INFLUENCE OF CALCIUM AND NAA ON THE GROWTH, YIELD AND QUALITY OF HOT PEPPER (*Capsicum frutescens*)

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CERTIFICATE

This is to certify that the thesis entitled **"*INFLUENCE OF CALCIUM AND NAA ON THE GROWTH, YIELD AND QUALITY OF HOT PEPPER* (*Capsicum frutescens*)"** submitted to the Department of Horticulture, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Masters of Science (M.S.) in Horticulture**, embodies the result of a piece of *bona fide* research work carried out by **Md. Mehedi Zahan**, Registration No. **12-04928** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

June, 2018

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Dedicated to
My
Beloved Parents

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INFLUENCE OF CALCIUM AND NAA ON THE GROWTH, YIELD AND QUALITY OF HOT PEPPER (*Capsicum frutescens*)

ABSTRACT

The study was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from October 2017 to February 2018 to determine the effect of Ca and NAA on the growth, yield and quality of hot pepper variety BARI morich-3. The experiment consisted of two factors. NAA (3 levels) as N_0 = 0 ppm, NAA (Control), N_1 = 25 ppm NAA and N_2 = 50 ppm NAA; and Ca application (3 levels) as Ca_0 = 0 ppm Ca (Control), Ca_1 = 50 ppm Ca and Ca_2 = 100 ppm Ca. Different levels of NAA, Ca and their combination showed significant variation among the treatments. Results revealed that the in terms of yield and yield contributing parameters, the treatment combination of N_2Ca_1 gave the highest fruit length (7.18 cm), fruit diameter (0.63 cm), highest number of fruits plant^{-1} (473.80), and fruit yield (33.55 t ha^{-1}) where the lowest fruit length (5.88 cm), fruit diameter (0.37 cm), number of fruits plant^{-1} (260.40), and fruit yield (15.52 t ha^{-1}) was observed from the treatment combination of N_0Ca_0. In terms of quality parameters, the highest Vitamin C content (171.28 mg/100 gram of green fruit) was observed from the treatment combination of N_2Ca_1 where the lowest (72.84 mg/100 gram of fruit) was observed from the treatment combination of N_0Ca_0. From economic point of view the highest BCR (4.35) was obtained from the treatment combination of N_2Ca_1 and lowest BCR (2.14) was obtained from N_0Ca_0.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAT	=	Days After Transplanting
DMRT	=	Duncan's Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Eccectera
FAO	=	Food and Agriculture Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	Mili Litre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Chilli (*Capsicum frutescens* L.) commonly known as hot pepper, belongs to family solanaceae, having diploid species with mostly 2n = 2x = 24 chromosomes, but wild species with 2n = 2x = 26 chromosomes have been reported (Pickersgill, 1991) and is cultivated as an annual crop worldwide. The domestication of chilli first occurred in Central America, most likely in Mexico, with secondary centers in Guatemala and Bulgaria (Salvador, 2002). India, Mexico, Japan, Ethiopia, Uganda, Nigeria, Thailand, Turkey, Indonesia, China and Pakistan are the major chilli growing countries. It is also known as marich. It is an important spice as well as vegetable crop, where both ripe and unripe fruits are used for culinary, salad and processing purposes. Its extract is used in pharmaceutical industry for colouring the drugs. It is an excellent source of vitamin A and C. Being richest source of vitamin C, it is sometimes referred as capsule of vitamin C (Durust *et al.* 1997). The pungency in chilli is due to an alkaloid capsaicin ($C_9Hi_4O_2$) which is a digestive stimulant. It contains high nutritive value with 1.29 mg/100 g protein, 11 mg/100 g calcium, 870 I.U vitamins-A, 175 mg ascorbic acid, 0.06 mg thiamine, 0.03 mg riboflavin, 0.55 niacin per 100 g edible fruit and 321mg per 100 g of vitamin C (Agarwal *et al.*, 2007). They have beta carotene which is as much as that found in spinach of 180 mg per 100 g (Olivier *et al.*, 1981).

Chilli is one of the few vegetable crops which has tremendous export potential and help farmers in solving their problems of dependence on traditional crops. It is cultivated in all over the country. In the country, chilli crops occupies 103.24 thousand hectare of land with a production of 137 thousand metric tones (BBS 2017). Moreover, new processing units have established in the past which have encouraged the cultivation of chilli in the country.For commercial production of vegetable crops in many regions of the world, the use of growth regulators and Ca application can play an important role.Optimum growth regulators like NAA, GA_3 etc. and also Ca application can ensures proper growth and development of plant resulting maximum yield of crop and economic use of land with optimum fertilizer doses.

In general, there are significant economic losses of horticultural crops had been linked to inadequate calcium nutrition supply, or existing as unavailable form for absorption or immobile element and depends on transpiration rate. Calcium (Ca^{+2}) is an essential macronutrient for all higher plants. It is required for various structural roles in the cell wall and membranes and plays a key role in plant growth, fruit development. Also, it is involved in many biochemical and physiological processes in the plants which can improve yield (Marschner, 1995 and White & Broadley, 2003). For commercial production of vegetable crops in many regions of the world, the use of plant spacing has become an important cultural practice to maximize nutrient use efficiency by the plant and to improve the growth (Sharma and Kumar, 2017). Successful cultivation of any crop depends in several factors.

Naphthalene acetic acid, commonly abbreviated as NAA is an organic compound, which is a synthetic plant hormone of auxin group and is an ingredient in many commercial horticultural products; it is also a rooting agent and used for the vegetative propagation of plants from stem and leaf cutting (Dimitrios *et al*., 2008). NAA has been reported to be useful for thinning of fruits (Agusti *et al*., 2000). It has important role in fruit formation, abscission cell elongation, apical dominance, photoperiod and geotropism (Haidry *et al*., 1997). NAA application affects fruit formation through cell division and elongation (Dutta and Banik 2007). The role of NAA in enhancing the fruit set, growth and yield attributes in fenugreek (Alagukannan and Vijay Kumar, 1999), in coriander (Pareek, 1996;

Verma, 2002), in soybean (Dhopte and Suradhkar, 1999) and in french bean (Medhi, 2000) have been reported.

Keeping in view the importance of NAA and Ca in enhancing yield and quality of chilli, an investigation has been carried out to assess its effects with the following objectives:

1. To determine the optimum level of NAA for higher growth and yield of hot pepper
2. To determine the optimum level of Ca application for maximizing the yield of hot pepper.
3. To find out the combined effect of NAA and Ca for attending maximum yield of hot pepper.

CHAPTER II

REVIEW OF LITERATURE

Green pepper is an important vegetable in many parts of the world. Optimum Ca nutrition with suitable variety is the important and uncontroversial factor for maximizing the yield of a crop. NAA also influence different growth, yield and quality of green chilli. Many research have been conducted on growth, yield contributing parameters, yield and quality parameters of greenchilli on related terms (NAA and Ca) in abroad but scanty in Bangladesh. The available literatures related to the present study are reviewed here.

2.1 Effect of NAA

Tapdiya *et al*., (2018) conductedan experiment to study the Effect of Growth Regulators on Quantitative Characters ofChilli(*Capsicum annuum* L.). The study revealed that the seed treatment and foliar application influenced onthe yield attributing character of chilli over control. The result exhibited that the growthregulators namely NAA and GA_3 foliar spray during flower bud initiation stage was foundto be beneficial for increasing the plant height, number of branches per plant and stem girthover seed treatments compared to control. With regards to yield contributing character i.e.fruit setting percentage, fruit length, fruit girth, average fruit weight, number of fruit perplant, number of seeds per fruit, seed weight per fruit, and fruit yield per plant showedincrease in foliar spray of NAA 40 ppm than all other treatment including control.

Purabiya *et al*. (2018) conducted a field experiment to study the “Influence of integrated phosphorus management and growth regulators on growth and yield of fenugreek (*Trigonella foenum-graecum* L.)”. The experiment comprises twelve treatments. Treatment T_{11} (40 kg P_2O_5 ha^{-1} + NAA @ 20 ppm) was found significantly higher in seed yield (2274 kg ha^{-1}) than other treatments but was statistically at par with treatments T_7 (2136 kg ha^{-1}) and T_{10} (2207 kg ha^{-1}). The minimum seed yield was recorded by treatment T_1: PSB +VAM +Water spray (1761 kg ha^{-1}). The highest BCR of 3.65 was secured in T_{11} (40 kg P_2O_5 ha^{-1} + NAA @ 20 ppm). However, it was revealed that application of 40 kg P_2O_5 ha^{-1}+ NAA @ 20 ppm gave higher yield and net realization of fenugreek.

Choudhary *et al*. (2018) conducted a field experiment consisted of four levels of nitrogen (0, 30, 60 and 90 kg/ha) and five PGRs (control, NAA @ 50 ppm at 40 DAS, NAA @ 50 ppm at 40 and 60 DAS, thiourea @ 500 ppm at 40 DAS and thiourea @ 500 ppm at 40 and 60 DAS). The results revealed that application of PGRs significantly increased protein content and essential oil content in seed of ajwain over control, however all PGRs remained at par to each other, foliar application of thiourea @ 500 ppm spray at 40 and 60 DAS significantly increased seed (1112 kg/ha), straw (3082 kg/ha) and biological yields (4195 kg/ha) over thiourea @ 500 ppm spray at 40 DAS, NAA @ 50 ppm spray at 40 DAS and control but remained at par with NAA @ 50 ppm spray at 40 and 60 DAS in yield attributes and yields.

Suresh *et al*. (2018) carried out a field experiment to study the effect of nutrient levels and plant growth regulators on growth and yield of pearl millet. Ten treatments with nutrient levels and plant growth regulators were imposed. The plant growth regulators (PGRs) have potential for increasing crop productivity under environmental stress. Nutrient levels and plant growth regulators application had significant influence on growth parameters of Pearl millet. The significantly highest plant height, total number tillers, leaf area index, dry matter production and chlorophyll index was recorded with T_7 - 125% RDF + Foliar application of NAA @ 40 ppm at 20 and 40 DAS.

Patel *et al.* (2016) conducted a field experiment on chilli cultivar “Kashi Anmol” at SHIATS, Allahabad, UP. They applied two methods of application of PGR one was soaking seed and another foliar application. They found seed yield per plant (8.30g), seed yield per fruit (0.35g) and fresh weight of fruits per plant (39g) with NAA @ 40 ppm. Foliar spray of 40 ppm NAA at bud initiation stage increase in seed yield and quality parameters.

Singh *et al.* (2015) conducted an experiment on chilli variety "Pusa Jwala" with three treatments included farmers practice (T_1), NAA (T_2) and technology option (T_3) at KVK, Malda, West Bengal, under rain fed medium to upland sandy loam soil situation in rabi season. They sprayed NAA at the opening of first flower to last phase of flowering at 15 days interval. The result showed NAA reducing flower drop and increase in fruit set of chilli. Highest yield of chilli (14.37 q/ha) at NAA @ 50 ppm and followed by (12.32 q/ha) yield with NAA @ 20ppm.

Mehraj *et al.* (2015) conducted an experiment at Sher-e-Bangla Agriculture University, Bangladesh in okra, recorded that GA_3 and NAA @ 50 ppm both have the potentiality to increase the yield of okra. They found that foliar application of 50 ppm NAA increase yield (338.1 g/ha, 2.9 kg/plot and 16.4 t/ha).

Singh *et al.* (2014) studied on chilli variety G-4 at SHIATS, Allahabad, UP. They confined that the combined application of NAA @ 20 ppm, GA_3 @ 10 ppm and 2,4-D @ 1 ppm significantly increased vegetative growth, yield and quality of chilli. Combined application had positive effect on plant growth, flowering and yield potential of plants.

Moniruzzaman *et al.* (2014) conducted an experiment on brinjal having six PGR *Viz.,* GAs 30, 40, 50 ppm and NAA @ 20, 40, 60 ppm respectively and two varieties *Viz.,* "BARI Begun-5" and "BARI Begun-10 during rabi season for determine suitable dose of PGR for brinjal production. The variety "BARI Begun-5" was earlier to 100% flowering which took 44 days after transplanting which out yielded BARI Begun-10. NAA @ 40 ppm coupled with BARI Begun-5 gave the highest fruit yield 49.73 t/ha.

Pargi *et al.* (2014) conducted a pot experiment on tomato crop at SHIATS, Allahabad. They applied 5 levels of NAA spray (10, 20, 30, 40 and 50 ppm NAA) on the bud initiation stage and found maximum yield of tomato with NAA @ 50 ppm followed by NAA @ 30 ppm.

Meena *et al*. (2014) performed an experiment comprising four levels of bio-fertilizers (no inoculation, Rhizobium, PSB and Rhizobium+ PSB) and four levels of plant growth regulators (GA_3 50 and 100 ppm and NAA 10 and 20 ppm) and water were sprayed thrice during the crop growth period. The growth parameters, yield components and seed yield showed positive response to foliar application of plant growth regulators. Foliar application of 20 ppm NAA exhibited highest dry matter accumulation/plant, yield attributes, seed yield (17.99 q/ha) and BCR (4.06) followed by 20 ppm NAA.

Kiranmayi *et al*. (2014) reported at Dr. YSRHU, Andhra Pradesh on chilli variety "Lam-353" in summer when day temperature above 30^0C and warm night above 17^0C causes abscission of flowers and poor fruit set. They confined that spray of NAA @ 20 ppm + Boron @ 0.05 % recorded maximum plant height (83.33 cm), plant spread (137.33 cm), highest fruit setting (30.33%), fruits per fruit (124), fruit girth (2.98 cm), fruit weight (2.24 g). The green chilli yield per plant (263.5 g) with NAA @ 20 ppm. They found highest B:C ratio (4.29) with combination of NAA @ 20 ppm + Boron @ 0.05 % followed by 20 ppm NAA (4.21).

Danesh-Talab *et al*. (2014) carried out an experiment for evaluation of growth, phytochemical and morpho-physiological properties in fenugreek (*Trigonella foenum- graecum* L.) under application of plant growth regulators (PGRs). The experiment consist of 13 treatments; giberrellic acid (GA_3) and naphthalene acetic acid (NAA) each at 25 and 50 ppm by either a pre-plant soaking, a spraying at 20 days after planting, and a combination of pre-plant soaking plus a spraying at 20 days after planting along with control (distilled water application). Application of

PGRs (GA_3 and NAA 50 ppm) through combination of pre-plant soaking plus a spraying significantly increased shoot dry weight, 1000-seeds weight, number of seeds per pod, content of seed trigonelline, leaf area per plant (p.0.01), and also, plant height, stem diameter, number of pods per plant, content of seed mucilage, and root, stem, leaf and pod dry weight (p.0.05). Of course, application of PGRs had no significant effect on the amount of SPAD value and number of leaves per plant.

Rastogi *et al.* (2013) conducted an experiment on linseed variety “Neelam” which a high yielding variety of linseed. A combination of both PGR (200mg/l) and auxin (1.0 mg/l) is recommended for the enhancement of seed yield, where as a 0.5 mg l^{-1} dose of auxin is recommended for the enhancement of vegetative growth. It was concluded that the plant growth regulators can be successfully employed to enhance the yield economically.

Thapa *et al.* (2013) studied the influence of NAA and GA_3 on quality attributing character of sprouting Broccoli variety “Italica plank” at BCKV, Mohanpur. They confermed that NAA (30mg/l) + GA_3 (30mg/l) showed best result with respect to head diameter, plant height, spreading and yield. The plant growth regulator treatments significantly improved carotene, total sugar and total chlorophyll content, with highest increase have been recorded in case of T_1- GA_3 40 mg/l, whereas maximum Ascorbic content has been estimated with T_9- GA_3 20 mg/l+ NAA 20 mg/l. GA_3 (80 mg/l) treatment proved to be the most effective among all treatments and required minimum days for head initiation to head maturity.

Godara *et al*. (2013) carried out a field study with two bio-regulators, Triacontanol (500 ppm and 1000 ppm) and NAA (50 ppm), sprayed once and twice, were compared with water sprays (control). Application of NAA significantly improved the seed yield and yield attributes in fenugreek crop compared with Triacontanol and water sprays. Two sprays of NAA @ 50 ppm at 40 and 60 DAS produce maximum yield (19.34 q ha^{-1}) with 20% increase over control, and registered statistical superiority over both the doses of Triacontanol sprayed either once or twice, however it was at par with one spray of NAA (18.40 q ha^{-1}) at 40 DAS. In economic terms two sprays of NAA also fetched maximum gross (Rs. 54152) and net returns (Rs. 36006) with highest benefit: cost ratio (1.98). Therefore, one spray of 50 ppm NAA at 40 DAS followed by two sprays of NAA (at 40 and 60 DAS) is recommended for better growth, yield and economics of fenugreek crop.

Veishnav *et al.* (2012) studied effect of NAA on chilli during Rabi season. They recorded maximum plant height (70.52 cm) and number of branches (8.71) @ 40ppm NAA and genotype NUN-6525 treatment combination where as recorded higher values for green fruit plant^{-1} (179.59g) and dry fruit yield/ plant (38.68 g) with NAA @ 40ppm and genotype NUN-2070 treatment combination.

Nkansha *et al.* (2012) conducted an experiment to study the effect of plant growth regulators on fruit set and yield on "Keitt" mango trees in order to study the effect of Gibberellic acid (GA_3) and Naphthalene Acetic Acid (NAA) sprays at different concentrations on fruit retention, fruit quality and yield. Trees were sprayed at full bloom stage. All sprayed chemicals significantly increased fruit retention and tree yield. GA_3 (25 ppm) and NAA (25 ppm) gave the best results in terms of increasing fruit set, fruit retention, number of fruits cluster^{-1} and plant^{-1}, fruit weight and yield. No significant differences were observed between the quality of fruits harvested from treated and control trees. 25 ppm of GA_3 and 25 ppm NAA can be employed for spraying mango flowers at full bloom to increase mango fruit set, retention and yield of growers.

Athaneria *et al.* (2011) reported in chilli at JNKVV, Jabalpur, with 16 treatment combination of biofertilizer and NAA. The height (34.00, 51.86, 63.00 cm) and number of branches/plant (8.40, 12.33, 14.26) at 30, 60, 90 DAT respectively were noted with the treatment B_1G_2 (Azotobacter + 40 ppm NAA). Length of fruit

(9.65 cm), girth of fruit (3.14 cm), no. of fruits/plant (68.53), no. of fruits/plot (2308.800) and yield/plant (81.47 gm), yield/plot (2.93 kg)yield/ha (30.13 q) was recorded under the treatment combinations B3G2 (Azoctobacter + PSB + 40 ppm NAA).

Zaferanchi *et al*. (2011) investigated that the effect of two plant growth regulators, Naphtalene acetic acid (NAA) and Benzylamino purine (BAP) on yield, yield components, oil and protein content of sesame genotypes. The studied factors were two plants growth regulators BAP NAA each of which containing three levels as well as control with four sesame genotypes. Foliage spray at 30 ppm and 200 ppm of NAA and BAP concentrations were carried out at the beginning of flowering stage. The results of analysis of variance showed that NAA and BAP treated plants showed a better performance in yield, yield components and some parameters.

Kalshyam *et al.* (2011) conducted an experiment on chilli variety “Pusa Jwala” at CCSU, Meerut and concluded that combined application of that growth hormone and fertilizer each at higher concentration (75 ppm NAA 150 kg N/ha) gave the maximum growth and yield. The result revealed that plant height 58.43 cm, no. of branches/plant 82.65, green fruit yield 68.49 q/ha and dry fruit yield 6.74 q/ha with combined application of 75 ppm NAA and 150 kg N/ha.

Gour *et al*. (2009) conducted a field experiment to find out the effect of phosphorus and plant growth regulators on growth and yield of fenugreek (*Trigonella foenum-graecum*). Foliar spray of naphthalene acetic acid (NAA) 20 ppm at 25 days after sowing (DAS) and 55 DAS resulted in significantly higher growth and seed yield (17.41 q ha^{-1}). The highest benefit : cost ratio (4.20:1) was observed for the treatment, 60 kg phosphorus ha^{-1} + NAA 20 ppm.

Varma *et al*. (2009) reported that naphthaleneacetic acid is the organic substance which promotes the growth of plant and leads to more productivity, NAA application increased seed yield in black gram.

Sridhar *et al.* (2009) conducted an experiment on Bell Pepper at COA, Dharwad. They used three doses of NAA (50, 100 and 150 ppm) and Mepiquat chloride (500, 1000 and 1500 ppm) and observed the effect on yield, physiological and biochemical parameters of Bell Pepper variety "Tarihal". They found that fruit yield was significantly high (159.89 g/plant) 45 DAT.

Iqbal *et al.,* (2009) reported that the foliar spray with NAA at concentrations of 45 and 60 ppm when applied at marble and walnut stages of development in summer crop, significantly increased the fruit yield in guava. Ghosh *et al.,* (2009) reported that foliar application of NAA at 25 ppm to the plants of pomegranate cv. Ruby resulted in significant increase in fruit yield over the control.

Vejendla and Smith (2008) conducted a field experiment to study the effect of chemicals and growth regulators on fruit retention, yield and quality of mango cv. Amrapali. Treatments comprised: NAA at either25 or 50 ppm, 2, 4-D at either 10 or 20 ppm, ZnSO4 at 0.50% or 0.75% KNO_3 at 0.50% or 0.75%, and a control (water spray). Two sprays were applied, one at pea stage and other at marble stage. The chemicals and growth regulators showed significant influence on the fruit retention and yield of Amrapali over the control. NAA at 50 ppm recorded maximum (9.85%) fruit retention per panicle followed by 2, 4-D at 10 ppm. Plants receiving NAA at 50 ppm produced the highest number of fruits plant^{-1} and yield (88 plant^{-1} and 16.24 kg plant^{-1}) followed by2,4-D at 10 ppm and NAA at 25 ppm.

Stern *et al.,* (2007) applied 25-50 ppm 2,4-D, 15 ppm 3,5,6-TPA or 25-40 ppm2,4-D coupled with 30-50 ppm NAA at the beginning of pit-hardening stage of apricot, when the widest diameter of the fruit was 25 mm. They reported that there was appreciable and significant increase in fruit size. Dutta *et al.*, (2008) reported that the foliar application of NAA at 100 and 200 ppm effectively increased total soluble solids and total sugar content in mango cv. Himsagar.

Iqbal *et al.,* (2009) observed significant variation among various fruit quality parameters that is TSS, total sugar, acidity and ascorbic acid contents by the foliar application of NAA in guava.

Sultana *et al.* (2006) conducted an experiment on chilli during *rabi* season at BARI, Joydebpur, Bangladesh and results indicated that treatment of NAA @ 10 ppm gave significantly highest fruit yield (277.8 g/plant). Second highest fruit yield (221.1 g/plant) was obtained due to 100 ppm Ethephon, 1000 and 5000 ppm Knap treatments. Seedling vigour was highest in 10 ppm NAA followed by 50 ppm NAA and 100 ppm Ethephon.

Abu-Rayyan *et al.,* (2004) recorded higher yield per plant of Camarosa strawberry with the application of NAA. In a study Sharma and Ananda (2004) in Himachal Pradesh found pre-bloom foliar application of NAA at 5 ppm increased fruit yield in apple. Racsko *et al.,* (2006) reported that the yield in sour cherry and European plum could be increased by 22 and 15 per cent respectively, with application of Nevirol.

Jain Guo *et al.,* (2004) observed the pre- harvest application of NAA at 40 mg per litre obtained maximum size of litchi fruits. Nawaz *et al.,* (2008) studied the effect of growth regulators on preharvest fruit drop and quality of Kinnow mandrin *(Citrus reticulata* Blanco). Various concentration of 2, 4-D, GA_3 and NAA were applied during the last week of November, to check the impact of various treatments on preharvest fruit drop, yield and fruit quality. Exogenous application of growth regulators significantly decreased preharvest fruit drop percentage, leading to increase in total number of fruits per plant, fruit weight, juice percentage, total soluble solids, acidity, vitamin-C, reducing sugars and non reducing sugars % age while no effect was observed on fruit size. Auxin (2,4-D and NAA) performed better compared to gibberellins.

Khurana *et al*. (2004) also reported higher yield in chilli after the spray of NAA and inferred that the higher yield was due to appropriate growth of plants, control of abscission layer in full bloom stage and acceleration in full development by the positive hormonal actions.

Ramanathan *et al*. (2004) reported that foliar spray of NAA at 30 ppm concentrate was found to be more effective in increasing the number of branches, total dry weight, number of pods per plant, 1000 grain weight and grain yield, and chlorophyll content in black gram.

Kore *et al.* (2003) recorded significantly higher vine length (303.6 cm) intermodal length (10.03 cm) and number of branches (4.13) with NAA (20 ppm) compared to control in bottle gourd.

Masny *et al.*, (2002) studied the sprayed Betokson at 0.05, 0.1 and 0.2 per cent concentrations and found improved fruit size (11.6 per cent) and quality in strawberry cultivars Senga Sengana, Dukat and Elkat. Mir *et al.*, (2004) reported increase in quality parameters (length: diameter ratio, total soluble solids, total sugar and acidity) with increasing concentrations of NAA at 10, 15, 20, 25, 30 and 35 applied at 2 to 3 leaf stage on strawberry cv. Sweet Charlie.

Ganiger *et al.* (2002) investigated in cowpea crop that treatment with TIBA @ 25 ppm resulted in the highest seed yield (1801 Kg/ha), 1000 seed weight (132.4g) and pod length (12.79 cm), whereas treatment with TIBA @ 50 ppm resulted in the highest number of pods per plant (19.33), total dry matter (25.58 g/plant) and leaf area (10.08 $dm^{2/}$plant) at harvest. Treatment with TIBA @ 500 ppm resulted in the highest number of seeds per pod (10.14) followed by NAA @ 500 ppm treatment.

Balraj *et al*. (2002) obtained the maximum dry and fresh yield of chilli with 20 ppm NAA spray. Jat (2002) also reported that spray of NAA significantly increase the growth parameters, dry matter accumulation and N content of the groundnut plant. Sharma (2002) reported that application of NAA 100 ppm + GA_3 100 ppm + BA 200 ppm resulted in the highest saponin content in dried roots of safed musli.

Mehdi *et al.* (2002) conducted an experiment on French bean variety HUR- 137 to find out the effect of PGR on the dry matter production, flower initiation and pod setting of french bean. By reducing fruit drop (7.15%) NAA recorded highest pod yield (117.65 q/ha) @ 15 ppm which was 57% increase as compare to control. Dry matter accumulation increased and shoots and root ratio decreased due to application of the growth regulators.

Medhi and Borbora (2002) observed that foliar application of NAA (10, 15 ppm), triacontanol (10 and 15 ppm) and GA (10 and 15 ppm) increased flower initiation, pod setting and dry matter yield in french bean cv. HUR-137. NAA 15 ppm recorded highest pod yield by reducing the fruit drop.

Joshi and Singh (2001) conducted an experiment during the summer season of 1998, in Uttar Pradesh, India, to evaluate the effect of plant growth regulators, i.e. NAA (20, 40 and 60 ppm), GA_3 (10, 20 and 30 ppm), ethephon (50, 100 and 150 ppm), 2, 4-D (2, 4 and 6 ppm) and PP333 [paclobutrazol] (100, 200 and 300 ppm) on chilli cv. Pant C-1. Data were recorded for total leaf area per plant, shoot fresh weight, shoot dry weight, root fresh weight, root dry weight, pollen variability, number of seeds per fruit, weight of seeds, fruit dry weight and fruit yield per plant. The highest total leaf area (2970.90 cm^2) was recorded in NAA at 40 ppm. All concentrations of 2,4-D and PP333 showed significant reduction in total leaf area per plant, due to the herbicidal effects of both growth regulators. The highest shoot fresh weight (221.33 g), root fresh weight (47.26 g) and root dry weight (31.80 g) were recorded under 2, 4-D at 4 ppm. The highest shoot dry weight

(72.86 g) was noted in ethephon at 150 ppm, while the highest pollen variability (81.65%) was recorded in PP333 at 300 ppm. All growth regulators significantly increased fruit yield per plant over the control. The highest fruit yield per plant was recorded in PP333 at 300 ppm (282.20), followed by 2,4-D at 2 ppm (276.80g) and NAA at 40 ppm (274.13g). The higher yields in these treatments were due to more number of fruits per plant, higher percentage of fruit set per plant and higher values for fruit length and thickness.

Tewari *et al.* (2001) reported that seed germination significantly improved with GAs @ 100 ppm and NAA @ 10 ppm application. Longer seedlings were obtained with IAA @ 100 ppm and IBA @ 50 and 100 ppm. All treatments except GA_3 @ 100 ppm improved plant height. The greatest bulb diameter and yield were recorded for GA_3. The lowest rate (10 ppm) was most effective in increasing the growth and yield of onion. The highest rate (100 ppm) reduced bulb diameter and yield.

Sanaa *et al.* (2001) found in dry bean crop that increasing levels of NAA and SA increased the fresh and dry weights of the plants, pod setting pod weight and free amino acid content of fruits and seeds. SA resulted in an increase in phenolic compound content. SA at the higher concentration resulted in an increase in the total proteins of leaves and fruits. Combination treatment with the higher concentration of SA and NAA resulted in higher seed yield compared to the other treatments.

Kumar *et al.* (2000) reported that the dissipation and decontamination of cypermethrin (300 g a.i. ha^{-1}) in chilli fruits was studied in field studies in Andhra Pradesh, India, in 1997-98. The initial deposit of 0.85 mg kg^{-1} of cypermethrin dissipated to below detectable level by 5 d, after six sprayings with a half life of 1.32 days. The waiting period was found to be 1.80 days. Dipping of green chillies in 2% salt solution for 10 min followed by a water wash proved to be effective, facilitating the removal of 90.56 and 66.93% residues correspondingly at 0 and 5 d, after spraying.

Singh *et al.* (2000) conducted an experiment on chilli variety Longum at SKN, College of Agriculture, Jobner with foliar application of urea (0.5, 1 and 1.5%) and NAA (25, 50 and 75 ppm). They concluded that increasing concentrations of urea and NAA increased per cent fruit set, fruit weight and yield ha^{-1} and decreased fruit drop percentage. Whereas time taken to 50% flowering was decreased by the higher concentrations of NAA. The maximum yield (208.56 q/ha) was obtained with the treatment of 1.5% urea and 75 ppm NAA.

Medhi (2000) also recorded highest number of pods per plant, pod length, grains per pod, pod yield and chlorophyll content in french bean with foliar application of NAA. Foliar application of NAA 25 ppm (Hudge *et al*., 2001) and 50, 75 and 100 ppm (Singh *et al*., 1999) encouraged green fruit pickings, seed weight and seed yield in okra.

Singh and Mukherjee (2000) conducted a field trial (Rajasthan, India during the *kharif* season of 1997-98) which indicated that yield and yield attributes of chilli *(Capsicum annuum* var. longum) *cv.* RCH-1 were greatly influenced by the foliar sprays of urea (0.5, 1 and 1.5%) and naphthalene acetic acid [NAA] (25, 50 and 75 ppm). Increasing concentrations of urea and naphthalene acetic acid increased percent fruit set, fruit weight, percent dry yield and yield ha^{-1} and decreased fruit drop percentage, whereas time taken to 50% flowering was decreased by the higher concentrations of naphthalene acetic acid. The maximum yield was obtained with the treatment of 1.5% urea (193.06 q/ha) and 75 ppm.

In chilli, significantly higher yield (477.38 g/m^2) was obtained when 20 ppm NAA was sprayed compared to control (370.25 g/m^2) (Ramarao *et al.*, 1990). Similarly, application of NAA 40 ppm plus urea (1%) solution was found to increase the yield of green chillies significantly (286.25 q/ha) as compared to control (84.3 q/ha) (Katwale and Saraf, 1990).

Nimje *et al.,* (1990) sprayed growth regulators such as NAA, IAA and GA_3 (50 ppm) at 25 and 50 days after planting of bell pepper under green house conditions and found that NAA treatments produced higher yield of 419.3 q/ha, over control (341 q/ha). However, under open conditions, GA_3 proved to be the best (197.8 q/ha) than control (115.5 q/ha).

Revanappa (1993) reported that highest number of fruits per plant (139.29), average fruit weight (2.60 g), yield per plant (395.07 g), yield per hectare (95.9 q/ha) and number of seeds per fruit (95.49) were obtained when 20 ppm NAA was sprayed at 40 and 60 days after transplanting compared to control (118.40, 2.20 g, 322.84 g, 76.4 q/ha and 79.30, respectively) in chilli.

Singh and Singh (1996) sprayed 5 ppm 2,4-D at 20,30 and 40 DAT and recorded lower seed yield (287 kg/ha) than water spray (396 kg/ha) in tomato. They further concluded that higher doses of 2,4-D had adverse effect on seed yield due to poor pollen grain germination and parathenocarpic fruit set. In another study, Arun *et al.,* (1997) reported that spraying of GA3 (200 ppm) at per-bloom stage of brinjal increased fruit length (31.8 cm), fruit weight (49.3 g) and fruit yield (308.8 g/ha) compared to control.

Biradar (1999) reported that in chilli the highest number of fruits per plant (131. 74), fruit yield per plant (109.54 g), number of seeds per fruit (72.95), seed yield per plant (53.39 g) and seed yield per hectare (622 kg) were noticed with 20 ppm NAA was sprayed twice at flower initiation and 50 per cent flowering compared to control (92.54, 76.85 g, 62.29, 36.12 g and 434 kg, respectively).

Gollagi (1999) reported significant increase in number of fruits per plant (81.3) and fruit yield (11.75 q/ha) with application of 100 ppm NAA at 45 and 65 DAT compared to control (68.0 and 9.33 q/ha, respectively) in chilli.

Among the growth regulators, NAA at 50 ppm was found most effective for higher seed yield per vine (78.31 g) and seed yield per hectare (715.08 kg) in bitter gourd (Shantappa *et al.,* 2005a).

Markose *et al.,* (2006) recorded that tomato plants treated with 2,4-D at lower concentration (2 and 4 ppm) showed an increase in both fruit number and fruit yield per plant than control.

2.2 Effect of Ca

2.2.1 Effect of Ca on growth and yield

Pinero et al. (2018) conducted a study on sweet pepper fruit quality disorders as affected by foliar Ca applications to mitigate the supply of saline water under a climate change scenario. High CO_2 favoured generative growth instead of vegetative growth. Foliar Ca supply did not affect the marketable yield, but reduced the total yield when combined with salinity and 400 μmol mol^{-1} CO_2. Salinity affected negatively the total yield but this was overcome when CO_2 was applied. The B and K concentrations were reduced by foliar Ca application, while Ca and Mn were increased at 400 μmol mol^{-1} CO_2. The effect of Ca application differed according to the other treatments applied. This procedure should be optimized to overcome future climate impacts on fruit quality.

Halina *et al*. (2016) conducted an experiment to evaluate the effects of foliar Ca feeding on the yield of sweet pepper 'Caryca F_1' and on selected elements of its fruit quality in field ground cultivation. Ca was applied in the form of the following preparations: $Ca(NO_3)_2$, Insol Ca, or Librel Ca. Calcium preparations were applied on 3 or 5 dates in 1% concentration of the solution to the full wetting of the plants. A positive influence of Ca feeding on the marketable yield of the fruit was observed: 4.26–4.63 kg m^{-2} as compared with the controls at 3.80 kg m^{-2}. Calcium foliar feeding caused a limited number of fruits with BER symptoms at 4.3%–5.2% of the total number of fruits, as compared with 14.4% of those of the control fruits. The use of $Ca(NO_3)_2$ had a positive effect on the accumulation of vitamin C and carotenoids as compared with other fertilizers. Reduced Ca spraying proved to be beneficial in terms of fruit yield and concentrations of carotenoids.

Rubio *et al*. (2010) investigated a study on the influence of Ca^{2+} and K^+ levels on fruit yield and quality of sweet pepper (*Capsicum annuum* L. cv. Orlando) plants under hydroponic culture. The treatments consisted of three concentrations of Ca^{2+} (1.5, 4 and 8 mmol L^{-1}) and K^+ (2.5, 7 and 12 mmol L^{-1}) that were imposed separately. Fruit yield parameters and different fruit quality parameters, as well as dry matter production and mineral composition in individual parts of the plant, were determined. The increase of Ca^{2+} in the root medium increased the marketable yield from 1.67 to 2.38 kg $plant^{-1}$, mainly due to an increase in the number of fruits per plant, while higher K^+ levels decreased marketable yield from 2.2 to 1.66 kg $plant^{-1}$, due to decreases in the number of fruits per plant and the mean fruit weight. With respect to fruit quality, fruit shape index and, therefore, pepper fruit appearance improved with Ca^{2+} addition to the root medium. Fertilization with K^+ increased fruit acidity and decreased maturity index, which could improve fruit storability. Low Ca^{2+} or high K^+ levels reduced both root and shoot dry matter. Therefore, an adequate management of fertilization with Ca^{2+} and K^+ could improve the yield and fruit quality of pepper grown in soilless culture.

2.2.2 Role of Ca on crop protection

Manaf *et al*. (2017) reported that the amounts of Ca in soil solution are usually high enough to provide for all plant demands. Ca-deficiency in plants is a physiological disorder, and occurs only rarely as a result of low Ca levels in the soil. Ca- deficiency symptoms in plants do not generally disappear simply by raising the Ca level of the soil. Therefore, it is important to understand the mechanisms of Ca^{2+} ion uptake, transport, and distribution in plants. Any factor inhibiting root growth, such as low temperature, inadequate aeration, poor nutrient status, or high H+ ion concentration, can thus restrict Ca uptake and hence impair Ca translocation because of the absence of young root tip cells.

Manaf *et al*. (2017) executed a greenhouse experiment to evaluate the impact with two concentrations (5 and 10 mM l^{-1}) of calcium chloride ($CaCl_2$) foliar application on growth parameters, yield and some biochemical constituents and blossom-end rot (BER) incidence of sweet pepper *(Capsicum annuum* L.) under drought stress. The obtained results indicated that $CaCl_2$ foliar application $CaCl_2$ with under both irrigation regimes achieved an increment in most of growth parameters, yield and some biochemical constituents. On the contrary, the same applications led to decrease BER incidence in the plants under normal irrigation or water deficiency. However, no-significant effect of $CaCl_2$ was observed on chlorophyll a/b ratio, carotenoids and carotenoids/chlorophyll a+b.

Kerton *et al.* (2009) reported that Ca is not recycled when deposited in leaf tissue. Ca flows through the plant in the xylem (White and Broadley, 2003), mostly passively, with the water flow caused by transpiration (Kerton *et al.*, 2009).

Fedrizzi *et al*. (2008) found that a Ca signal is involved in the regulation of cell division and Ca can be found in the mitotic spindle. Ca is also critical in signal transduction path ways by binding with calmodulin, a cytosolic plant protein.

Lecourieux *et al.* (2006) described Ca ions as a second messenger in numerous plant signalling pathways, conveying a wide range of environmental and developmental stimuli to elicit the appropriate physiological responses.

Lecourieux *et al.* (2006) found that calmodulin is a highly conserved and broadly distributed Ca-binding protein which acts as a multifunctional intermediary by connecting Ca signals to the activation of other cellular components.

Ho and White (2005) showed that Ca controls cell expansion by influencing the incorporation into the plasma membrane of vesicles containing the materials and enzymes required for cell membrane and cell wall construction.

White and Broadley (2003) experimented that Ca is required for various structural roles in the cell wall and in membranes. Ca is essential for the synthesis of cell walls. Ca is bound as Ca-pectate in the middle lamella and it is essential for strengthening cell walls and plant tissues (Burns and Pressey, 1987).

Marschner (1995) reported that Ca is an essential plant mineral which plays many roles in normal plant functions. It readily enters the apoplasm and is bound, in an exchangeable form, to cell walls and to the exterior surface of the plasma membrane. Marschner (1995) also reported that a high proportion of cellular Ca can be found in the vacuoles, whereas its concentration in the cytosol is extremely low. Most of its activity is related to its capacity for co-ordination, by which it provides stable, but reversible, intermolecular linkages, predominantly in the cell walls and in the plasma membrane.

Bush *et al.* (1993) reported that Ca also plays a significant role in the processes of seed germination with gibberellic acid (GA) and abscisic acid (ABA) which regulate a-amylase production in aleurone tissues during germination of the barley grain. They found that GA increased and ABA decreased both the Ca ion flux into the endoplasmatic reticulum and the amount of Ca that accumulated in the endoplasmic reticulum of barley aleurone cells *in vivo*.

Bush *et al.* (1986) concluded that Ca directly affects the processes of enzyme synthesis and transport. Ca is required by many enzymes as a cofactor, although, at high concentrations, it may inhibit enzyme activity.

Poovaiah (1985) reported that Ca and calmodulin, together, are involved in regulating many metabolic processes including plant responses to the environment, and metabolic responses to plant growth-regulators.

Konno *et al*. (1984) postulated that polygalacturonase activity is increased in Ca-deficient cells and tissues. The degradation of pectates is mediated by polygalacturonase, which is inhibited by high Ca concentrations. Typical symptoms of Ca-deficiency are the disintegration of cell walls and the collapse of affected tissues such as petioles and the upper parts of the stem.

Collier and Tibbits (1984) found that diurnal fluctuations in the water potential of lettuce increased the Ca^{2+} ion concentration in inner leaves and delayed the incidence of tipburn.

Egmond (1979) found that Ca and other cations precipitate as oxalate crystals in shoot cells. Oxalate results from a carboxylation reaction in which the excess OH^- ions generated in shoot cells by nitrate assimilation are neutralised. Any Ca in these cells will be precipitated as oxalate crystals, and thus cause Ca-deficiency in the plant.

Kirkby (1979) reported that Ca is absorbed only by young root tips in which the cell walls of the epidermis are not yet suberised. Once a suberin layer develops in these cells, water and Ca can no longer be absorbed. Suberin is a waxy substance through which water and nutrients cannot move. Ca is absorbed as divalent Ca^{2+} ions. Ca uptake by roots is associated with water uptake. The uptake of Ca is stimulated by high levels of NO_3^- ions and depressed by high levels of NH_4+, K+, Mg^{2+}, or Al^{3+} ions.

Palzkill and Tibbits (1977) found that a root pressure flow is required to move adequate amounts of Ca to prevent tipburn in cabbage plants that are not undergoing transpirational water loss (e.g., the innermost leaves of the head). Ca movement in plants is influenced by transpiration and by fluctuations in transpiration.

Ragnekar (1975) reported that Ca is important for photosynthesis. In Ca-deprived leaf tissues, the early products of photosynthesis were less available for those respiratory activities which occur outside the chloroplasts.

Manaf *et al*. (2017) reported that Ca sprays help to prevent Ca-deficiency disorders in plants. Ca-deficiency-related disorders are usually linked to the inability of a plant to translocate adequate Ca to the affected part rather than insufficient levels of soil Ca. Ca is a relatively immobile element in plants. Foliar sprays can be used to correct these deficiencies. It is important to cover any young terminal growth with Ca, as application on the older leaves will not benefit the plant.

Kleemann (2000) demonstrated that spraying with Ca reduced the incidence of Ca-deficiency injury in plants.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2017 to February 2018 to study the effect of Ca and NAA on the growth, yield and quality of hot pepper - BARI morich-3. The details of the materials and methods have been presented below:

3.1 Experimental location

The present piece of research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is90°33´ E longitude and 23°77´ N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

3.2 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and was dark grey terrace soil. The selected plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka. The details of morphological and chemical properties of initial soil of the experiment plot were presented in Appendix II.

3.3 Climate

The climate of experimental site was subtropical, characterized by three distinct seasons, the winter from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al*., 1979). Details on the meteorological data of airtemperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix III.

3.4Plant materials

The crop; chilli was considered for the present study. Seed of chilli variety BARI morich-3 was used.

3.5 Experimental details

3.5.1 Treatments

The experiment comprised of two factors.

Factor A: Growth regulator – NAA

1. N_0 = 0 ppm (Control)
2. N_1 = 25 ppm
3. N_2 = 50 ppm

Factor B: Ca application

1. Ca_0 = 0 ppm (Control)
2. Ca_1 = 50 ppm
3. Ca_2 = 100 ppm

Treatment combinations - nine treatment combinations

N_0Ca_0, N_0Ca_1, N_0Ca_2, N_1Ca_0, N_1Ca_1, N_1Ca_2, N_2Ca_0, N_2Ca_1, N_2Ca_2.

3.5.2 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the combination of Naphthalene acetic acid (NAA)and different calcium (Ca)levels. The 9 treatment combinations of the experiment were assigned at random into 27 plots. The size of each unit plot 1.5 m × 1 m. The distance between blocks and plots were 0.5 m and 0.25 m respectively.The layout of the experiment field is presented in Appendix IV.

3.6Seed collection

The chilli variety; BARI morich-3 was used for the present study. Seeds were collected from Bangladesh Agricultural Research Institute (BARI), Joyddebpur, Gazipur, Bangladesh.

3.6.1 Raising of seedlings

The land selected for nursery bed was well drained and were sandy loam type soil. The area was well prepared and converted into loose friable and dried mass to obtain fine tilth. All weeds and dead roots were removed and the soil was mixed with well rotten cowdung at the rate of 5 kg/bed. Seed bed size was 3m × 1m raised above the ground level. One bed was prepared for raising the seedlings. Five (5) grams of seeds were sown in the seed bed on 5 November, 2017. After sowing, the seeds were covered with light soil. Complete germination of the seeds took place with 5 days after seed sowing. Necessary shading was made by bamboo mat (chatai) from scorching sunshine or rain. No chemical fertilizer was used in the seed bed.

3.7 Preparation of the main field

The plot selected for the experiment was opened in the first week of December, 2017 with a power tiller, and was exposed to the sun for a few days, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for transplanting. The land operation was completed on 6December 2017. The individual plots were made by making ridges (20 cm high) around each plot to restrict lateral runoff of irrigation water.

3.8 Fertilizers and manure application

The N, P, S and B fertilizer were applied according to Krishi Projukti Hat Boi (BARI, 2015) through urea, Triple super phosphate (TSP), MoP and Borax, respectively. Cowdung also used as organic manure. Calcium (Ca) was applied through $CaCl_2$ as per treatment by foliar spray. Nutrient doses used through fertilizers under the present study are presented as follows:

Nutrients	Manures/fertilizers	Doses ha^{-1}
-	Cowdung	10 ton
N	Urea	210 kg
P	TSP	330 kg
K	MoP	200 kg
B	Borax	5 kg
Ca	$CaCl_2$	As per treatment

(Source: BARI, 2015)

One third (1/3) of whole amount of Urea and full amount of TSP, MoP, Gypsum and Borax were applied at the time of final land preparation. The remaining Urea was top dressed in two equal installments- at 25 days after transplanting (DAT) and 50 DAT respectively.

3.9 Transplanting of seedlings

Healthy and uniform sized 25 days old seedlings were taken separately from the seed bed and were transplanted in the experimental field on 6 December, 2017.Three plant spacing was maintained according to the treatments. The seed bed was watered before uprooting the seedlings so as to minimize the damage of the roots. This operation was carried out during late hours in the evening. The seedlings were watered after transplanting. Shading was provided by piece of banana leaf sheath for three days to protect the seedlings from the direct sun. A strip of the same crop was established around the experimental field as border crop to do gap filling and to check the border effect.

3.10 Intercultural Operation

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the chilli.

3.10.1 Gap filling and weeding

When the seedlings were established, the soil around the base of each seedling was pulverized. A few gaps filling were done by healthy plants from the border whenever it was required. Weeds of different types were controlled manually as and when necessary.

3.10.2 Irrigation

Irrigation was done at three times. The first irrigation was given in the field at 25 days after transplanting (DAT) through irrigation channel. The second irrigation was given at the stage of maximum vegetative growth stage (35 DAT). The final irrigation was given at the stage of fruit formation (50 DAT).

3.10.3 Plant protection

The crop was infested with cutworm, leaf hopper and others. The insects were controlled successfully by spraying Malathion 57 EC @ 2ml /L water. The insecticide was sprayed fortnightly from a week after transplanting to a week before first harvesting. During foggy weather precautionary measures against fungal diseases of chilli was taken by spraying Dithane M-45 @ 2 g/L.

3.11 Harvesting and cleaning

Fruits were harvested at 3 days intervals during maturity to ripening stage. Harvesting was started from 10 March, 2018 and completed by 4April, 2018.

3.12 Data collection

Ten plants were selected randomly from each unit plot for recording data on crop parameters and the yield of grain and straw were taken plot wise. The following parameters were recorded during the study:

3.12.1 Growth parameters

1. Plant height (cm)

2. Number of leaves plant^{-1}
3. Number of branches plant^{-1}

3.12.2 Yield contributing parameters

1. Days to 1st flowering
2. Fruit length (cm)
3. Fruit diameter (cm)

3.12.3 Yield parameters

1. Number of fruits plant^{-1}
2. Fruit weight plant^{-1}(g)
3. Single fruit weight (g)
4. Fruit yield (t ha^{-1})

3.12.4 Economic analysis

1. Total cost of production
2. Gross return (Tk. ha^{-1})
3. Net return (Tk. ha^{-1})
4. Benefit Cost Ratio (BCR)

3.12.5 Quality parameters

1. Vitamin C content (mg/100 gram of fruit)

3.13Procedure of recording data

3.13.1 Growth parameters

3.13.1.1Plant height (cm)

The height of plant was recorded in centimeter (cm) at different days after transplanting of crop duration. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the leaves. Data was taken at 40, 60 and 80 days after transplanting (DAT).

3.13.1.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} was counted at different days after sowing of crop duration. Leaves number plant^{-1}was recorded from pre selected 5 plantsby counting all leaves from each plot and mean was calculated. Data was taken at 40, 60 and 80 days after transplanting (DAT).

3.13.1.3Number of branches per plant

At different days after transplanting (DAT) i.e. at 40, 60 and 80 DAT, all the primary branches were counted from 5 plants of each plot and their average value was taken as number of branches per plant.

3.13.2 Yield contributing parameters

3.13.2.1 Days to 1st flowering

Days to first (1st) flowering was recorded from the date of transplanting to when 1st flower is appeared in the plant.

3.13.2.2 Fruit length (cm)

The length of the fruit was measured with a digital slide calipers in centimeter from the neck of the fruit to the bottom of the fruit. It was measured from each plot and their average was calculated in centimeter.

3.13.2.3 Fruit diameter (cm)

Breadth of the fruits were measured at the middle portion of 20 randomly selected marketable fruits from each plot with the digital slide calipers in centimeter and their average was taken as the breadth of the fruits.

3.13.3 Yield parameters

3.13.3.1 Number of fruits plant^{-1}

Total fruit number was counted from 5 selected plants from 1st to last harvest and average number was calculated as number of fruits per plant.

3.13.3.2 Fruit weight plant^{-1} (g)

Total fruit weight was counted from 5 selected plants from 1st to last harvest and average weight was calculated as fruit weight per plant and was expressed in gram.

3.13.3.34 Single fruit weight (g)

From first harvest to last harvest total fruit number and weight was counted from 5 plants to determine single fruit weight. By using the following formula, single fruit weight was calculated and expressed in gram.

$$\text{Weight of individual fruit (g)} = \frac{\text{Total weight of fruits from 5 selected plants (g)}}{\text{Total number of fruits from 5 selected plants}}$$

3.13.3.4Fruit weight ha^{-1} (t)

To calculate fruit yield per ha; at first a pan scale balance was used to take the weight or fruits per plot. It was measured by totaling of fruit yield from 5 selected plants from each unit plot during the period from first to final harvest and then it converted to per plot yield and was expressed in kilogram. After collection of per plot yield, it was converted to ton per hectare by the following formula:

$$\text{Fruit yield per hectare (ton)} = \frac{\text{Fruit yield per plot (kg)} \times 10000 \text{ m}^2}{\text{Plot size (m}^2) \times 1\,000 \text{ kg}}$$

3.14 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

3.15 Economic analysis

Economic analysis was done to find out the cost effectiveness of different treatments like different levels of spacing and potassium in cost and return were done in details according to the procedure of Alam *et al*. (1989).

3.15.1 Analysis of total cost of production

All the material and non-material input cost, interest on fixed capital of land and miscellaneous cost were considered for calculating the total cost of production. Total cost of production (input cost, overhead cost), gross return, net return and BCR are presented in Appendix VIII.

3.15.2 Gross income

Gross income was calculated on the basis of mature fruit sale. The price of chilli was assumed to be Tk. 25/kg basis of current market value of Kawran Bazar, Dhaka at the time of harvesting.

3.15.3 Net return

Net return was calculated by deducting the total production cost from gross income for each treatment combination.

3.15.4 Benefit cost ratio (BCR)

The economic indicator BCR was calculated by the following formula for each treatment combination.

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross income per hectare}}{\text{Total cost of production per hectare}}$$

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was carried out to find out the application of Ca in combination with NAA on the growth and yield and quality of hot pepper - BARI morich-3. Data on different growth parameters and yield of hot pepper plant was recorded and analyzed with MSTAT program. The results have been presented and discussed, and possible interpretations are given under the following headings:

4.1 Growth parameters

4.1.1 Plant height (cm)

Effect of NAA

Significant variation on plant height at different growth stages was observed influenced by different levels of NAA (Fig. 1 and Appendix V). Results revealed that the highest plant height (34.19, 46.01 and 65.07 cm at 40, 60 and 80 DAT, respectively) was recorded from the treatment N_2 (50 ppm NAA) which was statistically identical with N_1 (25 ppm NAA) at 40 DAT. The lowest plant height (28.46, 38.08 and 54.28 cm at 40, 60 and 80 DAT, respectively) was recorded from the control treatment N_0 (0 ppm NAA). Similar result was also observed by Tapdiya *et al*., (2018) and Suresh *et al*. (2018) which was supported the present study.

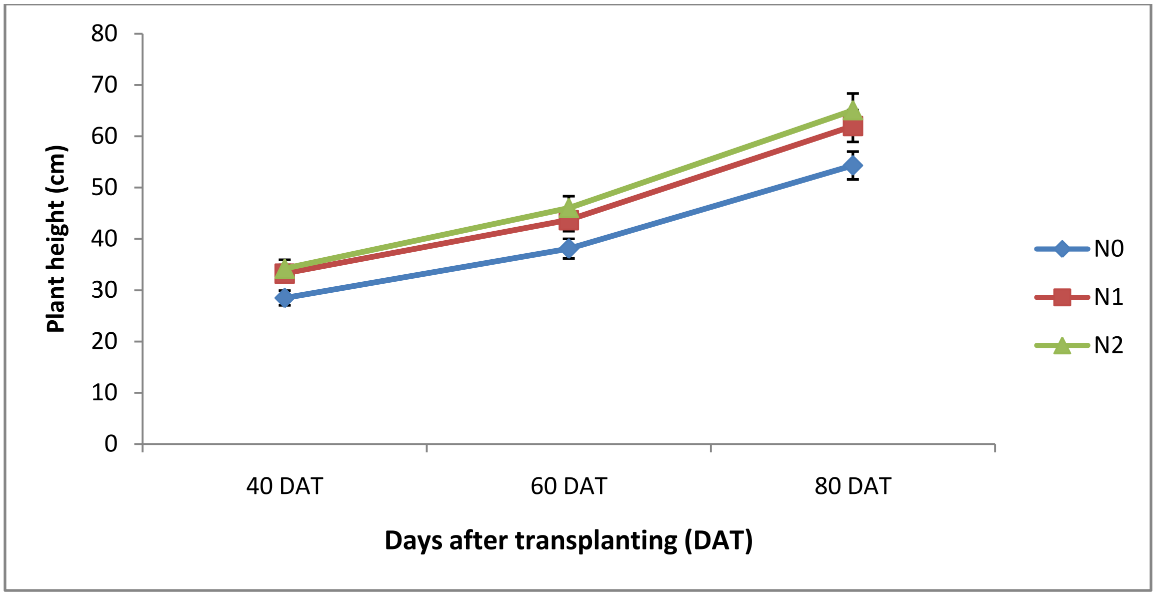


Fig. 1. Effect of NAA on plant height of hot pepper (vertical bars indicate LSD value)

N_0 = 0 ppm (Control), N_1 = 25 ppm, N_2 = 50 ppm

Effect of Calcium (Ca)

Significant variation was observed on plant height at different growth stages influenced by different levels of Ca application (Fig. 2 and Appendix V). Results showed that the highest plant height (34.56, 46.17 and 64.85 cm at 40, 60 and 80 DAT, respectively) was observed from the treatment Ca_2 (100 ppm Ca) which was significantly different from all other treatments at all growth stages where the lowest plant height (29.45, 39.13 and 55.84 cm at 40, 60 and 80 DAT, respectively) was observed from the control treatment Ca_0 (0 ppm Ca).

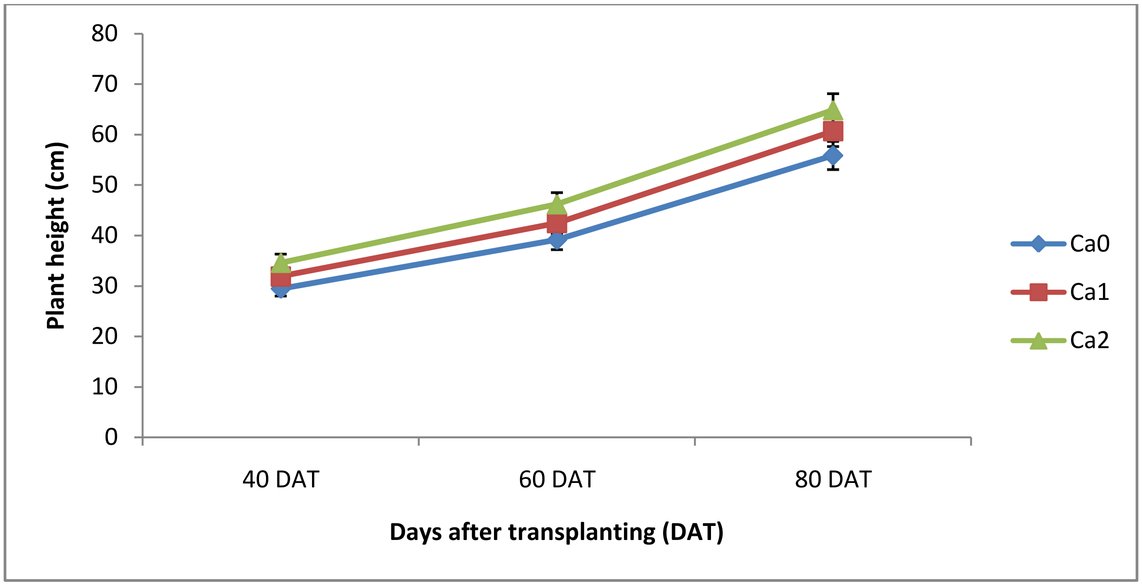


Fig. 2. Effect of Ca on plant height of hot pepper (vertical bars indicate LSD value)

Ca_0 = 0 ppm (Control), Ca_1 = 50 ppm, Ca_2 = 100 ppm

Combined effect of NAA and Ca

Plant heightwas significantly varied due to combined effect of NAA and Ca at different growth stages (Table 1 and Appendix V). Results indicated that the highest plant height (36.23, 50.44 and 71.28 cm at 40, 60 and 80 DAT, respectively) was observed from the treatment combination of N_2Ca_2 which was statistically identical with N_1Ca_2 at 40 and 60 DAT but significantly different from all other treatment combinations at 80 DAT.The lowest plant height (25.42, 36.40 and 51.62 cm at 40, 60 and 80 DAT, respectively t ha^{-1}) was observed from the treatment combination of N_0Ca_0which was significantly different from all other treatment combinations at 80 DAT followed by N_0Ca_1,N_0Ca_2 and N_1Ca_0

Table 1. Effect of Ca in combination with NAA on plant height of hot pepper

Treatments	Plant height (cm)		
	40 DAT	60 DAT	80 DAT
N_0Ca_0	25.42 f	36.40 e	51.62 f
N_0Ca_1	28.33 e	38.30 de	54.71 e
N_0Ca_2	31.64 cd	39.54 d	56.52 e
N_1Ca_0	30.44 d	39.21 d	56.74 e
N_1Ca_1	33.46 b	43.26 c	62.48 c
N_1Ca_2	35.81 a	48.53 a	66.74 b
N_2Ca_0	32.50 bc	41.78 c	59.17 d
N_2Ca_1	33.84 b	45.80 b	64.77 bc
N_2Ca_2	36.23 a	50.44 a	71.28 a
$LSD_{0.05}$	1.675	2.149	2.349
CV(%)	7.037	9.416	12.374

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

N_0 = 0 ppm (Control), N_1 = 25 ppm, N_2 = 50 ppm

Ca_0 = 0 ppm (Control), Ca_1 = 50 ppm, Ca_2 = 100 ppm

4.1.2 Number of leaves plant^{-1}

Effect of NAA

Remarkable variation was observed on number of leaves plant^{-1} at different growth stages influenced by different levels of NAA (Fig. 3 and Appendix VI). It was found that the highest number of leaves plant^{-1} (44.27, 85.51 and 96.34 at 40, 60 and 80 DAT, respectively) was recorded from the treatment N_2 (50 ppm NAA) which was significantly different from all other treatments at all growth stages followed byN_1 (25 ppm NAA). The lowest number of leaves plant^{-1} (35.26, 68.95 and 74.16 at 40, 60 and 80 DAT, respectively) was recorded from the control treatment N_0 (0 ppm NAA).

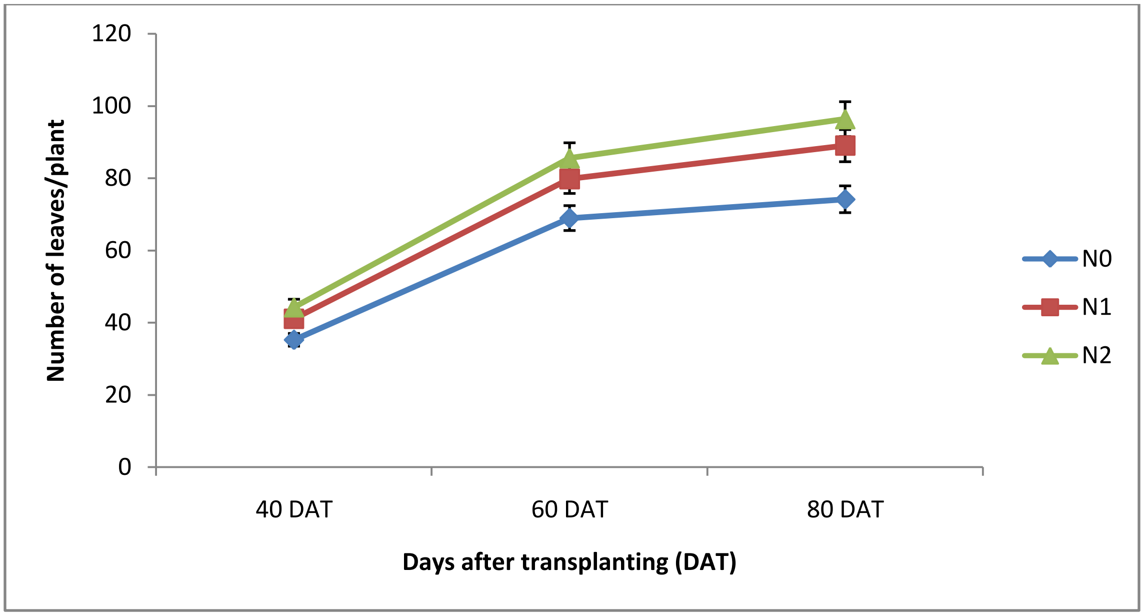


Fig. 3. Effect of NAA on number of leaves plant^{-1}of hot pepper (vertical bars indicate LSD value)

N_0 = 0 ppm (Control), N_1 = 25 ppm, N_2 = 50 ppm

Effect of Calcium (Ca)

Number of leaves plant^{-1}was significantly varied due to different levels of Ca application at different growth stages (Fig. 4 and Appendix VI). The highest number of leaves plant^{-1}(43.24, 82.89 and 92.72 at 40, 60 and 80 DAT, respectively) was observed from the treatment Ca_2 (100 ppm Ca). At all growth stages it was significantly different from all other treatments followed by Ca_1 (50 ppm Ca). The lowest number of leaves plant^{-1}(36.18, 72.36 and 78.54 at 40, 60 and 80 DAT, respectively) was observed from the control treatment Ca_0 (0 ppm Ca).

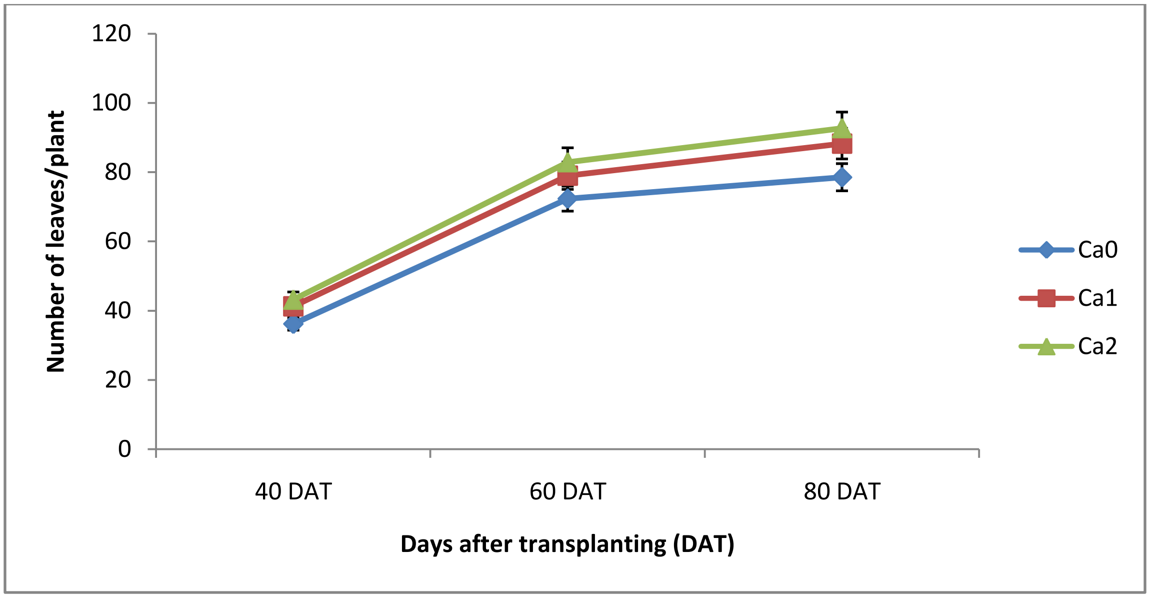


Fig. 4. Effect of Ca on number of leaves plant^{-1}of hot pepper (vertical bars indicate LSD value)

Ca_0 = 0 ppm (Control), Ca_1 = 50 ppm, Ca_2 = 100 ppm

Combined effect of NAA and Ca

Significant variation was observed on number of leaves plant^{-1} at different growth stages influenced by combined effect of NAA and Ca (Table 2 and Appendix VI). The highest number of leaves plant^{-1} (47.33, 92.36 and 101.5 at 40, 60 and 80 DAT, respectively) was observed from the treatment combination of N_2Ca_2. At 40 and 80 DAT, it was statistically similar with the treatment combination of N_2Ca_1.

The lowest number of leaves plant^{-1} (32.16, 64.34 and 68.42 at 40, 60 and 80 DAT, respectively) was observed from the treatment combination of N_0Ca_0 which was statistically identical with the treatment combination of N_0Ca_1 at 80 DAT.

Table 2. Effect of Ca in combination with NAA on number of leaves plant^{-1}of hot pepper

Treatments	Number of leaves plant^{-1}		
	40 DAT	60 DAT	80 DAT
N_0Ca_0	32.16 g	64.36 f	68.42 f
N_0Ca_1	35.36 f	70.12 e	72.27 f
N_0Ca_2	38.27 de	72.38 de	81.78 e
N_1Ca_0	36.74 ef	75.00 d	78.46 e
N_1Ca_1	42.48 c	80.37 c	93.67 c
N_1Ca_2	44.12 bc	83.92 b	94.87 bc
N_2Ca_0	39.63 d	77.72 c	88.75 d
N_2Ca_1	45.84 ab	86.45 b	98.76 ab
N_2Ca_2	47.33 a	92.36 a	101.5 a
$LSD_{0.05}$	1.938	2.705	4.251
CV(%)	7.866	10.539	10.208

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

N_0 = 0 ppm (Control), N_1 = 25 ppm, N_2 = 50 ppm

Ca_0 = 0 ppm (Control), Ca_1 = 50 ppm, Ca_2 = 100 ppm

4.1.3 Number of branches plant^{-1}

Effect of NAA

Number of branches plant^{-1} was significantly influenced by different levels of NAA at different growth stages (Fig. 5 and Appendix VII).The highest number of branches plant^{-1} (7.52, 14.42 and 15.50 at 40, 60 and 80 DAT, respectively) was recorded from the treatment N_2 (50 ppm NAA) and at all growth stages it was statistically identical with the treatment combination of N_1 (25 ppm NAA). The lowest number of branches plant^{-1} (5.91, 10.94 and 11.33 at 40, 60 and 80 DAT, respectively) was recorded from the control treatment N_0 (0 ppm NAA).

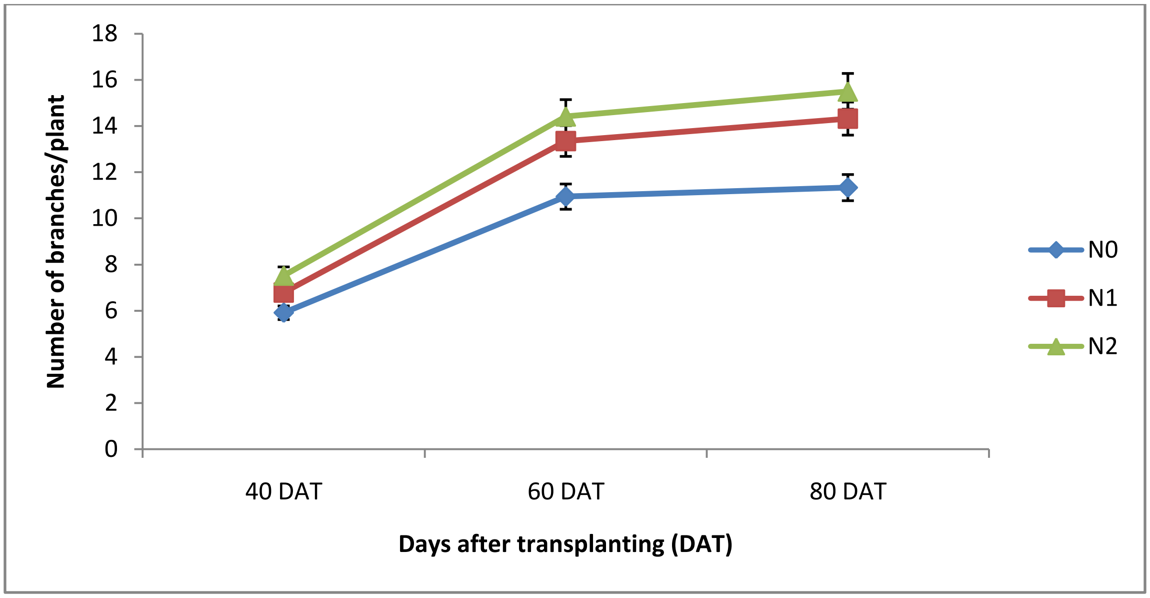


Fig. 5. Effect of NAA on number of branches plant^{-1}of hot pepper (vertical bars indicate LSD value)

N_0 = 0 ppm (Control), N_1 = 25 ppm, N_2 = 50 ppm

Effect of Calcium (Ca)

Remarkable variation was observed on number of branches plant^{-1} at different growth stages influenced by different levels of Ca application (Fig. 6 and Appendix VII). It was found that the the highest number of branches plant^{-1} (7.15, 13.71 and 14.76 at 40, 60 and 80 DAT, respectively) was observed from the treatment Ca_1 (50 ppm Ca) which was statistically identical with Ca_2 (100 ppm Ca) at all growth stages. The lowest number of branches plant^{-1} (6.06, 11.69 and12.36 at 40, 60 and 80 DAT, respectively) was observed from the control treatment Ca_0 (0 ppm Ca).

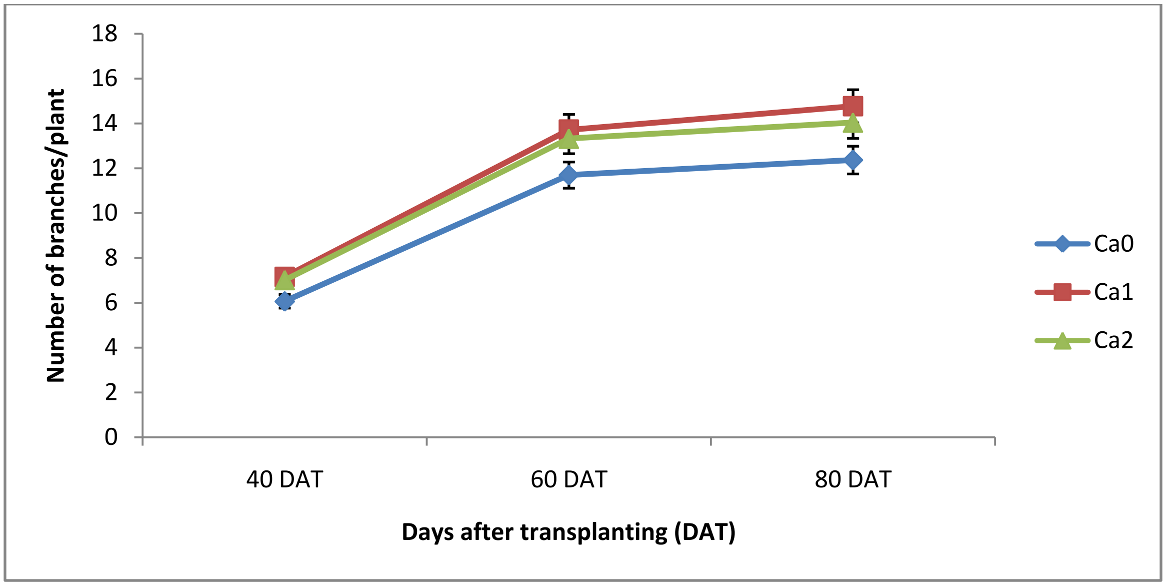


Fig. 6. Effect of Ca on number of branches plant^{-1}of hot pepper (vertical bars indicate LSD value)

Ca_0 = 0 ppm (Control), Ca_1 = 50 ppm, Ca_2 = 100 ppm

Combined effect of NAA and Ca

Significant variation was observed on number of branches plant^{-1} at different growth stages influenced by combined effect of NAA and Ca (Table 3 and Appendix VII). Results revealed that the treatment combination N_2Ca_1 gave the highest number of branches plant^{-1} (8.82, 15.52 and 16.74 at 40, 60 and 80 DAT, respectively) which was statistically similar with N_1Ca_2 at 40 and 80 DAT. The lowest number of branches plant^{-1} (5.44, 10.36 and 10.48 at 40, 60 and 80 DAT, respectively) was observed from the treatment combination of N_0Ca_0 which was statistically identical with the treatment combination of N_0Ca_1 at 40 and 80 DAT.

Table 3. Effect of Ca in combination with NAA on number of branches plant^{-1}of hot pepper

Treatments	Number of branches plant^{-1}		
	40 DAT	60 DAT	80 DAT
N_0Ca_0	5.440 f	10.36 f	10.48 f
N_0Ca_1	5.800 e	10.64 f	10.72 f
N_0Ca_2	6.480 cd	11.82 e	12.78 e
N_1Ca_0	6.180 d	11.39 e	12.42 e
N_1Ca_1	6.820 c	13.78 cd	14.63 cd
N_1Ca_2	7.380 b	14.88 ab	15.92 ab
N_2Ca_0	6.570 c	13.32 d	14.18 d
N_2Ca_1	8.820 a	15.52 a	16.74 a
N_2Ca_2	7.160 b	14.43 bc	15.57 bc
$LSD_{0.05}$	0.3284	0.6568	0.9528
CV(%)	8.521	9.314	8.117

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

N_0 = 0 ppm (Control), N_1 = 25 ppm, N_2 = 50 ppm

Ca_0 = 0 ppm (Control), Ca_1 = 50 ppm, Ca_2 = 100 ppm

4.2 Yield contributing parameters

4.2.1 Days to 1st flowering

Effect of NAA

The recorded data on days to 1st flowering was significantly influence by different levels of NAA (Table 4 and Appendix VIII) The highest days to 1st flowering (44.11) was recorded from the Control treatment N_0(0 ppm NAA). The lowest days to 1st flowering (39.60) was recorded from the control treatment N_2 (50 ppm NAA)

Effect of Calcium (Ca)

Days to 1^{st} flowering was significantly varied due to different levels of Ca application at different growth stages (Table 5 and Appendix VIII). It was found that the highest days to 1^{st} flowering (42.89) was observed from the controltreatment Ca_0 (Control; 0 ppm Ca) where the lowest days to 1^{st} flowering (40.78) was observed from the treatment Ca_2 (100 ppm Ca).

Combined effect of NAA and Ca

Days to 1^{st} flowering of hot pepperaffected by combined effect of NAA and Ca was significant (Table 6 and Appendix VIII). The highest days to 1^{st} flowering (44.67) was observed from the treatment combination of N_0Ca_0which was significantly different from all other treatments whereas the lowest days to 1^{st} flowering (39.33) was observed from the treatment combination of N_2Ca_2.

4.2.2 Fruit length (cm)

Effect of NAA

Fruit length was significantly varied due to at different different levels of NAA (Table 4 and Appendix VIII).The highest fruit length (6.86 cm) was recorded from the treatment N_2 (50 ppm NAA) which was statistically identical with N_1 (25 ppm NAA) which was statistically identical with N_2 (50 ppm NAA). The lowest fruit length (6.05 cm) was recorded from the control treatment N_0 (0 ppm NAA)

Effect of Calcium (Ca)

The recorded data on fruit length was significantly influence by different levels of Ca application (Table 5 and Appendix VIII). The highest fruit length (6.76 cm)was observed from the treatment Ca_1 (50 ppm Ca) which was statistically identical with Ca_2 (100 ppm Ca) where the lowest fruit length (6.15 cm) was observed from the control treatment Ca_0 (0 ppm Ca).

Combined effect of NAA and Ca

The recorded data on fruit length was significantly influence by combined effect of NAA and Ca (Table 6 and Appendix VIII). Results revealed that the highest fruit length (7.18 cm) was observed from the treatment combination of N_2Ca_1 which was statistically identical with N_2Ca_2 and N_1Ca_1. The lowest fruit length (5.88 cm) was observed from the treatment combination of N_0Ca_0which was statistically similar with N_0Ca_1.

4.2.3 Fruit diameter (cm)

Effect of NAA

Fruit diameter was significantly varied due to different levels of NAA application (Table 4 and Appendix VIII). The highest fruit diameter (0.56 cm) was recorded from the treatment N_2 (50 ppm NAA) which was statistically identical with which was statistically identical with N_1 (25 ppm NAA) whereas the lowest fruit diameter (0.42 cm) was recorded from the control treatment N_0 (0 ppm NAA)

Effect of Calcium (Ca)

Significant influence was noted on fruit diameter affected by different levels of Ca application (Table 5 and Appendix VIII). The highest fruit diameter (0.55 cm) was observed from the treatment Ca_1 (50 ppm Ca) which was statistically identical with Ca_2 (100 ppm Ca). The lowest fruit diameter (0.44 cm) was observed from the control treatment Ca_0 (0 ppm Ca)

Combined effect of NAA and Ca

Considerable influence was observed on fruit diameter persuaded by combined effect of NAA and Ca (Table 6 and Appendix VIII). The highest fruit diameter (0.63 cm) was observed from the treatment combination of N_2Ca_1 which was statistically similar with N_1Ca_1 whereas the lowest fruit diameter (0.37 cm) was observed from the treatment combination of N_0Ca_0 which was statistically similar with the treatment combination of N_0Ca_1.

Table 4. Effect of NAA on yield contributing parameters of hot pepper

Treatments	Yield contributing parameters		
	Days to 1st flowering	Fruit length (cm)	Fruit diameter (cm)
Effect of NAA			
N_0	44.11 a	6.05 b	0.42 b
N_1	41.67 b	6.60 a	0.53 a
N_2	39.66 c	6.86 a	0.56 a
$LSD_{0.05}$	0.817	0.314	0.102
CV(%)	5.869	5.263	3.752

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

N_0 = 0 ppm (Control), N_1 = 25 ppm, N_2 = 50 ppm

Table 5. Effect of Ca on yield contributing parameters of hot pepper

Treatments	Yield contributing parameters		
	Days to 1st flowering	Fruit length (cm)	Fruit diameter (cm)
Ca_0	42.89 a	6.15 b	0.44 b
Ca_1	41.78 b	6.76 a	0.55 a
Ca_2	40.78 c	6.60 a	0.52 a
$LSD_{0.05}$	0.414	0.226	0.061
CV(%)	7.217	6.414	5.247

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

Ca_0 = 0 ppm (Control), Ca_1 = 50 ppm, Ca_2 = 100 ppm

Table 6. Effect of Ca in combination with NAA on yield contributing parameters of hot pepper

Treatments	Yield contributing parameters		
	Days to 1st flowering	Fruit length (cm)	Fruit diameter (cm)
N_0Ca_0	44.67 a	5.88 e	0.37 g
N_0Ca_1	44.33 a	6.02 de	0.41 fg
N_0Ca_2	43.33 b	6.25 cd	0.47 de
N_1Ca_0	42.67 c	6.10 de	0.44 ef
N_1Ca_1	41.67 d	7.08 a	0.60 ab
N_1Ca_2	40.67 e	6.63 b	0.54 c
N_2Ca_0	41.33 d	6.48 bc	0.51 cd
N_2Ca_1	39.33 f	7.18 a	0.63 a
N_2Ca_2	38.33 g	6.92 a	0.55 bc
$LSD_{0.05}$	0.6289	0.2508	0.05193
CV(%)	7.217	6.414	5.247

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

N_0 = 0 ppm (Control), N_1 = 25 ppm, N_2 = 50 ppm
Ca_0 = 0 ppm (Control), Ca_1 = 50 ppm, Ca_2 = 100 ppm

4.3 Yield parameters

4.3.1 Number of fruits plant^{-1}

Effect of NAA

Number of fruits plant^{-1} was significantly varied due to different levels of NAA (Table 7 and Appendix IX). The highest number of fruits plant^{-1} (415.83) was recorded from the treatment N_2 (50 ppm NAA) which was significantly different from all other treatments where the lowest number of fruits plant^{-1} (299.83) was recorded from the control treatment N_0 (0 ppm NAA).

Effect of Calcium (Ca)

Number of fruits plant^{-1} was significantly varied due to different levels of Ca application at different growth stages (Table 8 and Appendix IX). The highestnumber of fruits plant^{-1} (403.50) was observed from the treatment Ca_1 (50 ppm Ca) which was significantly different from all other treatments whereas the lowest number of fruits plant^{-1} (314.13) was observed from the control treatment Ca_0 (0 ppm Ca).

Combined effect of NAA and Ca

Remarkable variation was identified on number of fruits plant^{-1} as influenced by combined effect of NAA and Ca (Table 9 and Appendix IX). Results revealed that the highest number of fruits plant^{-1} (473.80) was observed from the treatment combination of N_2Ca_1which was significantly different from all other treatment combinations followed by N_1Ca_1. The lowest number of fruits plant^{-1} (260.40) was observed from treatment combination of N_0Ca_0which was also significantly different from all other treatment combinations but nearest to the N_0Ca_1.

4.3.2 Fruit weight plant^{-1} (g)

Effect of NAA

Significant variation was remarked on fruit weight plant^{-1} as influenced by different levels of NAA (Table 7 and Appendix IX).The highest fruit weight plant^{-1} (704.24 g) was recorded from the treatment N_2 (50 ppm NAA) which was significantly different from the treatment combination of followed by N_1 (25 ppm NAA). The lowest fruit weight plant^{-1} (463.39 g) was recorded from the control treatment N_0 (0 ppm NAA).

Effect of Calcium (Ca)

The recorded data on fruit weight plant^{-1} was significantly influence by different levels of Ca application (Table 8 and Appendix IX). The highest fruit weight plant^{-1} (684.95 g) was observed from the treatment Ca_1 (50 ppm Ca) which was significantly different from all other treatments where the lowest fruit weightplant^{-1} (494.39 g) was observed from the control treatment Ca_0 (0 ppm Ca) which was also significantly different from others.

Combined effect of NAA and Ca

Fruit weight plant^{-1} of hot pepperwas significantly affected by combined effect of NAA and Ca was significant (Table 9 and Appendix IX).The highest fruit weight plant^{-1} (838.60 g) was observed from the treatment combination of N_2Ca_1followed by N_1Ca_1 where the lowest fruit weight plant^{-1} (388.00 g) was observed from the treatment combination of N_0Ca_0which was significantly different from all other treatment combinations followed by N_0Ca_1.

4.3.3 Single fruit weight (g)

Effect of NAA

Significant influence was noted on single fruit weight affected by different levels of NAA (Table 7 and Appendix IX). The highest single fruit weight (1.69 g) was recorded from the treatment N_2 (50 ppm NAA) which was statistically identical with N_1 (25 ppm NAA) where the lowest single fruit weight (1.54 g) was recorded from the control treatment N_0 (0 ppm NAA).

Effect of Calcium (Ca)

Single fruit weight was significantly varied due to different levels of Ca application at different growth stages (Table 8 and Appendix IX). The highest single fruit weight (1.68 g) was observed from the treatment Ca_1 (50 ppm Ca) which was statistically identical with Ca_2 (100 ppm Ca) where the lowest single fruit weight (1.57 g) was observed from the control treatment Ca_0 (0 ppm Ca).

Combined effect of NAA and Ca

The recorded data on single fruit weight was significantly influence by combined effect of NAA and Ca (Table 9 and Appendix IX). The highest single fruit weight(1.77 g) was observed from the treatment combination of N_2Ca_1which was statistically similar with the treatment combination of N_1Ca_1. The lowest single fruit weight (1.49 g) was observed from the treatment combination of N_0Ca_0which was statistically similar with the treatment combination of N_0Ca_1.

4.3.4 Fruit yield (t ha^{-1})

Effect of NAA

Significant variation was remarked on fruit yield ha^{-1} as influenced by different levels of NAA (Fig. 7 and Appendix IX). The highest fruit yield (28.17 t ha^{-1}) was recorded from the treatment N_2 (50 ppm NAA). which was significantly different from all other treatments followed by N_1 (25 ppm NAA). The lowest fruit yield (18.53 t ha^{-1}) was recorded from the control treatment N_0 (0 ppm NAA). The result obtained from the present study was similar with the findings of Tapdiya *et al*., (2018), Choudhary *et al*. (2018) and Singh *et al.* (2015).

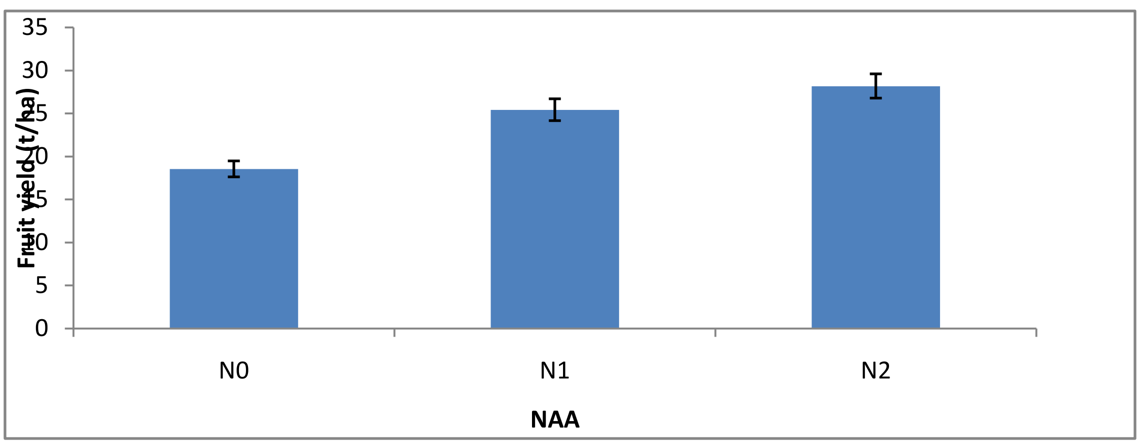


Fig. 7. Effect of NAA on fruit yield of hot pepper (bar graph indicates LSD value)

N_0 = 0 ppm (Control), N_1 = 25 ppm, N_2 = 50 ppm

Effect of Calcium (Ca)

The recorded data on fruit yield ha^{-1} was significantly influence by different levels of Ca application (Fig.8 and Appendix IX). The highest fruit yield (27.40 t ha^{-1}) was observed from the treatment Ca_1 (50 ppm Ca) which was significantly different from all other treatments followed by Ca_2 (100 ppm Ca). The lowest fruit yield (19.78 t ha^{-1}) was observed from the control treatment Ca_0 (0 ppm Ca). Similar result was also observed by Rubio *et al*. (2010) which supported the present stud.

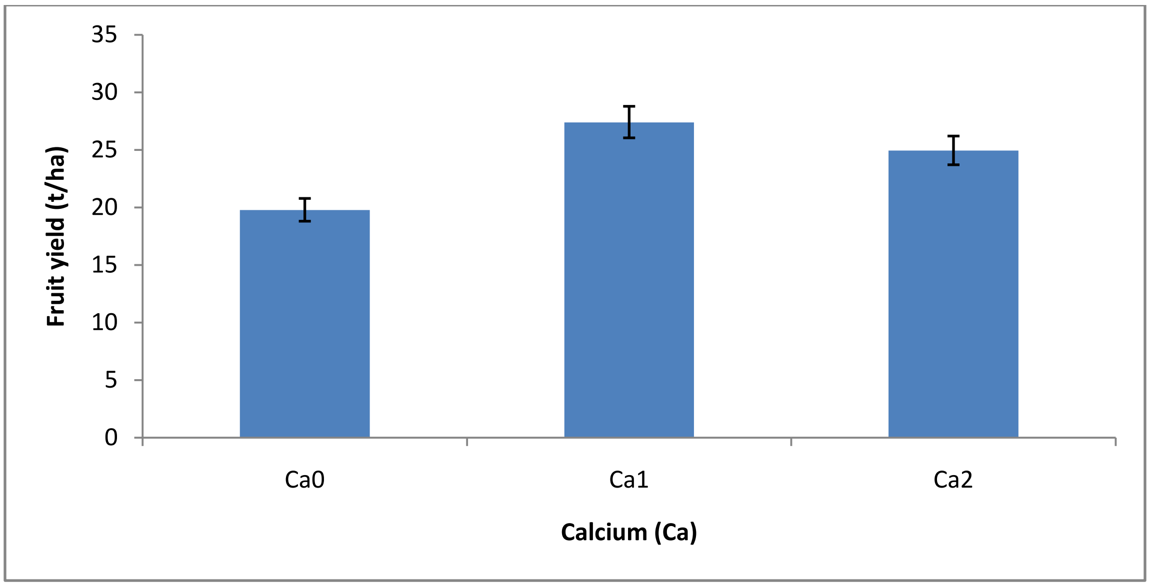


Fig. 8. Effect of Ca on fruit yield of hot pepper (bar graph indicates LSD value)

Ca_0 = 0 ppm (Control), Ca_1 = 50 ppm, Ca_2 = 100 ppm

Combined effect of NAA and Ca

Considerable influence was observed on fruit yield ha^{-1}persuaded by combined effect of NAA and Ca (Table 9 and Appendix IX).The highest fruit yield (33.55 t ha^{-1}) was observed from the treatment combination of N_2Ca_1which was significantly different from all other treatment combinations followed by N_1Ca_1. The lowest fruit yield (15.52 t ha^{-1}) was observed from the treatment combination of N_0Ca_0which was also significantly different from all other treatment combinations followed by N_0Ca_1.

Table 7. Effect of NAA on yield parameters of hot pepper

Treatments	Yield parameters			
	Number of fruits plant^{-1}	Fruit weight plant^{-1} (g)	Single fruit weight (g)	Fruit yield (t ha^{-1})
Effect of NAA				
N_0	299.83 c	463.39 c	1.54 b	18.53 c
N_1	381.73 b	635.29 b	1.66 a	25.41 b
N_2	415.83 a	704.24 a	1.69 a	28.17 a
$LSD_{0.05}$	5.514	6.103	0.103	1.052
CV(%)	8.317	10.813	5.276	7.812

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

N_0 = 0 ppm (Control), N_1 = 25 ppm, N_2 = 50 ppm

Table 8. Effect of Ca on yield parameters of hot pepper

Treatments	Yield parameters			
	Number of fruits plant^{-1}	Fruit weight plant^{-1} (g)	Single fruit weight (g)	Fruit yield (t ha^{-1})
Ca_0	314.13 c	494.39 c	1.57 b	19.78 c
Ca_1	403.50 a	684.95 a	1.68 a	27.40 a
Ca_2	379.77 b	623.58 b	1.64 a	24.94 b
$LSD_{0.05}$	6.171	8.314	0.011	1.017
CV(%)	10.114	12.529	7.876	9.317

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability. Ca_0 = 0 ppm (Control), Ca_1 = 50 ppm, Ca_2 = 100 ppm

Table 9. Effect of Ca in combination with NAA on yield parameters of hot pepper

Treatments	Yield parameters			
	Number of fruits plant^{-1}	Fruit weight plant^{-1} (g)	Single fruit weight (g)	Fruit yield (t ha^{-1})
N_0Ca_0	260.40 i	388.00 i	1.49 e	15.52 h
N_0Ca_1	291.40 h	445.80 h	1.53 de	17.83 g
N_0Ca_2	347.70 f	556.30 f	1.60 cd	22.25 e
N_1Ca_0	322.20 g	512.30 g	1.59 cd	20.49 f
N_1Ca_1	445.30 b	770.40 b	1.73 ab	30.81 b
N_1Ca_2	377.70 d	623.20 d	1.65 bc	24.93 d
N_2Ca_0	359.80 e	582.90 e	1.62 cd	23.32 de
N_2Ca_1	473.80 a	838.60 a	1.77 a	33.55 a
N_2Ca_2	413.90 c	691.20 c	1.67 bc	27.65 c
$LSD_{0.05}$	10.61	10.91	0.09481	1.664
CV(%)	10.114	12.529	7.876	9.317

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

N_0 = 0 ppm (Control), N_1 = 25 ppm, N_2 = 50 ppm

Ca_0 = 0 ppm (Control), Ca_1 = 50 ppm, Ca_2 = 100 ppm

4.4 Quality parameters - Vitamin C content (mg/100 gram of fruit)

Effect of NAA

Significant variation was remarked on Vitamin C content as influenced by different levels of NAA (Fig. 9 and Appendix IX). The highest Vitamin C content (144.77 mg/100 gram of fruit) was recorded from the treatment N_2 (50 ppm NAA) which was significantly different from all other treatments followed by N_1 (25 ppm NAA). The lowest Vitamin C content (89.02 mg/100 gram of fruit) was recorded from the control treatment N_0 (0 ppm NAA).

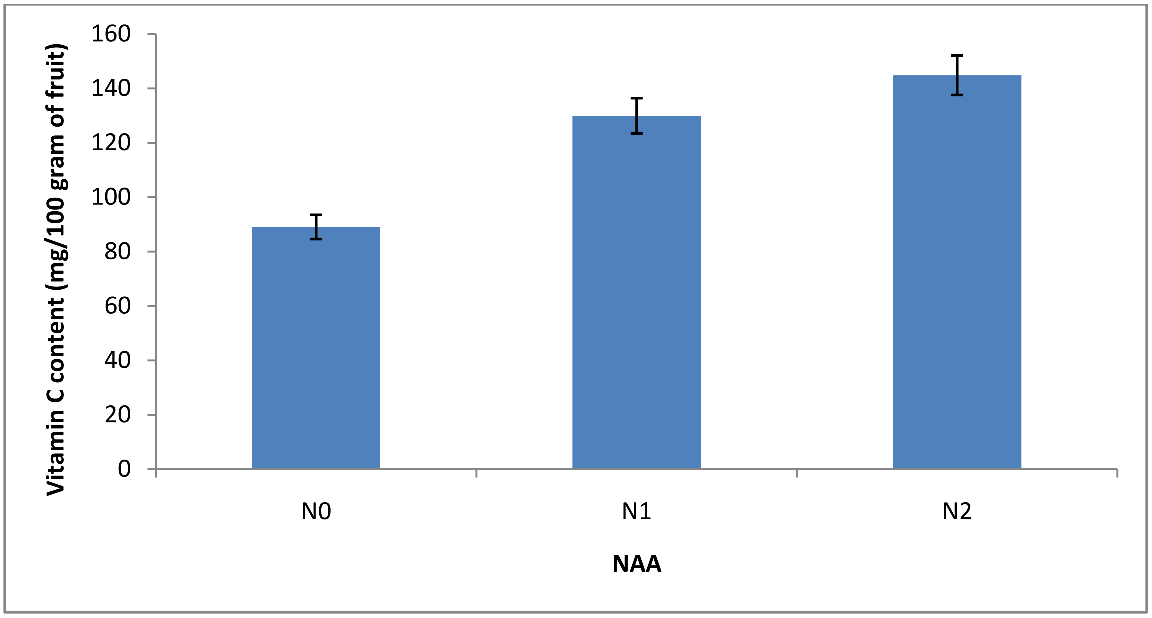


Fig. 9. Vitamin C content of green hot pepper as influenced by NAA (bar graph indicates LSD value)

N_0 = 0 ppm (Control), N_1 = 25 ppm, N_2 = 50 ppm

Effect of Calcium (Ca)

The recorded data on Vitamin C content was significantly influence by different levels of Ca application (Fig. 10 and Appendix IX). The highest Vitamin C content (143.54 mg/100 gram of fruit) was observed from the treatment Ca_1 (50 ppm Ca) which was significantly different from all other treatments followed by Ca_2 (100 ppm Ca). The lowest Vitamin C content (95.21 mg/100 gram of fruit) was observed from the control treatment Ca_0 (0 ppm Ca).

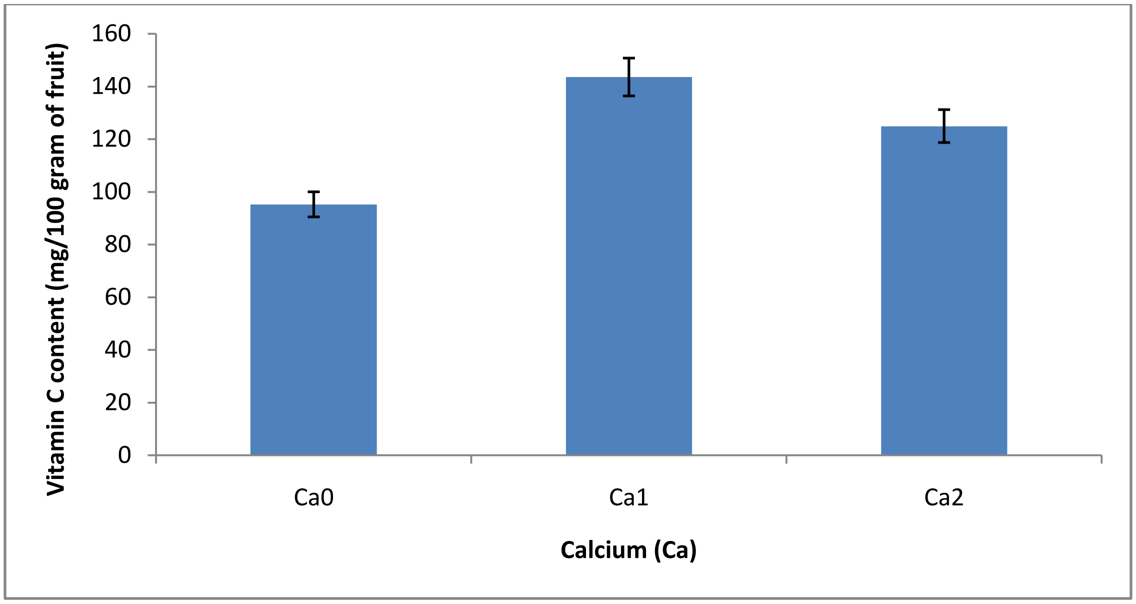


Fig. 10. Vitamin C content of green hot pepper as influenced by Ca (bar graph indicates LSD value)

Ca_0 = 0 ppm (Control), Ca_1 = 50 ppm, Ca_2 = 100 ppm

Combined effect of NAA and Ca

Considerable influence was observed on Vitamin C content (mg/100 gram of fruit) persuaded by combined effect of NAA and Ca (Table 10 and Appendix IX). The highest Vitamin C content (171.28 mg/100 gram of fruit) was observed from the treatment combination of N_2Ca_1 which was significantly same with the treatment combination of N_1Ca_1. The lowest Vitamin C content (72.84 mg/100 gram of fruit)was observed from the treatment combination of N_0Ca_0 which was also significantly different from all other treatment combinations followed by N_0Ca_1.

Table 10. Vitamin C content of green hot pepper as influenced by Ca and NAA and their combination

Treatments	Vitamin C content (mg/100 gram of fruit)
N_0Ca_0	72.84 g
N_0Ca_1	91.60 f
N_0Ca_2	102.63 e
N_1Ca_0	94.27 f
N_1Ca_1	167.75 a
N_1Ca_2	127.60 c
N_2Ca_0	118.52 d
N_2Ca_1	171.28 a
N_2Ca_2	144.50 b
$LSD_{0.05}$	5.267
CV(%)	9.524

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

N_0 = 0 ppm (Control), N_1 = 25 ppm, N_2 = 50 ppm

Ca_0 = 0 ppm (Control), Ca_1 = 50 ppm, Ca_2 = 100 ppm

4.5 Economic analysis

All the material and non-material input cost like land preparation, Hot pepper seed cost of organic manure, irrigation and manpower required for all the operation, interest on fixed capital of land (Leased land by ban loan basis) and miscellaneous cost were considered for calculating the total cost of production from planting seed to harvesting of hot pepper were recorded for unit plot and converted into cost per hectare (Table 11 and Appendix X). Price of hot pepper was considered at market rate. The economic analysis is presented under the following headlines:

4.5.1 Gross income

The combination of different NAA and Ca levels showed different gross return (Table 11). Gross income was calculated on the basis of sale of hot pepper. The highest gross return (Tk503250) obtained from N_2Ca_1 treatment combination and lowest gross return (Tk232800) obtained from the treatment combination of N_0Ca_0.

4.5.2 Net return

Treatment combinations of different NAA and Ca rate showed net returns variation (Table 11). The highest net return (Tk 387492) obtained from the treatment combination of N_2Ca_1 and lowest net return (Tk 124031) obtained from the treatment combination of N_0Ca_0.

Table 11. Economic analysis of hot pepper production as influenced by Ca in combination with NAA

Treatments	Economic analysis				
	Fruit yield (t ha^{-1})	Total cost of production	Gross return (Tk. ha^{-1})	Net return (Tk. ha^{-1})	BCR
N_0Ca_0	15.52	108769	232800	124031	2.14
N_0Ca_1	17.83	115758	267450	151692	2.31
N_0Ca_2	22.25	124931	333750	208819	2.67
N_1Ca_0	20.49	108769	307350	198581	2.83
N_1Ca_1	30.81	115758	462150	346392	3.99
N_1Ca_2	24.93	124931	373950	249019	2.99
N_2Ca_0	23.32	108769	349800	241031	3.22
N_2Ca_1	33.55	115758	503250	387492	4.35
N_2Ca_2	27.65	124931	414750	289819	3.32

Selling cost = 15.00 Tk kg^{-1}

N_0 = 0 ppm (Control), N_1 = 25 ppm, N_2 = 50 ppm
Ca_0 = 0 ppm (Control), Ca_1 = 50 ppm, Ca_2 = 100 ppm

4.5.3 Benefit cost ratio (BCR)

Among different treatment combinations of NAA and Ca, variation on BCR was observed among the treatment combinations (Table 11). The highest Benefit cost ratio (BCR); 4.35 was obtained from the treatment combination of N_2Ca_1 and lowest BCR (2.14) was obtained from N_0Ca_0.

From economic point of view, it was noticeable from the above results; the treatment combination of N_2Ca_1 was more profitable than rest of the treatment combinations.

CHAPTER V

SUMMARY AND CONCLUSION

The study was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from October 2017 to February 2018. The objective of the study was to study the effect of Ca and NAA on the growth, yield and quality of hot pepper variety BARI morich-3. The experiment consisted of two factors. NAA (3 levels) as N_0 = 0 ppm NAA (Control), N_1 = 25 ppm NAA and N_2 = 50 ppm NAA; and Ca application (3 levels) as Ca_0 = 0 ppm Ca(Control), Ca_1 = 50 ppm Ca and Ca_2 = 100 ppm Ca. Therewas a total of 9 (3 × 3) treatment combinations. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Size of each plot was 1.5 × 1 m. Data were collected in respect of yield contributing characters and yield of hot pepper and economic analysis. Collected data were statistically analyzed. Different levels of NAA, Ca and their combination showed significant variation among the treatments.

Considering NAA performance, in case of growth parameters, the highest plant height (34.19, 46.01 and 65.07 cm at 40, 60 and 80 DAT, respectively) number of leaves plant^{-1} (44.27, 85.51 and 96.34 at 40, 60 and 80 DAT, respectively) and number of branches plant^{-1} (7.52, 14.42 and 15.50 at 40, 60 and 80 DAT, respectively) were recorded from the treatment N_2 (50 ppm NAA) where the lowest plant height (28.46, 38.08 and 54.28 cm at 40, 60 and 80 DAT, respectively), number of leaves plant^{-1} (35.26, 68.95 and 74.16 at 40, 60 and 80 DAT, respectively) and number of branches plant^{-1} (5.91, 10.94 and 11.33 at 40, 60 and 80 DAT, respectively) was recorded from the control treatment N_0 (0 ppm NAA).In case of yield contributing parameters and yield, the lowest days to 1st flowering (39.60) was recorded from the control treatment N_2 (50 ppm NAA) where the highest fruit length (6.86 cm), fruit diameter (0.56 cm), number of fruits plant^{-1} (415.83), fruit weight plant^{-1} (704.24 g), single fruit weight (1.69 g) and fruit yield (28.17 t ha^{-1}) were also recorded from the treatment N_2 (50 ppm NAA) but the lowest fruit length (6.05 cm), fruit diameter (0.42 cm), number of fruits plant^{-1} (299.83), fruit weight plant^{-1} (463.39 g), single fruit weight (1.54 g) and fruit yield (18.53 t ha^{-1}) were recorded from the control treatment N_0 (0 ppm NAA). The highest days to 1st flowering (44.11) was also recorded from the control treatment N_0 (0 ppm NAA).

Regarding, Ca application, in terms of growth parameters,the highest plant height (34.56, 46.17 and 64.85 cm at 40, 60 and 80 DAT, respectively) and number of leaves plant^{-1} (43.24, 82.89 and 92.72 at 40, 60 and 80 DAT, respectively) were observed from the treatment Ca_2 (100 ppm Ca) but the highest number of branches plant^{-1} (7.15, 13.71 and 14.76 at 40, 60 and 80 DAT, respectively) was observed from the treatment Ca_1 (50 ppm Ca) whereas the lowest plant height (29.45, 39.13 and 55.84 cm at 40, 60 and 80 DAT, respectively) was observed from the control treatment Ca_0 (0 ppm Ca), number of leaves plant^{-1} (36.18, 72.36 and 78.54 at 40, 60 and 80 DAT, respectively) and number of branches plant^{-1} (6.06, 11.69 and12.36 at 40, 60 and 80 DAT, respectively) were observed from the control treatment Ca_0 (0 ppm Ca).Considering yield contributing parameters and yield, the lowest days to 1st flowering (40.78) was observed from the treatment Ca_2 (100 ppm Ca) but the highest fruit length (6.76 cm), fruit diameter (0.55 cm), number of fruits plant^{-1} (403.50), fruit weight plant^{-1} (684.95 g), single fruit weight (1.68 g) and fruit yield (27.40 t ha^{-1}) were observed from the treatment Ca_1 (50 ppm Ca). But the lowest fruit length (6.15 cm), fruit diameter (0.44 cm), number of fruits plant^{-1} (314.13), fruit weight plant^{-1} (494.39 g), single fruit weight (1.57 g) and lowest fruit yield (19.78 t ha^{-1}) was observed from the control treatment Ca_0 (0 ppm Ca) and this treatment also showed highest days to 1st flowering (42.89).

Treatment combination of NAA and Ca also showed significant influence on different parameters.In case of growth parameters, results showed that the highest plant height (36.23, 50.44 and 71.28 cm at 40, 60 and 80 DAT, respectively) and number of leaves plant^{-1} (47.33, 92.36 and 101.5 at 40, 60 and 80 DAT, respectively) was observed from the treatment combination of N_2Ca_2 but the highest number of branches plant^{-1} (8.82, 15.52 and 16.74 at 40, 60 and 80 DAT, respectively) was observed from the treatment combination of N_2Ca_1whereas lowest plant height (25.42, 36.40 and 51.62 cm at 40, 60 and 80 DAT, respectively t ha^{-1}), number of leaves plant^{-1} (32.16, 64.34 and 68.42 at 40, 60 and 80 DAT, respectively) and number of branches plant^{-1} (5.44, 10.36 and 10.48 at 40, 60 and 80 DAT, respectively) were observed from the treatment combination of N_0Ca_0. Again, in terms of yield and yield contributing parameters, the highest fruit length (7.18 cm), fruit diameter (0.63 cm), highest number of fruits plant^{-1} (473.80), fruit weight plant^{-1} (838.60 g), single fruit weight (1.77 g) and fruit yield (33.55 t ha^{-1}) were observed from the treatment combination of N_2Ca_1. Similarly, the lowest fruit length (5.88 cm), fruit diameter (0.37 cm), number of fruits plant^{-1} (260.40), fruit weight plant^{-1} (388.00 g), single fruit weight (1.49 g) and fruit yield (15.52 t ha^{-1}) was observed from the treatment combination of N_0Ca_0. It was also found that thelowest days to 1st flowering (39.33) was observed from the treatment combination of N_2Ca_2 but the highest days to 1st flowering (44.67) was observed from the treatment combination of N_0Ca_0.

In terms of quality parameters, the highest Vitamin C content (144.77 mg/100 gram of fruit) was recorded from the treatment N_2 (50 ppm NAA) where the lowest (89.02 mg/100 gram of fruit) was recorded from the control treatment N_0 (0 ppm NAA). Again, the highest Vitamin C content (143.54 mg/100 gram of fruit) was observed from the treatment Ca_1 (50 ppm Ca) where the lowest (95.21 mg/100 gram of fruit) was observed from the control treatment Ca_0 (0 ppm Ca). Regarding, combined effect, the highest Vitamin C content (171.28 mg/100 gram of fruit) was observed from the treatment combination of N_2Ca_1 where the lowest

(72.84 mg/100 gram of fruit) was observed from the treatment combination of N_0Ca_0.

From economic point of view, it was observed that the highest gross return (Tk 503250) obtained from N_2Ca_1 treatment combination and lowest gross return (Tk 232800) obtained from the treatment combination of N_0Ca_0. Again, the highest BCR (4.35) was obtained from the treatment combination of N_2Ca_1 and lowest BCR (2.14) was obtained from N_0Ca_0.

From the above findings, it can be concluded that the treatment combination of N_2Ca_1 (50 ppm NAA with 50 ppm Ca) gave the best performance regarding growth, yield and qualityparameters and also gross return of hot pepper. So, the treatment combination can be considered as the best among all the treatment combinations.

APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

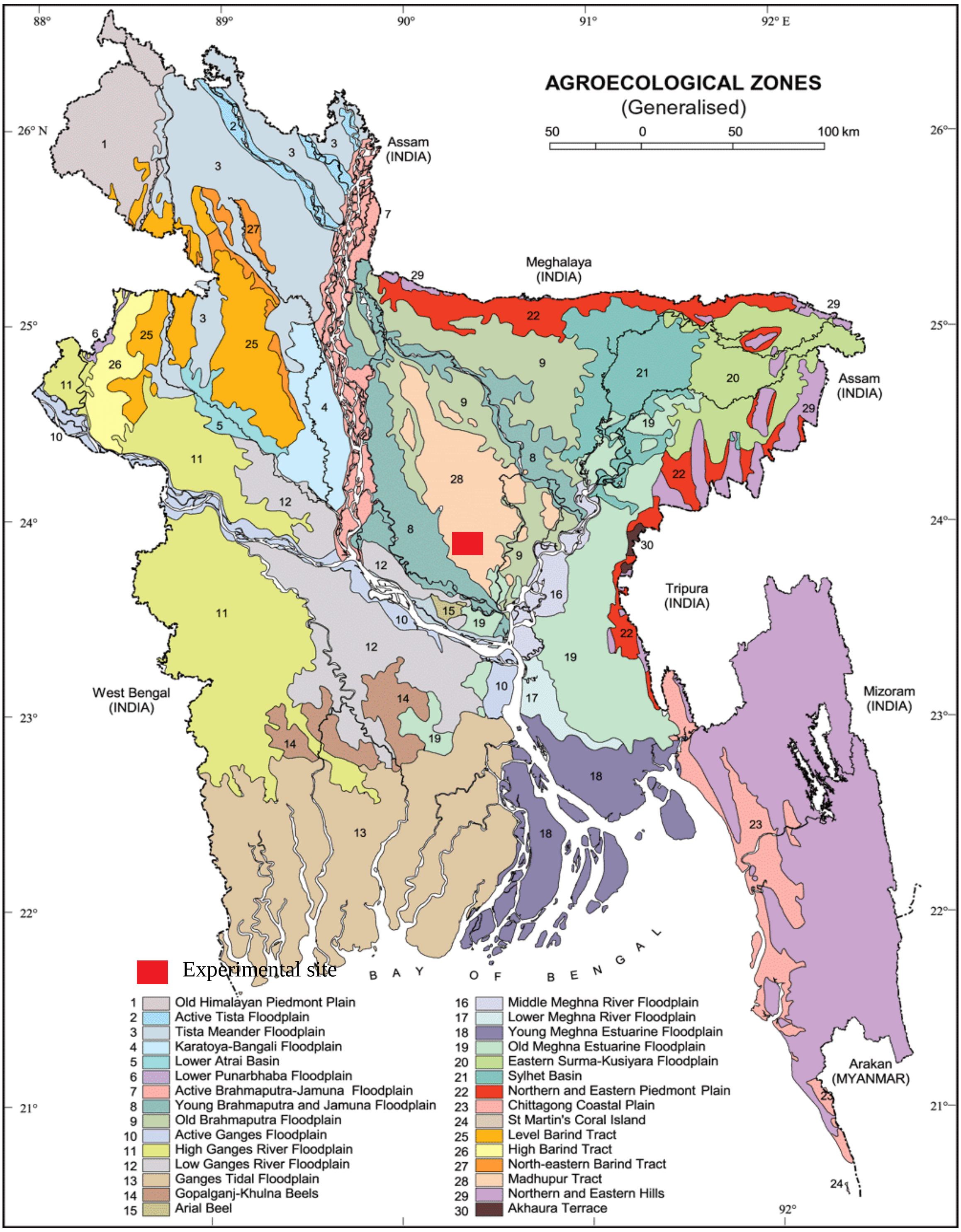


Fig. 11. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from October 2017 to February 2018.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2017	October	30.42	16.24	23.33	68.48	52.60
2017	November	28.60	8.52	18.56	56.75	14.40
2017	December	25.50	6.70	16.10	54.80	0.0
2018	January	23.80	11.70	17.75	46.20	0.0
2018	February	22.75	14.26	18.51	37.90	0.0

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

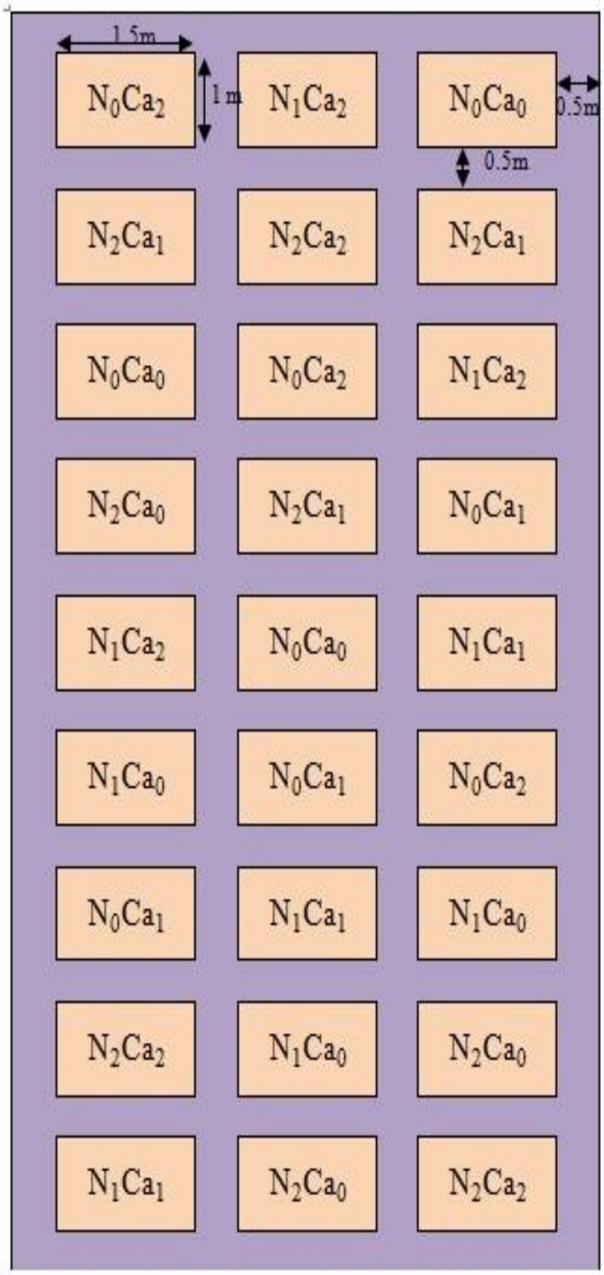
Source: Soil Resource Development Institute (SRDI)

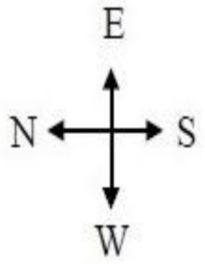
B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experiment field





Plot Size: 1.5 m x 1 m
Plant to plant distance: 50 cm
Row to row distance: 40 cm
Between Block: 1 m

Variety: BARI Morich-3

Factor A:
N_0: 0 ppm NAA
N_1: 25 ppm NAA
N_2: 50 ppm NAA

Factor B:
Ca_0: 0 ppm Ca
Ca_1: 50 ppm Ca
Ca_2: 100 ppm Ca

Fig. 12. Layout of the experimental plot

Appendix V. Effect of Ca, NAA and their combination on plant height of hot pepper

Sources of variation	Degrees of Freedom	Mean square of Plant height (cm)		
		40 DAT	60 DAT	80 DAT
Replication	2	1.911	3.233	3.360
Factor A	2	820.72*	158.63*	448.85*
Factor B	2	23.65*	48.902*	137.65*
AB	8	5.687**	14.622*	28.621*
Error	16	12.12	11.882	8.696

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Effect of Ca, NAAand their combination on number of leaves plant^{-1}of hot pepper

Sources of variation	Degrees of Freedom	Mean square of Number of leaves plant^{-1}		
		40 DAT	60 DAT	80 DAT
Replication	2	8.564	8.564	2.028
Factor A	2	94.530*	94.530*	876.78*
Factor B	2	84.162*	84.162*	1199.8*
AB	8	11.879*	11.879*	55.891*
Error	16	12.425	12.425	18.146

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Effect of Ca, NAAand their combination on number of branches plant^{-1}of hot pepper

Sources of variation	Degrees of Freedom	Mean square of Number of branches plant^{-1}		
		40 DAT	60 DAT	80 DAT
Replication	2	2.754	3.204	3.021
Factor A	2	4.937*	13.27*	21.59*
Factor B	2	5.13*	11.90*	20.58*
AB	8	0.206*	2.392*	2.262*
Error	16	0.786	2.559	1.169

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Effect of Ca, NAAand their combination on yield contributing parameters of hot pepper

Sources of variation	Degrees of Freedom	Mean square of Yield contributing parameters		
		Days to 1st flowering	Fruit length (cm)	Fruit diameter (cm)
Replication	2	0.344	0.001	0.001
Factor A	2	42.02*	1.535*	0.032**
Factor B	2	52.76*	1.123**	0.062**
AB	8	12.657*	0.167*	0.014**
Error	16	1.323	0.012	0.001

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IX. Effect of Ca, NAA and their combination on yield parameters of hot pepper

Sources of variation	Degrees of Freedom	Mean square of Yield parameters			
		Number of fruits plant^{-1}	Fruit weight plant^{-1} (g)	Single fruit weight (g)	Fruit yield (t ha^{-1})
Replication	2	5.961	7.583	0.002	0.736
Factor A	2	244.60*	1092.25*	NS	144.97*
Factor B	2	283.27*	1724.33*	0.046**	37.745*
AB	8	22.623*	106.583*	0.009*	15.000*
Error	16	14.966	17.038	0.005	0.416

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

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