the lowest 4.326 mg/g was in E_1 (Fig. 6). In second year, E_2 gave the maximum result 4.476 mg/g and the lowest 4.393 mg/g found in E_3 variety.

Calcium (Ca)

The effect of fertilizer application efficiency on calcium status of chili found highly significant in 2nd year. In 1st year, Metal variety (V_3) showed the highest result 0.830mg (Table 6A & 6B) and the lowest values (0.785 mg) obtain from Sikarpuri (V_1). In 2nd year, (Fig. 7) maximum result (0.83 mg) revealed from Metal variety (V_3) and lowest value (0.789mg) were observed in Sakata (V_2) variety which was highly significant.

Zinc (Zn)

Fertilizer application efficiency had no significant effect on zinc (Zn) content in chili. The highest value of zinc content in 5.253g/ml in 1st year and 5.336 g/ml in 2nd year were found in E_3 whereas the lowest value of zinc 5.163 g/ml in 1st year and 5.233 g/ml in 2nd year were recorded in E_1 variety (Fig. 6).

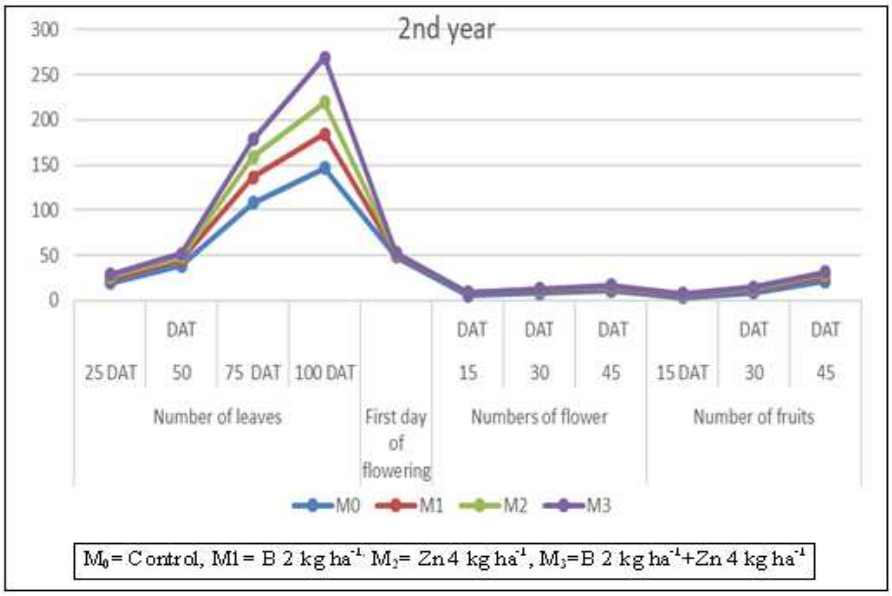

Fig. 7. Effect of Micronutrient on number of leaves, first day of flowering, number of flowers and number of fruits of chili at different days after transplanting (2nd year).

Beta carotene

The influence of fertilizer application efficiency on beta-carotene level of chili was found to be statistically significant in the 2nd year. In the 1st year, the maximum value of beta carotene in chili 3.241 µg was observed in E_3 and the lowest value of chili 3.179 µg was found in E_1 (Fig. 6). In the 2nd year, (Fig. 7) the maximum value 3.168 µg was noticed in E_3 and the lowest result 3.065 µg was found in E_2 which was statistically significant.

Ash

There was no significant variation on ash content of chili due to fertilizer application efficiency in both the years. In 1st year, the highest value 1.504% was found in E_3 and the lowest 1.48% derived from E_1 (Fig. 6).

On the other hand, in the 2nd year, (Fig. 7) maximum number of ash content 1.542% found in E_3 and the minimum value 1.529% observed in Sakata (V_2).

Protein

Protein had significant effect by fertilizer application efficiency in 2nd year. In respect of fertilizer application efficiency, in the 1st year, the highest values of protein 0.926% were found in E_3 whereas the lowest values of protein 0.875% were recorded in E_1 (Fig. 6). In the 2nd year, (Fig. 7) maximum number of protein content 0.940% found in E_3 and the minimum value 0.859% observed in E_1 which was statistically significant.

Effects of micronutrients on Growth parameters of chili

Plant height

It was observed that the significant effect of different levels of micronutrients was found on plant height at different days after transplanting (DAT) in both of the years.

Plant heights increased with the advancements of time from 25 to 125 DAT. In 1st year, the highest plant height (14.652cm, 20.788cm, 33.89cm, 46.011cm and 48.818cm) was found in M_3 (2 kg B ha^{-1} + 4 Kg Zn ha^{-1}) and the lowest value (9.392 cm, 13.282 cm, 19.137 cm, 27.206 cm and 30.408 cm) was found in control (M_0).

In 2nd year, the maximum plant height (15.138 cm, 20.271cm, 31.569 cm, 45.028cm and 48.520 cm) was found in M_3 and the minimum value 10.959 cm, 14.374 cm, 20.597 cm, 31.434 cm and 31.627 cm were found in control (M_0). K. D. Harris (2018). Sharma (1995), Yoganand (2001) recorded same results.

Numbers of fruits per plant

Micronutrients had significant effect on number of fruits per plant in both years. In 1st year, application of (M_3) showed the highest number of fruits per plant 11.321, 14.605 and 35.025 (Fig. 6 & 7) at 15 DAT, 30 DAT and 45 DAT and the lowest number of fruits 6.692, 9.115 and 24.957 per plant at 15 DAT and 45 DAT obtained from control (M_0). In the 2nd year, maximum number of fruits per plant 7.478, 14.781 and 31.219 were observed in (M_3) and the lowest number of leaves 3.623, 8.635 and 21.556 noticed in control (M_0) at 15 DAT, 30 DAT and 45 DAT. This result was agreement with the findings Gogoi *et al.* (2014).

CONCLUSION

The study revealed significant individual and interaction effects of variety, fertilizer method, and micronutrient levels on all measured growth, yield, and quality parameters across both years. Among the varieties, Picnic consistently outperformed others in yield and nutritional quality.

The combined application method (50% broadcast + 50% spray) proved most effective in improving fruit yield and nutrient uptake. The highest yield and quality attributes were achieved with the combined B (2 kg/ha) and Zn (4 kg/ha) application, particularly in the Picnic variety. Overall, the combined treatment of Picnic variety with 50% broadcast + 50% spray of B and Zn yielded the best results, making it the most suitable practice for maximizing chili production in calcareous soils of Bangladesh. While Picnic was best for yield and quality, Sikarpuri showed potential for flavorful consumption.

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