RESPONSE OF SWEET PEPPER VARIETIES TO DIFFERENT LEVELS OF CHITOSAN RAW MATERIAL POWDER

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This is to certify that thesis entitled, "RESPONSE OF SWEET PEPPER VARIETIES TO DIFFERENT LEVELS OF CHITOSAN RAW MATERIAL POWDER" submitted to the Department of Soil science, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirement for the degree of MASTER OF SCIENCE (MS) in SOIL SCIENCE, embodies the result of a piece of bona-fide research work carried out by MD. HELAL UDDIN, Registration no. 19-10030 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledge.

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DEDICATED TO

MY

BELOVED PARENTS

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The Author

RESPONSE OF SWEET PEPPER VARIETIES TO DIFFERENT LEVELS OF CHITOSAN RAW MATERIAL POWDER

ABSTRACT

A pot experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from October, 2019 to April 2020, to study the response of sweet pepper varieties to different levels of chitosan raw material powder. The experiment was consisted of two factors, and followed Completely Random Design (CRD) with seven replications. Factor A: Sweet pepper varieties viz (2): V_1 : BARI Sweet pepper 1 and V_2 : BARI Sweet pepper 2; and Factor B: Application of different levels of chitosan raw material powder *viz* (4); C_0= 0%, C_1= 0.1%, C_2= 0.5% and C_3= 1% chitosan raw material powder. Result revealed that the highest fruit yield plant^{-1} pot^{-1} (139.18 g) was recorded in V_2 (BARI sweet pepper 2) treatment. Application of 1 % chitosan raw material powder (C_3) played a major role for plant growth and yield of sweet peppers and it's also influenced soil characteristics. The highest number of fruits plant^{-1} (3.07), fruit yield plant^{-1} pot^{-1} (157.29 g), soil pH (6.5), soil total nitrogen content (0.12 %), organic carbon (0.76 %) and organic matter (1.31 %) were recorded in C_3 treatment. Increasing chitosan levels influenced plant growth and development and the highest fruit yield plant^{-1} pot^{-1} (188.43 g) was recorded in BARI sweet pepper 2 cultivation along with application of 1 % chitosan raw material powder (V_2C_3). From these results it can be concluded that yield and yield contributing characters of sweet peppers and some chemical properties of soil were improved due to the application of chitosan raw material powder. Taken together, our results suggest that chitosan raw material powder have some positive effect on slow releasing nitrogen supplementation, soil organic carbon and soil pH which influenced plant growth, development and yield.

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ABBREVIATIONS

Full word	Abbreviations	Full word	Abbreviations
Agriculture	Agric.	Milliliter	mL
Agro-Ecological Zone	AEZ	Milliequivalents	Meqs
And others	et al.	Triple super phosphate	TSP
Applied	App.	Milligram(s)	mg
Asian Journal of Biotechnology and Genetic Engineering	AJBGE	Millimeter	mm
Bangladesh Agricultural Research Institute	BARI	Mean sea level	MSL
Bangladesh Bureau of Statistics	BBS	Metric ton	MT
Biology	Biol.	North	N
Biotechnology	Biotechnol.	Nutrition	Nutr.
Botany	Bot.	Pakistan	Pak.
Centimeter	Cm	Negative logarithm of hydrogen ion concentration (-log[H+])	pH
Completely randomized design	CRD	Plant Genetic Resource Centre	PGRC
Cultivar	Cv.	Regulation	Regul.
Degree Celsius	°C	Research and Resource	Res.
Department	Dept.	Review	Rev.
Development	Dev.	Science	Sci.
Dry Flowables	DF	Society	Soc.
East	E	Soil plant analysis development	SPAD
Editors	Eds.	Soil Resource Development Institute	SRDI
Emulsifiable concentrate	EC	Technology	Technol.
Entomology	Entomol.	Tropical	Trop.
Environmment	Environ.	Thailand	Thai.
Food and Agriculture Organization	FAO	United Kingdom	U.K.
Gram	g	University	Univ.
Horticulture	Hort.	United States of America	USA
International	Intl.	Wettable powder	WP
Journal	J.	Serial	Sl.
Kilogram	Kg	Percentage	%
Least Significant Difference	LSD	Number	No.
Liter	L	Microgram	µ

CHAPTER-I

INTRODUCTION

Sweet pepper (*Capsicum annuum* L) is a member of the Solanaceous group. It is one of the popular vegetable crops cultivated which are commonly called "filfil akhdar", where "filfil" means pepper and "akhdar" means green. It is mainly used as a spice, salad and vegetables in Bangladesh. Sweet pepper covers a production area of 434757 acres in year 2014 according to the Ministry of Agriculture Statistics, Bangladesh (BBS, 2018).

Capsicum attained a status of high value low volume crop in Bangladesh in recent years and occupies a place of pride among vegetables in Bangladeshi cuisine, because of its delicacy and pleasant flavour coupled with rich content of ascorbic acid along with other vitamins and minerals (Islam *et al*., 2017). Nutritionally, it is rich in vitamin-A (8493 IU), vitamin-C (283 mg) and minerals like, calcium (13.4 mg), magnesium (14.9 mg), phosphorus (28.3 mg) and potassium (263.7 mg) per 100 g fresh fruit weight. (Kumar *et al*., 2021). Capsicum is also good source of β-carotene and capsanthin which accounts for about 36 per cent of the total carotenoid content. Violaxanthin for about 10 per cent, cryptoxanthin and capsorubin for 6 per cent each and cryptocapsin for about 4 per cent are other carotenoids present in capsicum (Mohd *et al*., 2019).

The mature fruits (green, red and yellow) of capsicum are eaten raw or widely used in stuffings, bakings, pizza and burger preparations. The high market price is attributed to heavy demand from the urban consumers. There is a good demand for export too. The export market needs fruits with longer shelf life, medium size tetra lobed with attractive colour, mild pungency and good taste. The production and supply of capsicum during winter months and early summer period is stated to be good in Bangladesh. However, the supply is inadequate during other periods due to low productivity of the crop.

Productivity of any crop can be influenced by introducing high yielding cultivars, fertilizer managements, proper agronomic managements etc. Chilli cultivars greatly vary in ability to flowering, fruit set, yield potential and other quantitative attributes under different agro-climates (Yatagiri *et al*., 2017 and Gupta, 2003).

But all the varieties may not perform equally in all regions of Bangladesh. It is essential to know the performance of varieties in a specific area.

Yield and quality of fruit depends on various pre- and postharvest factors which include environmental conditions, harvest maturity and post-harvest factors (Tyagi., 2017). Many research groups are struggling to enhance quality and yield of bell peppers. For this purpose chemicals and hormones had been in use for many decades but now round the globe health concerns are increasing among people.

Demand for chemical free and safe food is increasing day by day. These emerging concerns are leading towards use of biostimulants which are food grade chemicals and also known as GRAS (Generally regarded as safe) chemicals for producing food crops. Although significant amount of work has been reported on enhancement of quality of bell pepper through use of mineral nutrition, there are very few reports on the use of biostimulants to enhance the yield and quality of the bell pepper fruit. GRAS chemicals are not only capable to enhance yield and quality of fruits and vegetables but they also improve plant health by controlling diseases.

Chitosan (CHT) is a biodegradable compound found naturally and is derived from crustaceous shells. Chitosan is harmless to crops, animal and human. The molecule of chitosan triggers a defensive mechanism within the plant, which leads to the formation of physical and chemical barriers against invading different plant pathogens. Chitosan seems to be a natural biodegradable compound with low toxic in nature which is obtained from deacetylation of chitin and most application of the chitosan in agriculture is used for the stimulation of plant defense mechanisms (Kumar *et al*., 2018). Chitosan seems to act as a stress tolerance inductor it enhanced a hyper sensible reaction and lignification, inducing lipid peroxidation, and production of defense against pathogens when directly applied to plant tissue (Hassnain *et al.*, 2020). Seeds treated with chitosan reduced the mean germination time; increased germination index leads to improving seedling growth under low temperature stress and also reported that the application of chitosan reduced the vanadium toxicity when applied to wheat and barley in irradiated form (Islam and Khatoon, 2021). During drought stress foliar application of chitosan helps to reduce the loss of water from the leaves by including stomatal type closing compounds, which are able to decrease water loss from the leaf by improving plant biomass or yield of crop (Hidangmayum *et al*., 2019). Foliar application of chitosan helps to reduce the water stress effect on yield which may be due to increase in stomatal conductance under water stress and its role in reducing transpiration rate (Farouk and Ramadan., 2012).

Although not known the exact mechanisms by which chitosan stimulates growth and development of plants, it has been proposed that is involved in physiological processes, it prevents water loss via transpiration (Young *et al*., 2005). In this regard, the presence of stomatal closure has been demonstrated when sprinkled plants with chitosan, suggesting that the stimulatory effect of growth, after stomatal closure could be related to an antiperspirant effect on the ground (Hidangmayum *et al*., 2019), stating, moreover, foliar application of chitosan in potato reduced the effects of water stress (Jiao *et al*., 2012).

By considering the above fact the proposed research work was undertaken to achieve the following objectives:

i. To evaluate the performance of sweet pepper varieties.

ii. To examine the growth and yield performance of sweet pepper as influenced by different levels of chitosanraw material powder.

iii. To observe the combined effects of variety and chitosan raw material powder on the growth and yield of sweet pepper.

CHAPTER II

REVIEW OF LITERATURE

An attempt was made in this section to collect and study relevant information available regarding to ' response of sweet pepper varieties to different levels of chitosan raw material powder' to gather knowledge helpful in conducting the present piece of work and subsequently writing up the result and discussion.

2.1 Effect of sweet pepper variety

According to Syafruddin (2017) each variety has genetic differences that can affect growth and yield and the adaptability of a variety varies.

Zubir (2017) that the treatment of varieties on Andisol soil had a very significant effect on plant height, stem diameter, number of productive lengths, plant fresh weight, plant dry weight, root dry weight, number of fruit crops, weight of planting fruit and fruit length. The Lado F1 variety has the best yield if cultivated on Andisol Burni Telong Bener Meriah soil.

Safrianto *et al.* (2015) that superior varieties have properties that are superior to local varieties. These advantages can be seen from the high fruit yield per plant, response to fertilization, and resistance to plant pests and diseases.

Chate *et al*. (2012) evaluated performance of nine cultivars of sweet pepper (*Capsicum annuum* L.) under 50 % shade net house. The cultivar Bombi performed better in number of fruits plant^{-1}, average weight of fruit and yield m^{-2}, while it required more number of days for first harvesting. The cultivar Orobelle had maximum plant height, maximum leaf area, more number of harvestings, while it required more number of days for first flowering and long duration of harvesting. Maximum length, breadth and volume of fruit were observed in cultivar Orobelle. Cultivar Bombi recorded maximum thickness of flesh pericarp, number of locules. Cultivar Royal Wonder required minimum number of days for first flowering and first harvesting. Overall performance of cultivars Bombi, Orobelle, Indra, Royal Wonder were found better.

Awani *et al.* (2011) reported enhanced crop duration in poly house (270 days), in poly tunnel (180 days), poly-mulching (150 days) technology as compared to open field condition (117 days). Highest yield (2.91 kg $plant^{-1}$ and 17.48 kg m^{-2}) were achieved in poly house followed by poly tunnel (1.89 kg $plant^{-1}$ and11.34 kg m-2), poly-mulching (1.57 kg $plant^{-1}$ and 9.43 kg m^{-2}) and open field condition (0.98 kg $plant^{-1}$ and 5.90 kg m^{-2}, respectively).

Ilic *et al*. (2011) conducted three year trial on bell pepper cv. Cameleon under four different coloured shade nets (pearl, red, blue and black) with different relative shading (40 % and 50 %) showed an increase in total yield by 49.5 per cent under pearl shade net and 43.5 % under red shade net. Total and marketable yield increased with 40 % shading level and then decreased with increased shading level of 50 %.

Singh *et al.* (2011) reported that protected technology prolonged crop duration (270 days) in polyhouse, 180 days in poly tunnel and 150 days in polymulching as compared to 117 days in open field conditions. The highest fruit yield $plant^{-1}$ (2.91 kg) and fruit yield m^{-2} (17.48 kg) were achieved in polyhouse, followed by poly-tunnel (1.89 kg $plant^{-1}$, 11.34 kg m^{-2}), polymulching (1.57 kg $plant^{-1}$, 9.43 kg m^{-2}) and open field conditions (0.98 kg $plant^{-1}$, 5.90 kg m^{-2}), respectively. Different protected technologies exhibited greater net returns (Rs. 253.84 m-2) in polyhouse, Rs 132.08 m^{-2} in poly-tunnel, Rs 88.56 m^{-2} in poly-mulching when compared to open field conditions (Rs.37.37 m^{-2}). Highest B:C ratio of 4.72 in polyhouse, 3.68 in polytunnel, 3.03 in poly-mulching was achieved while, it was lowest in open field conditions (2.12). Minimum bacterial wilt (3.40 %) and blossom end-rot of fruit (4.32 %) was observed under polyhouse conditions while, it was maximum in open field conditions (68.7 and 17.10%, respectively).

Joshi *et al.* (2010) evaluated eleven genotypes of capsicum under naturally ventilated polyhouse condition. Vigour index-I was observed highest in Solan pepper (757.30) followed by California wonder (591.10) and vigour index- II was highest in Solan pepper (30.04) followed by California wonder (28.46). The maximum fruit yield was recorded in Solan pepper (1066 g $plant^{-1}$) followed by PRSM-1 (971 g $plant^{-1}$). Fruit diameter was maximum in Solan pepper (7.18 cm) followed by PRSM-1 (6.43 cm). Maximum number of $fruitsplant^{-1}$ were recorded in Solan pepper (8.40) followed by PRSM-1(6.12).There was nonsignificant difference with respect to number of locules and pedicle length.

Aruna and Sudagar (2010) studied the performance of capsicum varieties viz., Arka Mohini, Arka Basant and Arka Gaurav under polyhouse conditions. The results revealed that, among the three varieties, Arka Mohini recorded increased fruit weight (199.6 g) and length of the fruit (10.54 cm). In case of Arka Basant, the girth of the fruit was high (17.70 cm) followed by Arka Mohini (15.50 cm) but it recorded the lowest individual fruit weight of 82.82 g. The variety, Arka Mohini also registered an increased fruit yield (1.204 kg plant^{-1}) followed by Arka Gaurav (0.678 kg plant^{-1}) and Arka Basant (0.403 kg plant^{-1}). The increase in yield was due to increase in fruit length, fruit weight and fruit girth etc.

Raghav Manoj *et al.* (2009) evaluated five hybrids and varieties of capsicum for growth, yield and its components in naturally ventilated polyhouse for identifying suitable variety/hybrid. A non-significant difference was found between all the varieties for all the characters except, fruit yield m^{-2} and fruit yield ha^{-1}. Hybrid Bharat gave maximum number of fruits plant^{-1}. Hybrid Indira gave maximum fruit weight and yield plant^{-1}, although the differences were nonsignificant. The minimum fruit yield plant^{-1} and fruit yield ha^{-1} was recorded with variety Bullnose (check).

Kurubetta and Patil (2009) studied the performance of capsicum hybrids viz., Orobelle, Bomby and Indra under different protected structures. The results revealed that, the earliest flower initiation (33.00 days), least time taken for first harvesting (86.00 days) and highest per cent fruit set (49.81) were recorded under NVP and the quality parameters like fruit weight (160.00 g), fruit volume (320.00 cc), rind thickness (0.91 cm) and shelf life (8.62 days) were also significantly maximum under naturally ventilated polyhouse than under naturally ventilated shadow hall. The hybrid Indra recorded significantly earliest flower initiation (35.42 days), lower time taken for first harvesting (86.00 days) and higher percent fruit set (45.45) as compared to other two hybrids. Among the hybrids, Bomby recorded significantly higher fruit weight (158.50 g), fruit volume (310.00 cc) and Indra recorded higher rind thickness (0.87 cm) and shelf life (8.60 days).

Vethamoni *et al.* (2008) reported that 35 % shade is most suitable for cultivating sweet pepper under tropical conditions and Indra is a suitable cultivar under shade net for year round cultivation.

Shahak (2008) observed that all bell pepper cultivars showed increased productivity under photoselective shading, as there was an increase in number of fruits per plant by 30 to 40 per cent compared to the use of common black net. Among the different coloured nets used for photoselective shading, the red net was found to have some productivity advantage over the pearl and yellow nets. The risk of infestation by small pests like aphids, thrips and the incidence of insect borne viral diseases were significantly lower under yellow net compared to all other nets. The results demonstrated the potential of photoselective light dispersive netting in improving the production of horticultural crops.

Singh *et al.* (2007) reported that capsicum variety ‘California Wonder’ gave a yield of 6.5 kg m^{-2} fruits with average weight of 54 g under naturally ventilated polyhouse as compared to no fruit yield in open field.

Hutton and Handley (2007) assessed the performance of twenty sevengreen bell pepper (*Capsicum annuum* L.) cultivars transplanted into double rows on raised beds covered with black plastic mulch under green house. Among the cultivars, ‘Ace' and 'New Ace' consistently produced the largest crop by both weight and number of fruit. However, both of these cultivars had undesirable characteristics of small fruit size (<150 g), few lobes (two-three) and thin fruit walls (<6 mm) limiting their commercial market potential. Other cultivars, including 'Vivaldi', 'Patriot', and ‘Socrates’ had significantly better fruit quality but very low or inconsistent yield.

Elad *et al.* (2007) carried out a study showed increased yields of two bell pepper cultivars when grown under black (25% and 40% shade), blue (40% shade), blue-silver (40% shade), silver (40% shade), and white (25% shade) shade nets as compared with the no net (control). Although powdery mildew (*Leveillula taurica*) leaf coverage and leaf shedding resulting from disease were more severe in the shade.

Raul Leonel *et al.* (2006) evaluated nine bell pepper varieties in the greenhouse. Among the varieties, Laroles, Asaia, Far-114 and Cupid recorded higher yields of 65.6, 63.1, 78.5 and 90.0 t ha^{-1}, respectively. Cadia and Parker had the lowest yield with 60.1 and 57.4 t ha^{-1}, respectively. The fruit weight was good in all varieties, however, Far-114 and Asaia had higher fruit weight with 272.5 g and 269.5 g, respectively.

Naik (2005) reported that among the three growing conditions namely, medium cost polyhouse, low cost polyhouse and net house, the medium cost polyhouse recorded higher yield. The favourable environmental conditions prevailing in medium cost polyhouse might have helped in better growth of roots and shoots which directly helped in better vegetative growth and finally improving the yield attributing parameters viz., number of fruits plant^{-1} (10.29), fruit weight plant^{-1} (1.02 kg), pericarp thickness at blossom end (1.23 cm), fruit length (8.49 cm) and fruit breadth (7.24 cm) and these finally led to highest total yield of 37.77 t ha^{-1}.

Verma *et al.* (2003) evaluated the fruits of F1 hybrids of *Capsicum* and found significant difference among the hybrids in terms of length, width, weight, volume of fruits, number of seeds per fruit, flesh thickness, total soluble solids and crop yield plant^{-1}. The hybrid, HC 201 x EC 203602 recorded the highest yield followed by Yolo Wonder x EC 143570 and Yolo Wonder × HC 201. However, the flattish fruits of HC 201 x EC 203602 were undesirable in the market. Based on the economic characters, the hybrid Yolo Wonder x HC 201 is the most promising.

According to Adisarwanto (2000) varieties that are able to survive with environmental conditions and can grow well with the superior properties possessed by varieties, if planted in optimal conditions will achieve the potential results.

2.2 Effect of chitosan

2.2.1 Chitosan

Chitosan is a deacetylated biopolymer of chitin, used in food, cosmetic, medical and agricultural sectors (Du Jardin, 2015). Chitosan is a linear polymer of α (1→4) linked 2 amino-2-deoxy-β-D-glucopyranose and is derived by N-deacetylation (Dutta *et al*., 2004). Chitosan and chitin are N- acetyl-D-glucosamine and D-glucosamine where the monomer ratio in polymer chain can define its physical chemical and biological properties. Chitosan contains higher proportion of N- acetyl-D- glucosamine and are not abundantly found in nature (Pichyankura and Chadchawan, 2015). Chitosan is a natural alternative for plant growth regulators (Acemi *et al*., 2018). It is found in shells of crustaceans and carapaces of insects, cell membranes of fungi and some algae (Nge *et al*., 2006). Chitosan is biodegradable, biocompatible, non-toxic and non- carcinogenic, making it useful in many fields (Alves *et al*., 2008). Chitosan can induce defence reactions in plants by induction of chitinase, chitosanase and β - 1, 3 glucanase isoforms. Chitosan can remove heavy metals and dyes, control algal contamination from lakes and acts as soil conditioner. Foliar application of chitosan increase stomatal conductance and reduce transpiration without affecting plant height, root length, leaf area or plant biomass. Besides it is used as a seed coating material in cereals, nuts, fruits and vegetables. It acts as a carrier promoting slow release of fertilizer and improves water retention of soil (Pandey *et al*., 2018). Depending on the plant structure, concentration, molecular weight, incubation period and solvent of chitosan molecule, plant response can vary. Lactic acid dissolved chitosan show the best inhibitory effect as compared to dissolved in formic acid and acetic acid (Hassan and Chang, 2017). Poor solubility is a limiting factor in its utilization (Dutta *et al*., 2004).

2.2.2 Chitosan preparation

Chitosan is a natural polysaccharide, produced after the N-deacetylation of chitin (Sharif *et al*., 2018). Collected crustacean shells size reducted in to small pieces. From crustacean shells, removal of proteins and calcium carbonate has to be done. Protein presented in crustacean shells is separated by using NaOH. Then washed with HCl and later dewatering and discoloration of chitin is carried out. Finally, chitin is deacetylated with sodium hydroxide at 120°C for 1- 3 hours and washed to get chitosan. In this treatment 70 per cent of deacetylated chitosan is obtained (Dutta *et al*., 2004).

Crustacean shell → Decalcification→ Deprotenization → Demineralization→ Discoloration→ Chitin → Deacetylation→ Washing and drying → Chitosan.

2.2.3 Effect of chitosan on plant characters

Xu and Mou (2018) carried out an experiment conducted in Lettuce (*Lactuca sativa*) to study the influence of chitosan, when used as soil amendment. Results showed that chitosan at 0.05 per cent, 0.02 per cent and 0.15 per cent increased leaf area (856, 847 and 856 cm^2, respectively) over control (674 cm^2).

Malekpoor *et al*. (2016) found that chitosan plays positive role in growth and development of basil in water deficient condition by reducing transpiration rate. When plants treated with Chitosan at 0.4 g L^{-1} by foliar sparys on *Ocimum basilicum* recorded better in plant growth characters when compared to untreated plants.

Sathiyabama *et al*. (2014) conducted a field experiment in Oonjallur village of Erode district, Tamil Nadu, to study the effect of chitosan on growth, yield and curcumin content. Turmeric plants sprayed with chitosan 0.1 per cent at regular interval of 30 days upto 210 days increased the number of leaves per plant and shoot height compared to the control and over all curcumin production per plant. Fifty six per cent increases in curcumin content were observed in rhizomes and overall production were doubled with foliar application of chitosan.

Sultana *et al*. (2015) reported that foliar application of chitosan in rice production improved the morphological characters like plant height, number of tillers, length of panicle and yield of rice when compare to control.

Saif-Eldeen *et al*. (2014) reported that foliar spraying of chitosan 2 ml L^{-1} and seaweed extract 2 g L^{-1} significantly improved the plant height, number of leaves, head weight, fresh and dry weight and the quality parameters such as total soluble solids in globe artichoke.

Salachna and Zawadzinska (2014) reported that chitosan acts as a biostimulant in freesia. Chitosan treated plants exhibited more number of leaves, flowers, corms and earliness in flowering. There was an increased in corm weight and chlorophyll content in plants treated with chitosan.

Hossain *et al*. (2013) found that when chitosan irradiated at suitable radiation dose, and applied on plants through foliar application or through hydroponics system, has become a successful method in modern commercial farming.

Chookhongkha *et al*. (2012) reported that chilli seedlings transplanted in soil containing high molecular weight chitosan (0.1%) increased the plant height, number of leaves per plant, leaf width and leaf length.

Mondal *et al*. (2012) conducted an experiment at Bangladesh Institute of Nuclear Agriculture during 2010-2011 for studying the effect of foliar application of chitosan on growth and yield of okra. Five concentrations of chitosan spray viz., 0, 50, 75, 100 and 125 ppm was sprayed on 25, 40 and 55 days after planting. Result showed that plant height and leaf number increased significantly till 100 ppm. The increase in growth parameters was not significant after 100 ppm. The study also indicates that the application of chitosan in early growth stage had tremendous effect on the growth and development in okra.

Yin *et al*. (2012) reported that chitosan oligosaccharide at 200 and 500 ppm concentration tends to promote plant height and 50 ppm and 200 ppm concentration tends to increase polyphenol content in Greek oregano.

Chookhongkha *et al*. (2012) reported that chilli seeds cultured in soil containing high molecular weight chitosan at 1.0 per cent resulted in significantly highest fresh fruit weight per plant, fruit number per plant, seed number per fruit and seed weight in chilli.

Mondal *et al.* (2011) reported that chitosan sprays affected the growth and developmental characters of Indian spinach. Height of the plant, number of leaves and fresh weight of stem and leaf increased with chitosan application.

Abdel-Mawgoud (2010) recorded increased plant height, number of leaves and yield in strawberries with foliar application of chitosan.

Ghoname *et al.* (2010) recorded that chitosan sprays promoted plant vegetative growth as well as fresh and dry weight, individual fruit weight and number of fruits in sweet pepper.

Kowalski *et al.* (2006) stated that chitosan has also been used to increase yield and tuber quality of micro propagated greenhouse-grown potatoes.

Hien *et al*. (2000) reported that when chitosan exposed with the range of 10 to 500 kGy Co-60 gamma rays, proved very effective for considerable plant growth promotion.

Hien (2004) found that chitosan treatment increased the productivity of soybean (using Mitani and Rajabasa varieties) in about 40 % than control and stated that growth-promotion effect of radiation degraded alginate on tea has also been studied in Vietnam, which indicated that a 100 ppm radiated alginate causes an increase in the bud weight almost 35 %.

Ohta *et al.* (2001) also reported that the application of soil mixed with chitosan 1%w/w at sowing remarkably increased flower numbers of *Eustoma grandiflorum*.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to investigate the response of sweet pepper varieties to different levels of chitosan raw material powder'. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental period

The experiment was conducted during the period from October-2019 to April 2020.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted in the Agronomy field of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level (Anon., 2004).

3.2.2 Agro-Ecological Zone

The experimental site belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28 (Anon., 1988 a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1988 b). For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.2.3 Soil

The soil of the experimental pot belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Soil pH ranges from 5.4–5.6 (Anon., 1989). The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0–15 cm depths were collected from the Sher-e-Bangla Agricultural University (SAU) Farm, field. The soil analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The morphological and physicochemical properties of the soil are presented in below table.

Table 1. Morphological characteristics of the experimental area

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University soil research field, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

Table 2. The initial physical and chemical characteristics of soil use in this experiment

Physical characteristics	
Constituents	Percent
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	Value
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10

3.2.4 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season 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). Meteorological data related to the temperature, relative humidity and rainfall during the experiment period of was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix-II.

3.3 Experimental materials

Sweet pepper varieties and different level of chitosan raw material powder were used as experimental materials for this experiment. The important characteristics of these are mentioned below:

3.3.1 BARI Misti Morich 1

BARI Misti Morich 1 was released by Bangladesh Agricultural Research Institute (BARI). The lifetime of this variety was 125-135 days and production was 14-15 t ha^{-1}

Characteristics of the species

Contain 8-9 fruits/plant are available. The average fruit weight is 75-85 grams. Bright green bell-shaped fruits turn red when ripe.

3.3.2 BARI Misti Morich 2

BARI Misti Morich 2 was released by Bangladesh Agricultural Research Institute (BARI). The lifetime of this variety was 125-135 days and production was 15-20 t ha^{-1}

Characteristics of the species

It weighs 80-90 grams. Attractive Bell shaped fruit. Glossy green fruit, yellow when ripe. There are 12-13 fruits per tree. Yield 15-20 tons per hectare and life span: 125-135 days.

3.3.3 Chitosan raw material powder

The composition of chitosan raw material powder was given below

Table 3: Composition of the chitosan raw materials powder which was used in this research work.

Name of the nutrients	Nutrient content
Nitrogen (N)	4.06 %
Phosphorus (P)	0.643 %
Potassium (K)	0.28 %
Sulphur (S)	0.092 %
Calcium (Ca)	2.43 %
Magnesium (Mg)	0.36 %
Zinc (Zn)	92.03 ppm
Boron(B)	152 ppm
Organic Carbon (OC)	7.52%
Organic Matter (OM)	12.96%

3.4 Seed collection

Sweet peppers seed were collected from, Bangladesh Agricultural Research Institute, Gazipur. Healthy and disease free seeds were selected, following standard technique.

3.5 Experimental treatments

There were two factors in the experiment namely sweet pepper varieties and different levels of chitosan raw material powder as mentioned below:

Factor A: Sweet pepper varieties viz (2):

V_1 : BARI Misti Morich 1

V_2 : BARI Misti Morich 2

Factor B: Application of different levels of chitosan raw material powder *viz* (4);

C_0= 0% chitosan raw material powder

C_1= 0.1% chitosan raw material powder

C_2= 0.5% chitosan raw material powder and

C_3= 1% chitosan raw material powder.

3.6 Experimental design

The experiment was laid out in completely randomized design (CRD) with 2 factor and seven replications. Total 56 unit pots were be made for the experiment with 8 treatments.

3.7 Details of the experimental preparation

3.7.1 Seeds soaking

At first seeds were soaked in water in petridis before sowing. Seeds were soaked on 28 October 2019.

3.7.2 Sprouted seeds sowing

After soaking, seeds were sprouted. The sprouted seeds were sowing into 6 inch earthen pot containing soil mixtures of different levels of chitosan raw material powder. It was done on 31 October 2019.

3.7.3 First transplanting

14 days old seedlings were transplanted into small tea cup pot. The tea cup pot was filled with soil mixtures of different levels of chitosan raw material powder. Single seedling was transplanted into individual tea cup pot. Seedlings first transplanting were done on 13 November 2019.

3.7.4 Selection and preparation of the pot

Earthen pots having 12 inches diameter, 12 inches height with a hole at the centre of the bottom were used. Silt soil was used in the experiment. The upper edge diameter of the pots was 30 cm (r= 15 cm). While filling with soil, the upper one inch of the pot was kept vacant so that irrigation can be provided using a hose pipe. As such the diameter of the upper soil surface was 15 inch (30 cm) and the area of the upper soil surface was (πr^2 = 3.14x 0.015x 0.015=0.07 m^2). The pot soil was mixed with different levels of chitosan raw material powder. The preparation of the pot was done on 4 December 2019.

3.7.5 Fertilizer management and chitosan application

The following doses of fertilizer were applied for cultivation of sweet pepper (Saha, 2001).

Fertilizers	Quantity (kg/ha)	Fertilizer given pot^{-1} (g)
Cowdung	10000	700
Urea	250	17.5
TSP	350	24.5
MOP	250	17.5
Gypsum	110	7.7
Zinc oxide	5	0.35

At first pot soil mixed with half of the quantity of cowdung. The remaining half of cowdung, the entire quantity of TSP, ZnO, Gypsum and one third each of urea and MOP were applied during pot filling stage. Different levels of chitosan raw material were also added according to per treatment requirements. The rest of Urea and MOP were applied in two equal splits, 25 and 50 days after transplanting in the big pot.

3.7.6 Second transplanting to the pot

From the tea cup, seedlings were transplanted into 12 inches diameter pot (Big pot). Seedlings transplantation were done at 5 December 2019.

3.7.7 List of schedule of operations done at different days

Operations	**Date**
Seeds soaking in a petridis	28 October 2019
Collection of field moist soil	29 October 2019
6 inch pot filling with different levels of chitosan raw material powder and mixed with field moist soil for sprouted seed sowing	30 October 2019
Sprouted seeds sowing	31 October 2019
First transplanting into the small tea cup pot contained, mixed soil of different levels of chitosanraw material powder	13 November 2019
Selection and preparation of the earthen pot (Big pot)	3 December 2019
Fertilizer management and application of different chitosan raw material powder and filled it in the pot	4 December 2019
Second transplanting to the pot	5 December 2019

3.8 Intercultural operations

3.8.1 Application of irrigation water

Irrigation water was added to each pot according to the critical stage. It was given by using water pipe.

3.8.2 Weeding

The crop was infested with some common weeds, which were controlled by uprooting and removed them three times from the pot during the period of experiment. Weeding was done after 20, 30 and 45 days after transplanting.

3.8.3 Top dressing

The remaining two-third of urea and MoP were applied as top dressing in each plot by 2 installments.

3.9 Plant protection measures

The established plants were affected by mites and aphids. Malathion @ 2 ml/1 water was applied against aphids and other insects. Sweet pepper plants infected with anthracnose and were controlled by spraying Bavistin @ 2 g/1 water at 15 days interval. Few plants were found to be infected by bacterial wilt and Phytophthora blight and controlled by spraying Admier and Ridomil Gold @ 2 g/1 of water and uprooted.

3.10 Harvesting

First harvesting of green sweet pepper was done on 18 February, 2020, 21 February, 2020, 23 February, 2020, 4 March, 2020, 13 March, 2020, 18 March 2020 and 19 March 2020 respectively. Harvesting was done by hand.

3.11 Data collection

The data were recorded on the following parameters

i. Plant height
ii. Number of primary branches plant^{-1}
iii. Number of secondary branches plant^{-1}

iv. Number of leaves $plant^{-1}$
v. Number of flowers $plant^{-1}$
vi. Number of fruits $plant^{-1}$
vii. Individual fruits weight $plant^{-1}$
viii. Fruit yield pot^{-1}

3.12 Procedure of data collection

i) Plant height

The height of the plant was measured from the ground level to the tip of the plant at 35 and 50 DAT respectively. Mean plant height of the plant were calculated and expressed in cm.

ii) No. of primary branches $plant^{-1}$

The primary branches $plant^{-1}$ was counted from sampled plants. It was done by counting total number of primary branches of all sampled plants then the average data were recorded. Data were recorded at 35, 50 and 65 DAT respectively.

iii) No. of secondary branches $plant^{-1}$

The secondary branches $plant^{-1}$ was counted from sampled plants. It was done by counting total number of secondary branches of all sampled plants then the average data were recorded. Data were recorded at 35, 50 and 65 DAT respectively.

iv) No. of leaves $plant^{-1}$

The number of leaves $plant^{-1}$ was counted from the selected plants and their average was taken as the number of green leaves $plant^{-1}$. It was at 35 and 50 DAT respectively

v) No. of flowers $plant^{-1}$

The number of flowers $plant^{-1}$ was counted from the selected plants and their average was taken as the number of flowers $plant^{-1}$. It was at 50, 60 and 70 DAT respectively.

vi) No. of fruits plant^{-1}

Number of fruits plant^{-1} was counted at every picking, which was finally added up to work out total and average number of fruits plant^{-1}.

vii) Individual fruits weight plant^{-1}

Mean fruit weight in gram was calculated from the 3 selected fruits weight to determine the individual fruits weight plant^{-1}.

viii) Yield pot^{-1} (g)

Yield pot^{-1} was calculated in gram by a balance from the total weight of fruits per selected plants harvested at different periods and was recorded.

3.13 Chemical analysis of pot soil after harvesting of sweet peppers

3.13.1 Particle size analysis

Particle size analysis of soil was done by Hydrometer Method and then textural class was determined by plotting the values for % sand, % silt and % clay to the "MarshalL-1s Textural Triangular Coordinate" according to the USDA system.

3.13.2 Soil pH

Soil pH was measured with the help of a glass electrode pH meter using soil and water at the ratio of 1:2.5 as described by Jackson (1962).

3.13.3 Organic C

Organic carbon in soil was determined by Walkley and Black (1934) wet oxidation method. The underlying principle is to oxidize the organic carbon with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and to titrate the residual $K_2Cr_2O_7$ solution with 1N $FeSO_4$ solution. To obtain the organic matter content, the amount of organic carbon was multiplied by the Van Bemmelen factor, 1.73. The result was expressed as percentage.

3.13.4 Total nitrogen

The amount of N was calculated using the following formula:

% N = (T-B) × N × 0.014 × 100/S

Where, T = Sample titration (ml) value of standard H_2SO_4, B = Blank titration (ml) value of standard H_2SO_4, N = Strength of H_2SO_4 and S = Sample weight in gram.

3.13.5 Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al*., 1954). Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured calorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve.

3.14 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program name MSTAT-C. The significance of the difference among the treatment means were estimated at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

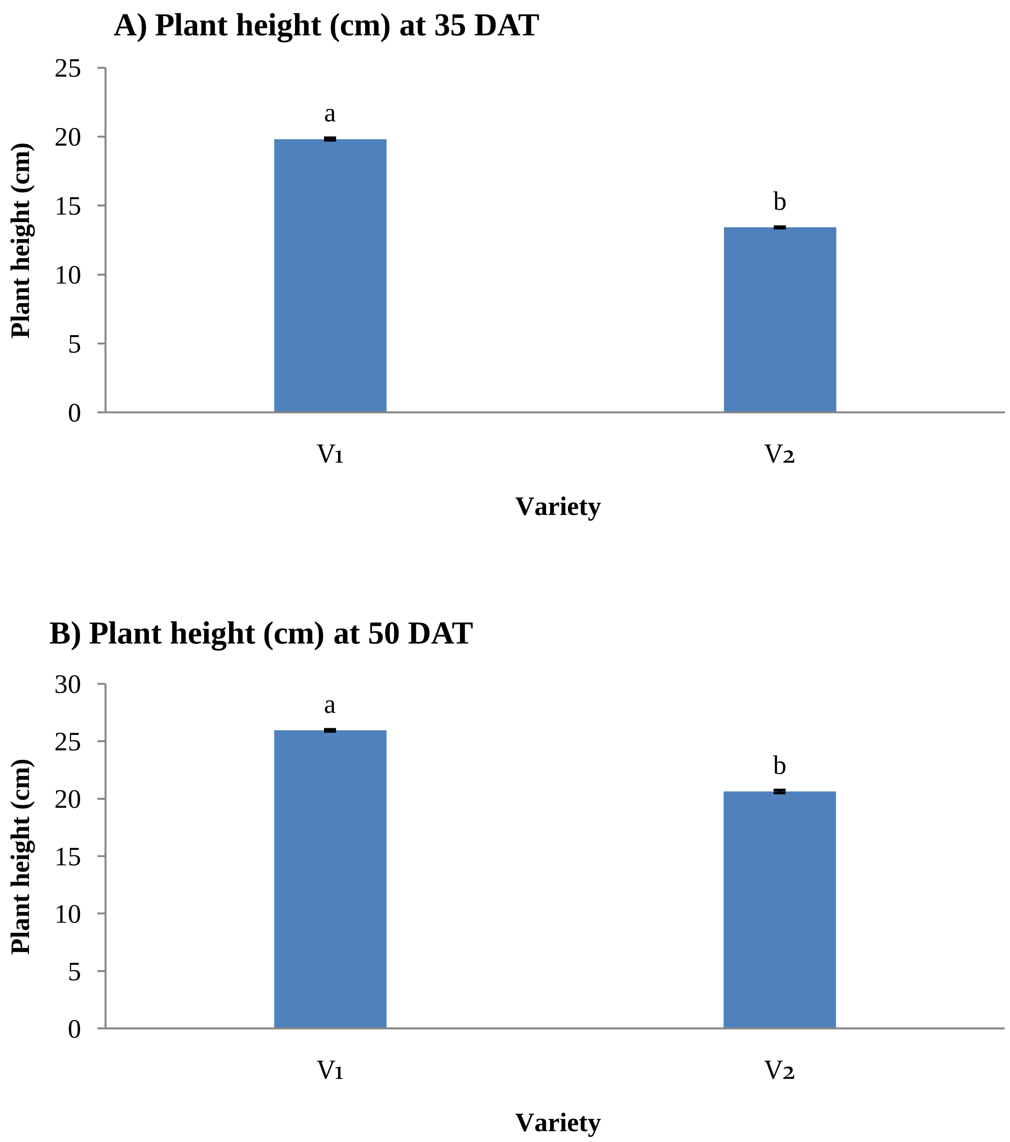
RESULTS AND DISCUSSION

Results obtained from the present study have been presented and discussed in this chapter with a view to study the response of sweet pepper varieties to different levels of chitosan raw material powder'. The data are given in different tables and figures. The results have been discussed, and possible interpretations are given under the following headings.

4.1 Plant height

Effect of variety on plant height of sweet pepper

Plant height is an important morphological character that acts as a potential indicator of availability of growth resources in its approach. Plant height was recorded at 35 and 50 DAT respectively. Different sweet pepper varieties significantly differ plant height at different days after transplanting (Figure 1). Experimental results revealed that, the highest plant height (19.83 and 25.95 cm) at 35 and 50 DAT respectively was recorded in V_1 (BARI sweet pepper 1) treatment. Whereas the lowest plant height (13.42 and 20.63 cm) at 35 and 50 DAT was recorded in V_2 (BARI sweet pepper 2) treatment. The variation in plant height due to the effect of varietal differences. The variation of plant height is probably due to the genetic make-up of the variety. Syafruddin (2017) reported that each variety has genetic differences that can affect growth and yield and the adaptability of a variety varies. Zubir *et al.* (2017) also found similar result with the present study and reported that height of a plant is determined by genetical character and under a given set of environment different variety will acquire their height according to their genetical make up.

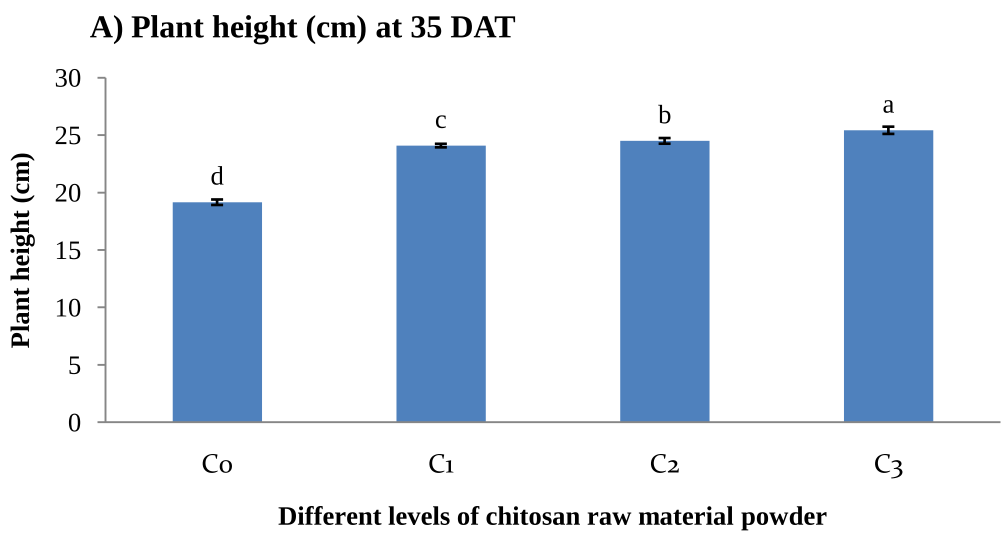


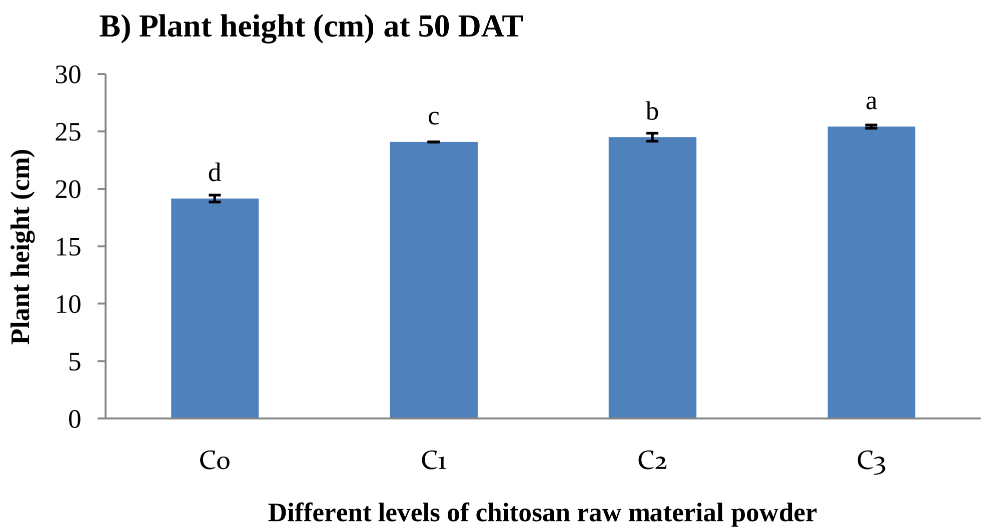
Here; V_1: BARI sweet pepper 1 and V_2: BARI sweet pepper 2.

Figure 1. Effect of variety on plant height of sweet pepper at different DAT. A) Plant height at 35 DAT and B) Plant height at 50 DAT.

Effect of different levels of chitosan raw material powder on plant height of sweet pepper

Application of different levels of chitosan raw material powder significantly influenced the plant height of sweet peppers at different days after transplanting (Figure 2). Experimental results showed that, the lowest plant height (14.34 and 19.16 cm) at 35 and 50 DAT was recorded in C_0 (Control treatment). Increasing chitosan levels gradually increased plant height and the highest plant height (19.42 and 25.42 cm) at 35 and 50 DAT was recorded in C_3 (1% Chitosan raw material powder) treatment. Chitosan enhances the ability of plants to survive in times of heat or cold stress and drought. It can give plants the ability to grow with less water and can accelerate growth and germination, and improve the quality of flowers and fruits. Sultana *et al*. (2015) reported that foliar application of chitosan in rice production improved the morphological characters like plant height, number of tillers, length of panicle and yield of rice when compare to control.





Here: C_0= 0% chitosan raw material powder, C_1= 0.1% chitosan raw material powder, C_2= 0.5% chitosan raw material powder and C_3= 1% chitosan raw material powder.

Figure 2. Effect of different levels of chitosan raw material powder on plant height of sweet pepper at different DAT. A) Plant height at 35 DAT and B) Plant height at 50 DAT.

Combined effect of variety and different levels of chitosan raw material powder on plant height of sweet pepper

Different varieties cultivated at different levels of chitosan raw material powder significantly affect on the plant height of sweet pepper at different DAT (Table 4). Experimental result showed that the highest plant height (23.67 and 29.17) at 35 and 50 DAT was recorded in V_1C_3. Whereas the lowest plant height (11.17 and 15.17 cm) at 35 and 50 DAT was recorded in was recorded in V_2C_0.

Table 4. Combined effect of variety and different levels of chitosan raw material powder on plant height of sweet pepper at different DAT

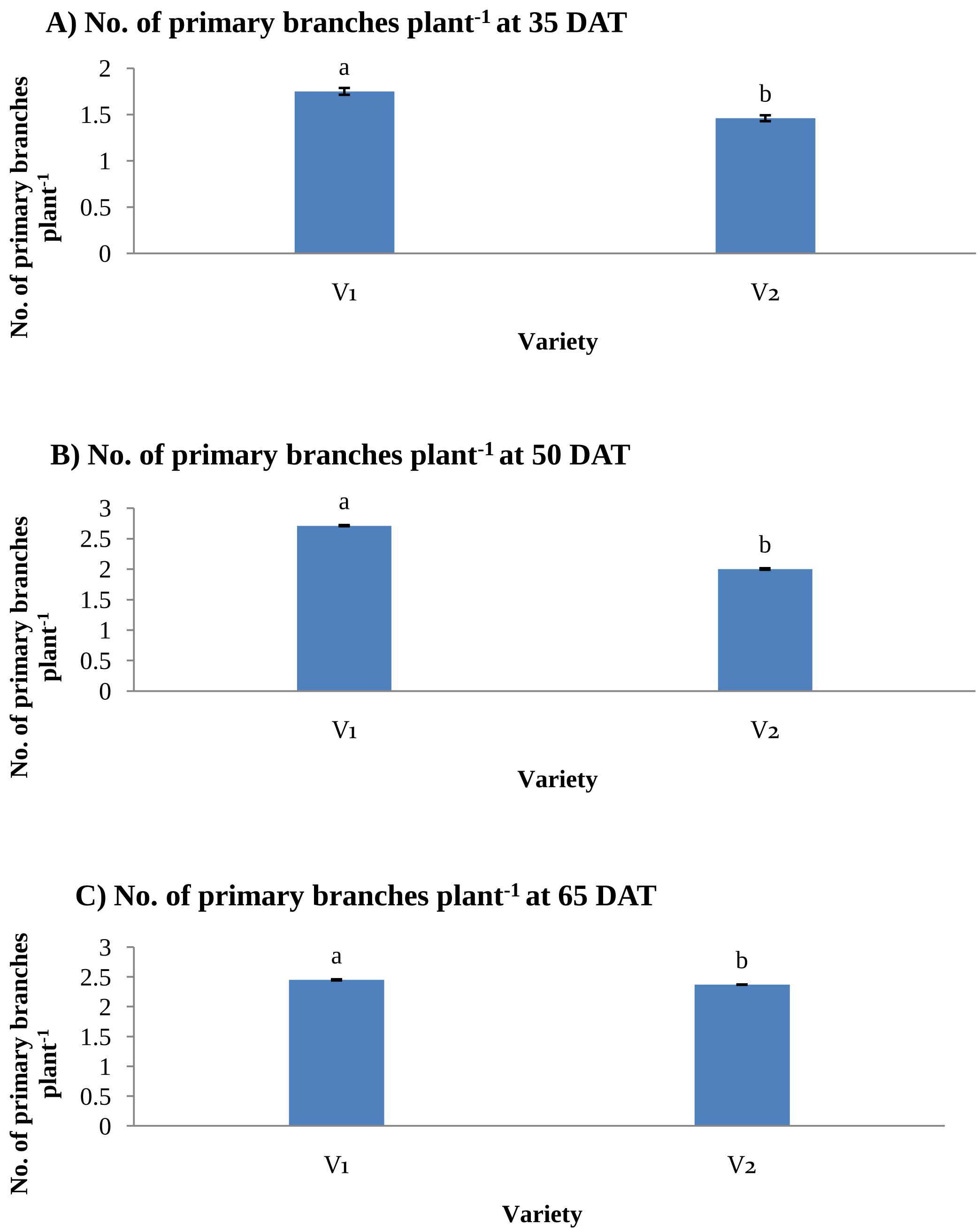
Treatments	Plant height at	
	35 DAT	50 DAT
V_1C_0	17.50 d	23.14 d
V_1C_1	17.83 c	24.17 c
V_1C_2	20.33 b	27.33 b
V1C_3	23.67 a	29.17 a
V_2C_0	11.17 g	15.17 f
V_2C_1	13.67 f	24.00 c
V_2C_2	13.67 f	19.83 e
V_2C_3	15.17 e	23.50 d
$LSD_{0.05}$	0.31	0.41
CV(%)	1.74	1.62

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. Here; V_1: BARI sweet pepper 1, V_2: BARI sweet pepper 2, C_0= 0% chitosan raw material powder, C_1= 0.1% chitosan raw material powder, C_2= 0.5% chitosan raw material powder and C_3= 1% chitosan raw material powder.

4.2 No. of primary branches plant^{-1}

Effect of variety on no. of primary branches plant^{-1} of sweet pepper

Number of primary branches plant^{-1} of sweet pepper had shown significant differences at different days after transplanting due to the effect of different varieties of sweet pepper cultivation (Figure 3). Experimental result showed that the highest number of primary branches plant^{-1} (1.75, 2.71 and 2.45) at 35, 50 and 65 DAT was recorded in $V_{1.}$ Whereas the lowest number of primary branches plant^{-1} (1.46, 2.0 and 2.37) at 35, 50 and 65 DAT was recorded in V_2. The variation in number of primary branches plant^{-1} may be due to the effect of varietal differences.

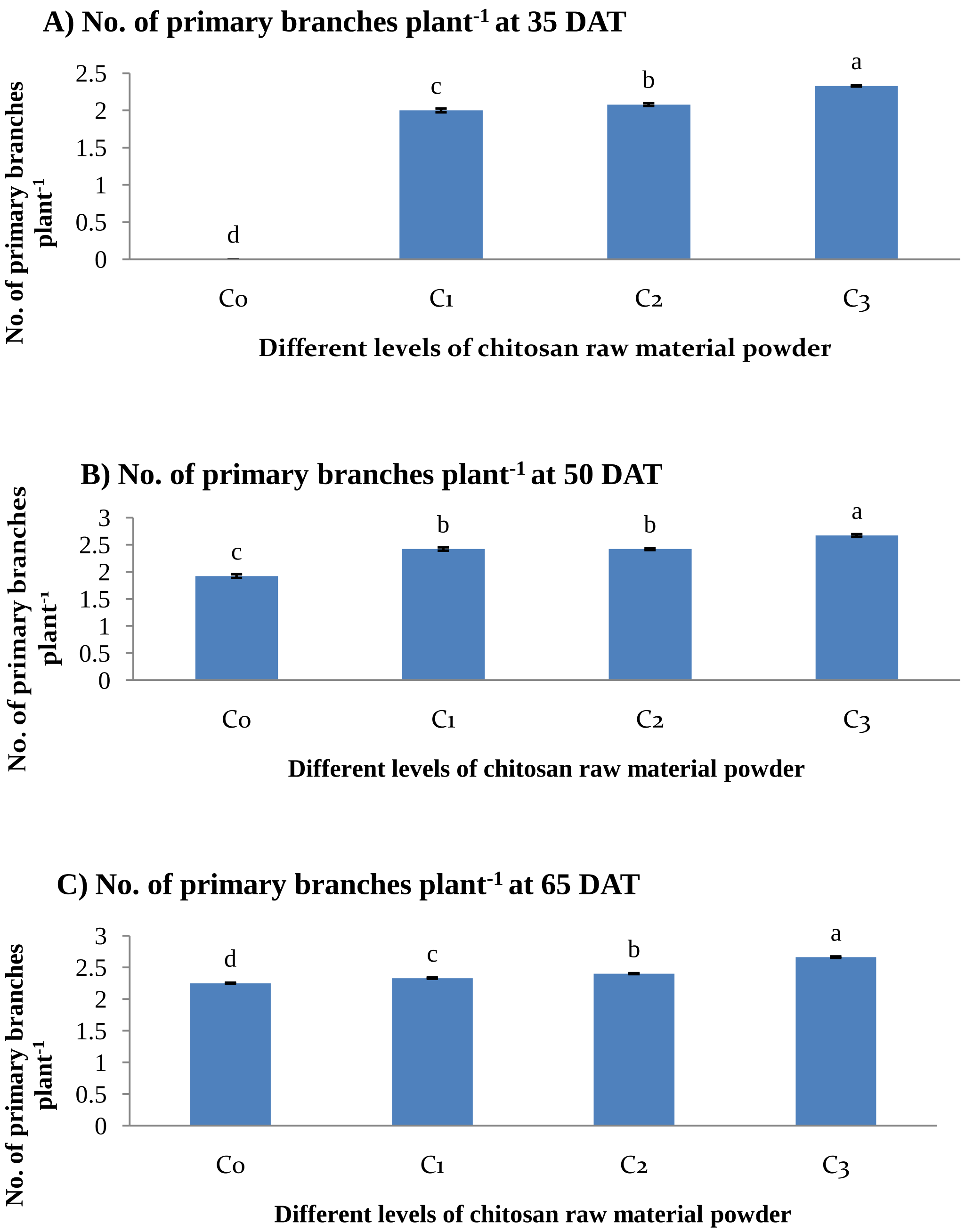


Here; V_1: BARI sweet pepper 1 and V_2: BARI sweet pepper 2.

Figure 3. Effect of variety on no. of primary branches plant^{-1} of sweet pepper at different DAT. A) No. of primary branches plant^{-1} at 35 DAT, B) No. of primary branches plant^{-1} at 50 DAT and C) No. of primary branches plant^{-1} at 65 DAT.

Effect of different levels of chitosan raw material powder on no. of primary branches plant^{-1} of sweet pepper

Soil mixed with different levels of chitosan raw material powder significantly influenced the number of primary branches plant^{-1} of sweet pepper at different days after transplanting (Figure 4). Experimental results showed that the highest number of primary branches plant^{-1} (2.33, 2.67 and 2.66) at 35, 50 and 65 DAT was recorded in $C_{3.}$ Whereas the lowest number of primary branches plant^{-1} (0.00, 1.92 and 2.25) at 35, 50 and 65 DAT was recorded in $C_{0.}$ Malekpoor *et al*. (2016) found that chitosan plays positive role in growth and development of basil in water deficient condition by reducing transpiration rate. When plants treated with Chitosan, its improved plant growth characters when compared to untreated plants.



Here: C_0= 0% chitosan raw material powder, C_1= 0.1% chitosan raw material powder, C_2= 0.5% chitosan raw material powder and C_3= 1% chitosan raw material powder.

Figure 4. Effect of different levels of chitosan raw material powder on no. of primary branches plant^{-1} of sweet pepper at different DAT. A) No. of primary branches plant^{-1} at 35 DAT, B) No. of primary branches plant^{-1} at 50 DAT and C) No. of primary branches plant^{-1} at 65 DAT.

Combined effect of variety and different levels of chitosan raw material powder on no. of primary branches plant^{-1} of sweet pepper

Combined effect of variety and different levels of chitosan raw material powder had shown significant effect on the number of primary branches plant^{-1} of sweet pepper at different days after transplanting (Table 5). Experimental results showed that the highest number of primary branches plant^{-1} (2.33, 3.00 and 2.83) at 35, 50 and 65 DAT was recorded in V_1C_3 which was statistically similar with V_2C_3 (2.33), V_1C_2 (2.33) and V_1C_1 (2.33) at 35 DAT. Whereas at 35 and 50 DAT the lowest number of primary branches plant^{-1} (0.00 and 1.50) was recorded in $V_2C_{0,}$ which was statistically similar with V_1C_0 (0.00) at 35 DAT. At 65 DAT the lowest number of primary branches plant^{-1} (2.17) was recorded in V_1C_0.

Table 5. Combined effect of variety and different levels of chitosan raw material powder on no. of primary branches plant^{-1} of sweet pepper at different DAT

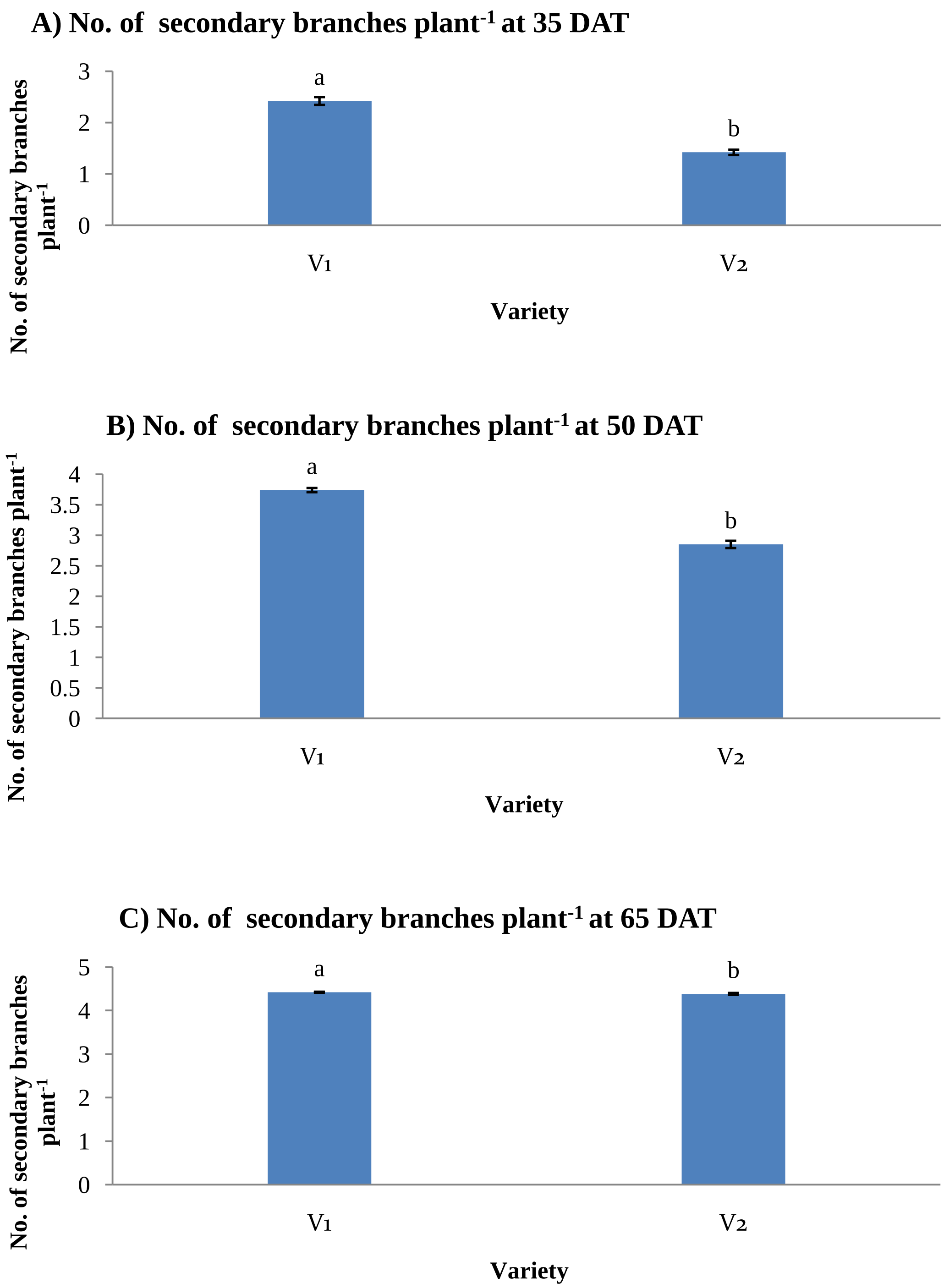
Treatments	No. of Primary branches plant^{-1} at		
	35 DAT	**50 DAT**	**65 DAT**
V_1C_0	0.00 d	2.33 d	2.17 d
V_1C_1	2.33 a	2.83 b	2.33 c
V_1C_2	2.33 a	2.67 c	2.50 b
$V1C_3$	2.33 a	3.00 a	2.83 a
V_2C_0	0.00 d	1.50 g	2.33 c
V_2C_1	1.67 c	2.00 f	2.33 c
V_2C_2	1.83 b	2.17 e	2.33 c
V_2C_3	2.33 a	2.33 d	2.50 b
$LSD_{0.05}$	0.10	0.13	0.08
CV(%)	5.94	5.21	3.14

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. Here; V_1: BARI sweet pepper 1, V_2: BARI sweet pepper 2, C_0= 0% chitosan raw material powder, C_1= 0.1% chitosan raw material powder, C_2= 0.5% chitosan raw material powder and C_3= 1% chitosan raw material powder.

4.3 No. of secondary branches plant^{-1}

Effect of variety on no. of secondary branches plant^{-1} of sweet pepper

Significant variation was recorded due to the effect of different varieties of sweet peppers cultivation in respect of secondary branches plant^{-1} at different days after transplanting (Figure 5). Experimental results showed that the highest number of secondary branches plant^{-1} (2.42, 3.74 and 4.42) at 35, 50 and 65 DAT respectively was recorded in $V_{1.}$ Whereas the lowest number of secondary branches plant^{-1} (1.42, 2.85 and 4.38) at 35, 50 and 65 DAT was recorded in V_2. The variation in number of secondary branches plant^{-1} may be due to the effect of varietal differences.

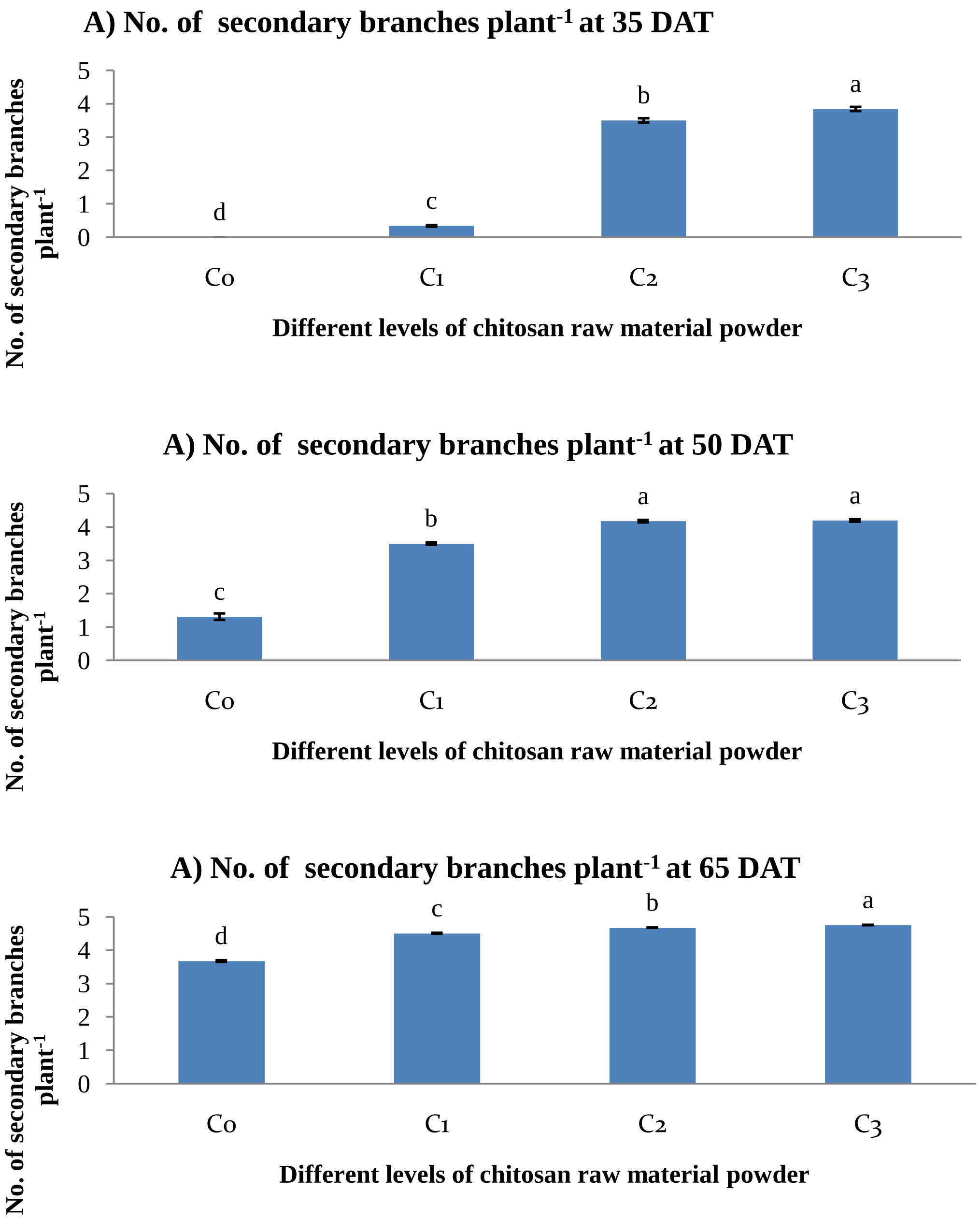


Here; V_1: BARI sweet pepper 1 and V_2: BARI sweet pepper 2.

Figure 5. Effect of variety on no. of secondary branches plant^{-1} of sweet pepper at different DAT. A) No. of secondary branches plant^{-1} at 35 DAT, B) No. of secondary branches plant^{-1} at 50 DAT and C) No. of secondary branches plant^{-1} at 65 DAT.

Effect of different levels of chitosan raw material powder on no. of secondary branches plant^{-1} of sweet pepper

Number secondary branches plant^{-1} of sweet pepper had showed significant differences at different days after transplanting due to the effect of different levels of chitosan raw material powder application (Figure 6). Experimental results showed that the highest number of secondary branches plant^{-1} (3.84, 4.19 and 4.75) at 35, 50 and 65 DAT was recorded in C_3 which was statistically similar with C_2 (4.17) at 50 DAT. Whereas the lowest number of secondary branches plant^{-1} (0.00, 1.31 and 3.67) at 35, 50 and 65 DAT was recorded in C_0.



Here: C_0= 0% chitosan raw material powder, C_1= 0.1% chitosan raw material powder, C_2= 0.5% chitosan raw material powder and C_3= 1% chitosan raw material powder.

Figure 6. Effect of different levels of chitosan raw material powder on no. of secondary branches plant^{-1} of sweet pepper at different DAT. A) No. of secondary branches plant^{-1} at 35 DAT B) No. of secondary branches plant^{-1} at 50 DAT and C) No. of secondary branches plant^{-1} at 65 DAT.

Combined effect of variety and different levels of chitosan raw material powder on no. of secondary branches plant^{-1} of sweet pepper

Number of secondary branches plant^{-1} of sweet pepper at different days after transplanting shown significant variation due to the combined effect of variety and different levels of chitosan raw material powder (Table 6). Experimental results showed that the highest number of secondary branches plant^{-1} (4.67, 4.67 and 4.83) at 35, 50 and 65 DAT was recorded in V_1C_3 which was statistically similar with V_1C_2 (4.67) at 50 DAT. Whereas the lowest number of secondary branches plant^{-1} (0.00, 0.00 and 3.33) was recorded in $V_2C_{0,}$ which was statistically similar with V_2C_1 (0.00) and V_1C_0 (0.00) at 35 DAT.

Table 6. Combined effect of variety and different levels of chitosan raw material powder on no. of secondary branches plant^{-1} of sweet pepper at different DAT

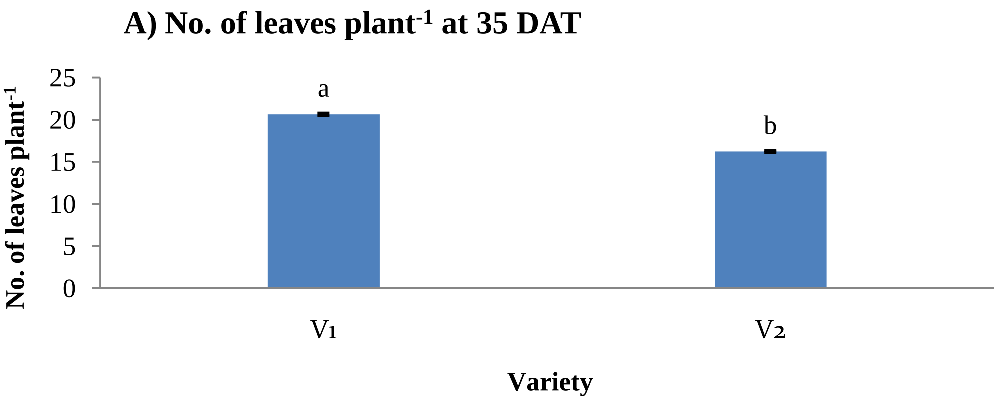
Treatments	Number of secondary branches plant^{-1} at		
	35 DAT	50 DAT	65 DAT
V_1C_0	0.00 f	2.63 e	4.00 d
V_1C_1	0.67 e	3.00 d	4.33 c
V_1C_2	4.33 b	4.67 a	4.67 b
$V1C_3$	4.67 a	4.67 a	4.83 a
V_2C_0	0.00 f	0.00 f	3.33 e
V_2C_1	0.00 f	4.00 b	4.67 b
V_2C_2	2.67 d	3.67 c	4.67 b
V_2C_3	3.00 c	3.71 c	4.67 b
$LSD_{0.05}$	0.06	0.08	0.07
CV(%)	3.37	2.53	1.43

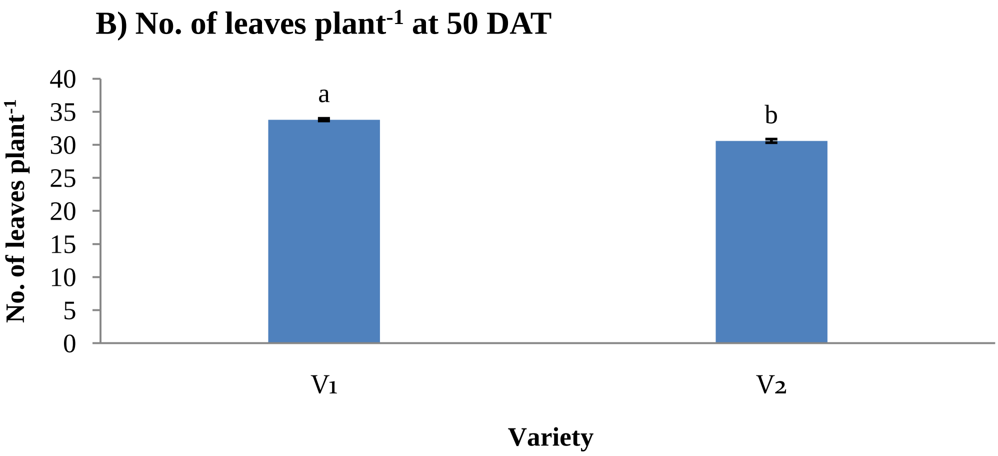
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Here; V_1: BARI sweet pepper 1, V_2: BARI sweet pepper 2, C_0= 0% chitosan raw material powder, C_1= 0.1% chitosan raw material powder, C_2= 0.5% chitosan raw material powder and C_3= 1% chitosan raw material powder.

4.4 No. of leaves plant^{-1}

Effect of variety on no. of leaves plant^{-1} of sweet pepper

Different varieties of sweet pepper had shown significant variation in respect of number of leaves plant^{-1} of sweet pepper at different days after transplanting (Figure 7). Experimental results showed that the highest number of leaves plant^{-1} (20.63 and 33.79) at 35, 50 DAT was recorded in $V_{1.}$ Whereas the lowest number of leaves plant^{-1} (16.21 and 30.58) at 35 and 50 DAT was recorded in V_2. The variation in number of secondary branches plant^{-1} may be due to the effect of varietal differences. Adisarwanto (2000) reporting that different varieties are able to survive with environmental conditions and can grow well with the superior properties possessed by their genetic materials, if planted in optimal conditions will achieve the potential results.



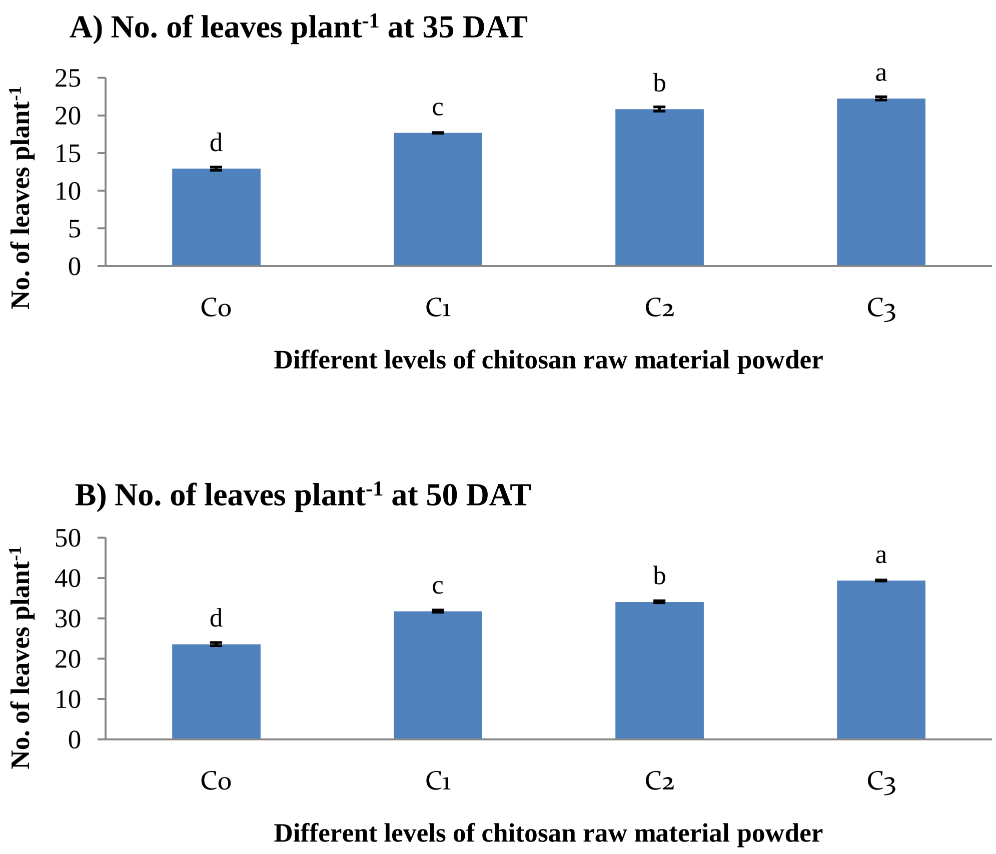


Here; V_1: BARI sweet pepper 1 and V_2: BARI sweet pepper 2.

Figure 7. Effect of variety on no. of leaves plant^{-1} of sweet pepper at different DAT. A) No. of leaves plant^{-1} at 35 DAT and B) No. of leaves plant^{-1} at 50 DAT.

Effect of different levels of chitosan raw material powder on no. of leaves plant^{-1} of sweet pepper

Application of different levels of chitosan raw material powder significantly influenced the number of leaves plant^{-1} of sweet pepper at different days after transplanting (Figure 8). Experimental results showed that the highest number of leaves plant^{-1} (22.25 and 39.34 a) at 35, 50 DAT was recorded in C_3. Whereas the lowest number of leaves plant^{-1} (12.92 and 23.58) at 35 and 50 DAT was recorded in C_0. Sathiyabama *et al.* (2016) reported that turmeric plants treated with chitosan, increased the number of leaves per plant and shoot height compared to the control treatment.



Here: C_0= 0% chitosan raw material powder, C_1= 0.1% chitosan raw material powder, C_2= 0.5% chitosan raw material powder and C_3= 1% chitosan raw material powder.

Figure 8. Effect of different levels of chitosan raw material powder on no. of leaves plant^{-1} of sweet pepper at different DAT. A) No. of leaves plant^{-1} at 35 DAT and B) No. of leaves plant^{-1} at 50 DAT.

Combined effect of variety and different levels of chitosan raw material powder on no. of leaves plant^{-1} of sweet pepper

Combined effect of variety and different levels of chitosan raw material powder had shown significant effect on the number of leaves plant^{-1} of sweet pepper (Table 7). Experimental results revealed that the highest number of leaves plant^{-1} (25.17 and 41.00) at 35 and 50 DAT was recorded in V_1C_3. Whereas the lowest number of leaves plant^{-1} (10.17 and 18.33) at 35 and 50 DAT was recorded in V_2C_0.

Table 7. Combined effect of variety and different levels of chitosan raw material powder on no. of leaves plant^{-1} of sweet pepper at different DAT

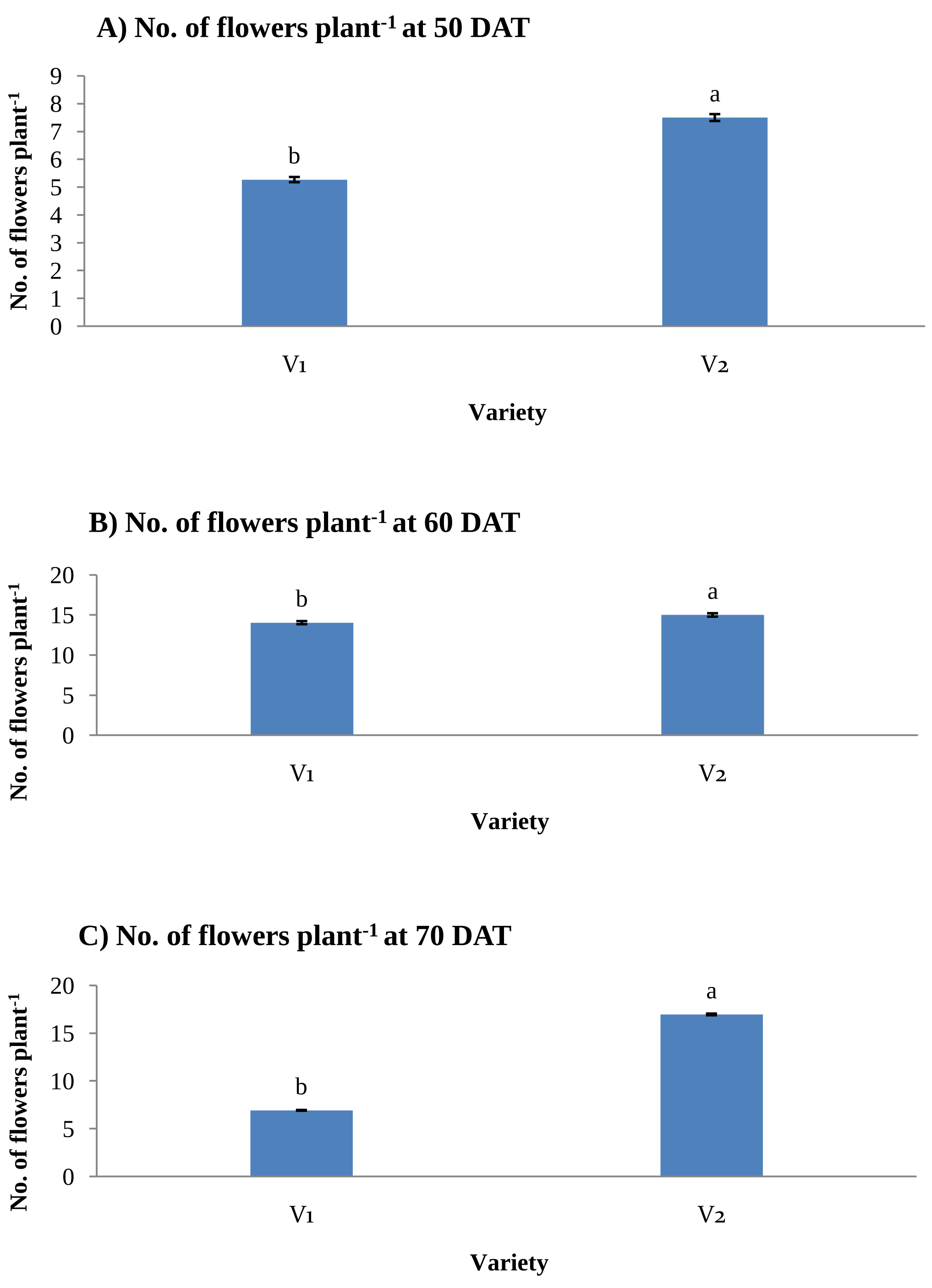
Treatments	No. of leaves plant^{-1} at	
	35 DAT	50 DAT
V_1C_0	15.67 f	28.83 e
V_1C_1	17.00 e	28.00 f
V_1C_2	24.67 b	37.33 b
$V1C_3$	25.17 a	41.00 a
V_2C_0	10.17 g	18.33 g
V_2C_1	18.33 d	35.50 c
V_2C_2	17.00 e	30.83 d
V_2C_3	19.33 c	37.67 b
$LSD_{0.05}$	0.43	0.22
CV(%)	2.20	1.26

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. Here; V_1: BARI sweet pepper 1, V_2: BARI sweet pepper 2, C_0= 0% chitosan raw material powder, C_1= 0.1% chitosan raw material powder, C_2= 0.5% chitosan raw material powder and C_3= 1% chitosan raw material powder.

4.5 No. of flowers plant^{-1}

Effect of variety on no. of flowers plant^{-1} of sweet pepper

The primary purpose of the flower is reproduction. Since the flowers are the reproductive organs of the plant, they mediate the joining of the sperm, contained within pollen, to the ovules contained in the ovary. Pollination is the movement of pollen from the anthers to the stigma. In this experiment different varieties cultivation had shown significant variation in respect of number of flowers plant^{-1} of sweet pepper at different days after transplanting (Figure 9). The highest number of flowers plant^{-1} (7.50, 15.00 and 16.96) at 50, 60 and 70 DAT was recorded in V_2. Whereas the lowest number of flowers plant^{-1} (5.27, 14.04and 6.92) at 50, 60 and 70 DAT was recorded in V_1. The higher number of flowers plant^{-1} is the result of genetic makeup of the crop and environmental conditions which play a remarkable role towards the final yield of the crop.

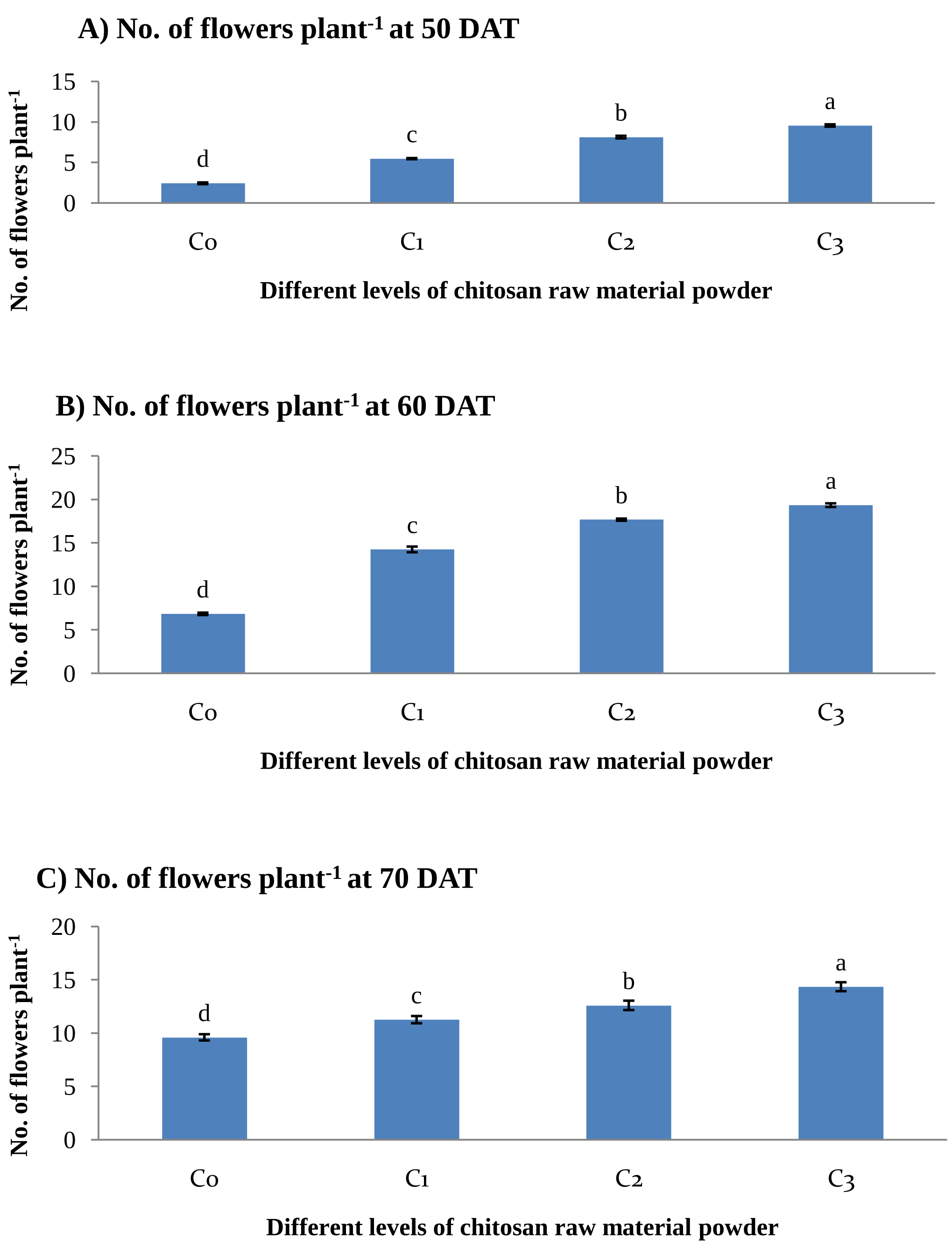


Here; V_1: BARI sweet pepper 1 and V_2: BARI sweet pepper 2.

Figure 9. Effect of variety on no. of flowers plant^{-1} of sweet pepper at different DAT. A) No. of flowers plant^{-1} at 50 DAT, B) No. of flowers plant^{-1} at 60 DAT and C) No. of flowers plant^{-1} at 70 DAT.

Effect of different levels of chitosan raw material powder on no. of flowers plant^{-1} of sweet pepper

Application of different chitosan raw material powder to the soil significantly influenced on the number of flowers plant^{-1} at different days after transplanting (Figure 10). Experimental results showed that the highest number of flowers plant^{-1} (9.55, 19.34 and 14.34) at 50, 60 and 70 DAT was recorded in C_3. Whereas the lowest number of flowers plant^{-1} (2.42, 6.84 and 9.59) at 50, 60 and 70 DAT was recorded in C_0. Pandey *et al*. (2018) reported that chitosan acts as a carrier promoting slow release of fertilizer and improves water retention of soil which influenced plant growth and development. Salachna and Zawadzinska (2014) also reported that chitosan treated plants exhibited more number of leaves, flowers, corms and earliness in flowering. Ohta *et al.* (2001) also reported that the application of soil mixed with chitosan 1%w/w at sowing remarkably increased flower numbers of *Eustoma grandiflorum*.



Here: C_0= 0% chitosan raw material powder, C_1= 0.1% chitosan raw material powder, C_2= 0.5% chitosan raw material powder and C_3= 1% chitosan raw material powder.

Figure 10. Effect of different levels of chitosan raw material powder on no. of flowers plant^{-1} of sweet pepper at different DAT. A) No. of flowers plant^{-1} at 50 DAT, B) No. of flowers plant^{-1} at 60 DAT and C) No. of flowers plant^{-1} at 70 DAT.

Combined effect of variety and different levels of chitosan raw material powder on no. of flowers plant^{-1} of sweet pepper

Different varieties along with different levels of chitosan raw material powder treated pot significantly influenced the number of flowers plant^{-1} of sweet pepper at different days after transplanting (Table 8). Experimental results showed that, the highest number of flowers plant^{-1} (11.43, 22.17 and 20.00) at 50, 60 and 70 DAT was recorded in V_2C_3. Whereas the lowest number of flowers plant^{-1} (1.00, 5.00 and 5.67) at 50, 60 and 70 DAT was recorded in $V_1C_{0.}$

Table 8. Combined effect of variety and different levels of chitosan raw material powder on no. of flowers plant^{-1} of sweet pepper at different DAT

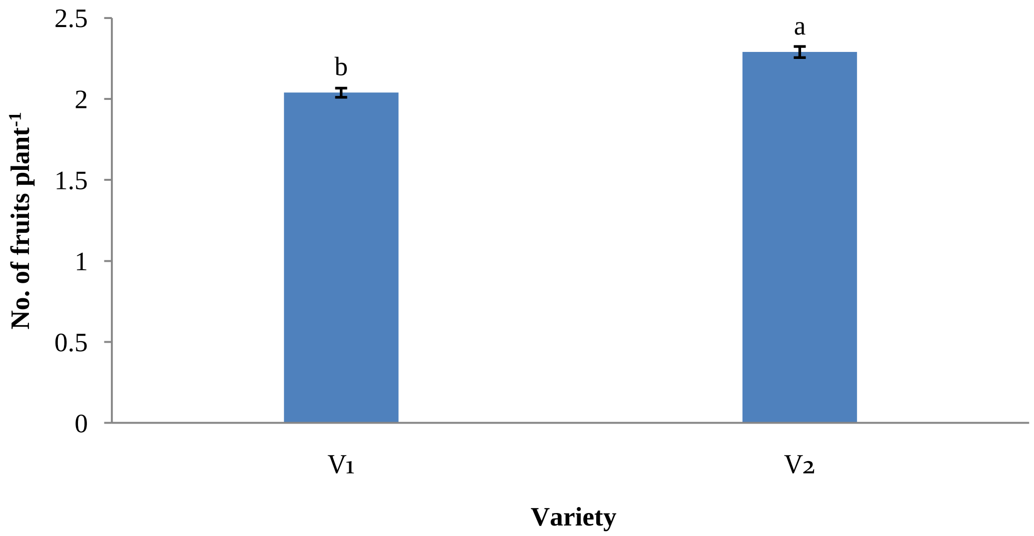
Treatments	Flowers plant^{-1} at		
	50 DAT	**60 DAT**	**70 DAT**
V_1C_0	1.00 h	5.00 h	5.67 g
V_1C_1	6.42 d	18.67 c	6.67 f
V_1C_2	6.00 e	16.00 e	6.67 f
$V1C_3$	7.67 c	16.50 d	8.67 e
V_2C_0	3.83 g	8.67 g	13.50 d
V_2C_1	4.50 f	9.83 f	15.83 c
V_2C_2	10.24 b	19.33 b	18.50 b
V_2C_3	11.43 a	22.17 a	20.00 a
$LSD_{0.05}$	0.39	0.23	0.23
CV(%)	2.52	1.48	1.80

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. Here; V_1: BARI sweet pepper 1, V_2: BARI sweet pepper 2, C_0= 0% chitosan raw material powder, C_1= 0.1% chitosan raw material powder, C_2= 0.5% chitosan raw material powder and C_3= 1% chitosan raw material powder.

4.6 No. of fruits plant^{-1}

Effect of variety on no. of fruits plant^{-1} of sweet pepper

Number of fruits plant^{-1} showed significant variation due to cultivation of different sweet pepper varieties (Figure 11). Experimental results showed that, the highest number of fruits plant^{-1} (2.29) was recorded in V_2. Whereas the lowest number of fruits plant^{-1} (2.04) was recorded in V_1. The variations in terms of number of number of fruits plant^{-1} of sweet pepper among all the varieties due to reason of difference in the genetic makeup of the variety, which is primarily influenced by heredity. Chate *et al*. (2012) evaluated performance of nine cultivars of sweet pepper (*Capsicum annuum* L.) under 50 % shade net house and reported that the cultivar Bombi performed better in number of fruits plant^{-1}, average weight of fruit and yield m^{-2}, while it required more number of days for first harvesting.



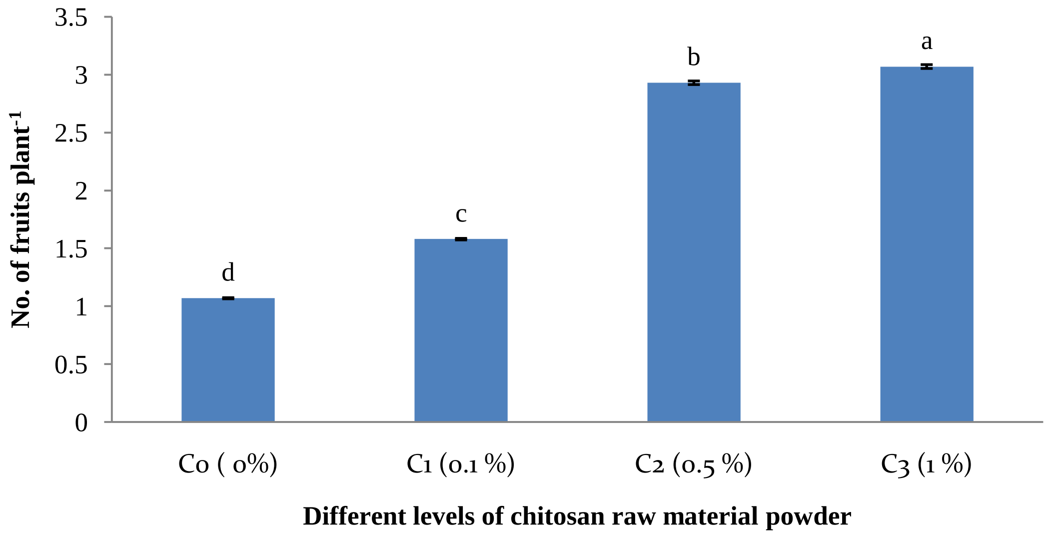
Here; V_1: BARI sweet pepper 1 and V_2: BARI sweet pepper 2.

Figure 11. Effect of variety on no. of fruits plant^{-1} of sweet pepper

Effect of different levels of chitosan raw material powder on no. of fruits plant^{-1} of sweet pepper

Application of different levels of chitosan raw material powder had shown significant effect on the fruits plant^{-1} of sweet pepper (Figure 12). Experimental results showed that, the highest number of fruits plant^{-1} (3.07) was recorded in C_3.

Whereas the lowest number of fruits plant^{-1} (1.07) was recorded in C_0. That was similar to the findings of Chookhongkha *et al*. (2012) who reported that chilli seeds cultured in soil containing high molecular weight chitosan at 1.0 per cent, resulted in significantly highest fresh fruit weight per plant, fruit number per plant, seed number per fruit and seed weight in chilli.



Here: C_0= 0% chitosan raw material powder, C_1= 0.1% chitosan raw material powder, C_2= 0.5% chitosan raw material powder and C_3= 1% chitosan raw material powder.

Figure 12. Effect of different levels of chitosan raw material powder on no. of fruits plant^{-1} of sweet pepper

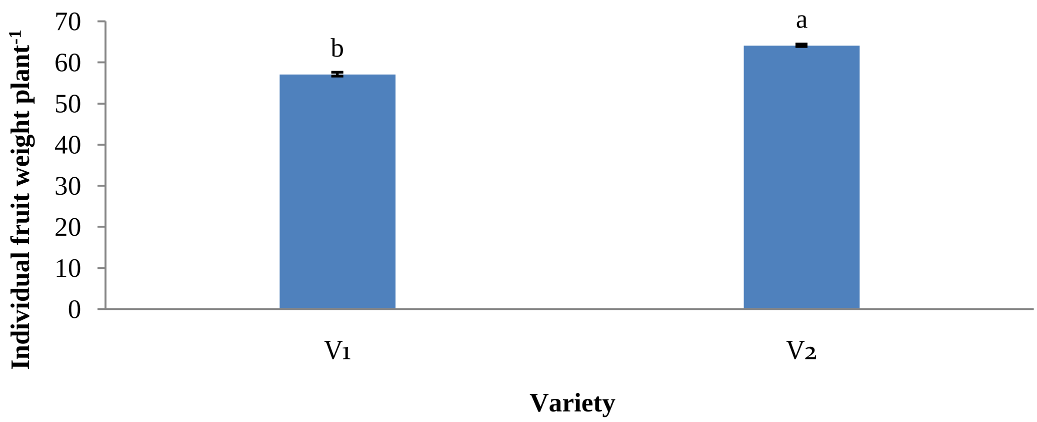
Combined effect of variety and different levels of chitosan raw material powder on no. of fruits plant^{-1} of sweet pepper

Significant variation was observed due to the combined effect of variety and different levels of chitosan raw material powder in terms of number of fruits plant^{-1} of sweet pepper (Table 9). Experimental results showed that, the highest number of fruits plant^{-1} (3.29) was recorded in V_2C_3. Whereas the lowest number of fruits plant^{-1} (1.00) was recorded in V_1C_0.

4.7 Individual fruit weight plant^{-1}

Effect of variety on individual fruit weight plant^{-1} of sweet pepper

Individual fruit weight plant^{-1} of sweet pepper showed significant variation due to the effect different sweet pepper varieties cultivation (Figure 13). Experimental results showed that, the highest individual fruit weight plant^{-1} (64.11 g) was recorded in V_2. Whereas the lowest individual fruit weight plant^{-1} (57.08 g) was recorded in V_1. Aruna and Sudagar (2010) also found similar result which supported the present finding who reported that, among the three capsicum varieties, Arka Mohini recorded increased fruit weight (199.6 g) and length of the fruit (10.54 cm). In case of Arka Basant, the girth of the fruit was high (17.70 cm) followed by Arka Mohini (15.50 cm) but it recorded the lowest individual fruit weight of 82.82 g.

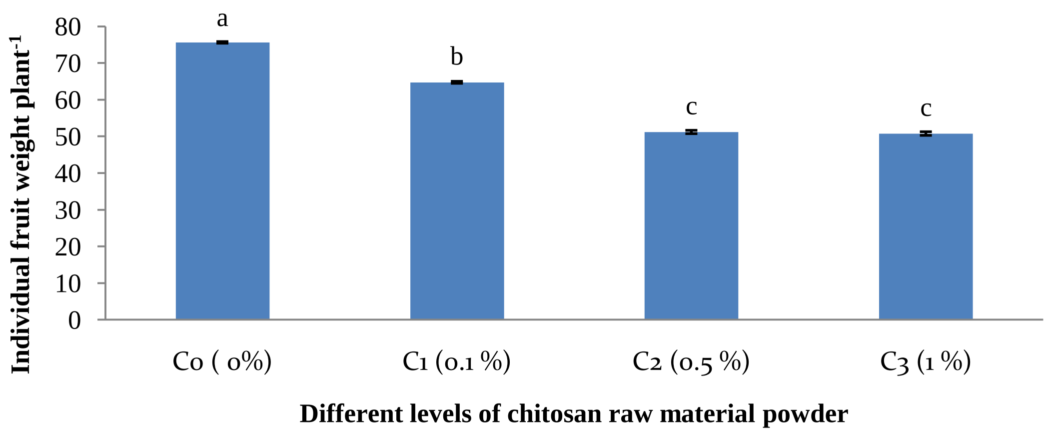


Here; V_1: BARI sweet pepper 1 and V_2: BARI sweet pepper 2.

Figure 13. Effect of variety on individual fruit weight plant^{-1} of sweet pepper

Effect of different levels of chitosan raw material powder on individual fruit weight plant^{-1} of sweet pepper

Individual fruit weight plant^{-1} of sweet pepper was significantly influenced due to the application of different levels of chitosan raw material powder (Figure 14). Experimental results showed that, the highest individual fruit weight plant^{-1} (75.63 g) was recorded in C_0. Whereas the lowest individual fruit weight plant^{-1} (50.78 g) was recorded in C_3 which was statistically similar with C_2 (51.21).



Here: C_0= 0% chitosan raw material powder, C_1= 0.1% chitosan raw material powder, C_2= 0.5% chitosan raw material powder and C_3= 1% chitosan raw material powder.

Figure 14. Effect of different levels of chitosan raw material powder on individual fruit weight plant^{-1} of sweet pepper

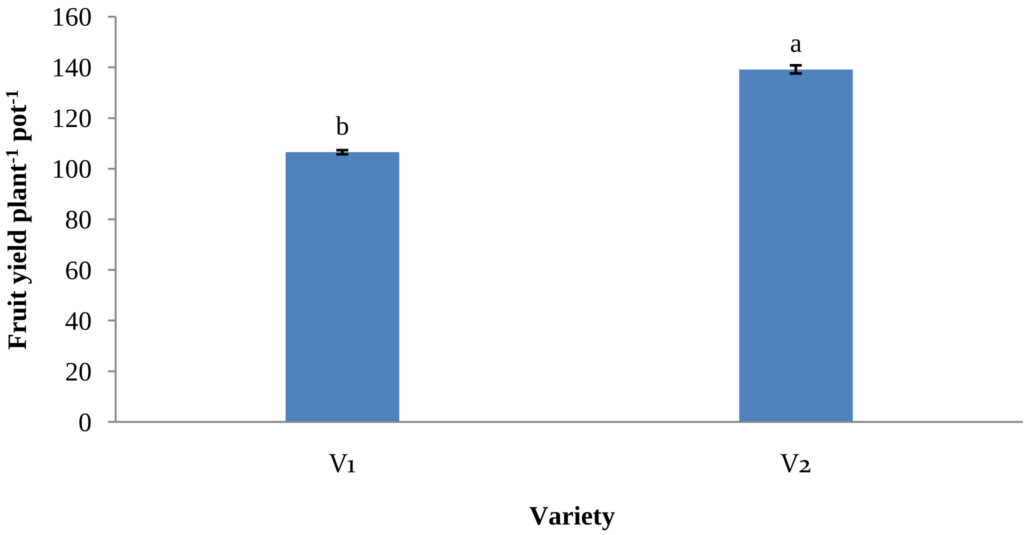
Combined effect of variety and different levels of chitosan raw material powder on individual fruit weight plant^{-1} of sweet pepper

Combined effect of variety and different levels of chitosan raw material powder showed significant variation in terms of individual fruit weight plant^{-1} of sweet pepper (Table 9). Experimental results showed that, the highest individual fruit weight plant^{-1} (77.13 g) was recorded in V_2C_0 which was statistically similar with V_1C_0 (74.14 g). Whereas the lowest individual fruit weight plant^{-1} (44.15 g) was recorded in V_1C_3 which was statistically similar with V_1C_2 (46.05).

4.8 Fruit yield plant^{-1} pot^{-1}

Effect of variety on fruit yield plant^{-1} pot^{-1} of sweet pepper

Significant variation was recorded for different varieties cultivation of bell pepper in terms of fruit yield plant^{-1} pot^{-1} (Figure 15). Experimental result showed that, the highest fruit yield plant^{-1} pot^{-1} (139.18 g) was recorded in V_2. Whereas the lowest fruit yield plant^{-1} pot^{-1} (57.08 g) was recorded in V_1. Syafruddin (2017) each variety has genetic differences that can affect growth and yield and the adaptability of a variety varies. Singh *et al.* (2007) reported that capsicum variety ‘California Wonder’ gave a yield of 6.5 kg m^{-2} fruits with average weight of 54 g under naturally ventilated polyhouse as compared to no fruit yield in open field. Verma *et al.* (2003) evaluated the fruits of F1 hybrids of *Capsicum* and found significant difference among the hybrids in terms of length, width, weight, volume of fruits, number of seeds per fruit, flesh thickness, total soluble solids and crop yield plant^{-1}. The hybrid, HC 201 x EC 203602 recorded the highest yield followed by Yolo Wonder x EC 143570 and Yolo Wonder × HC 201.

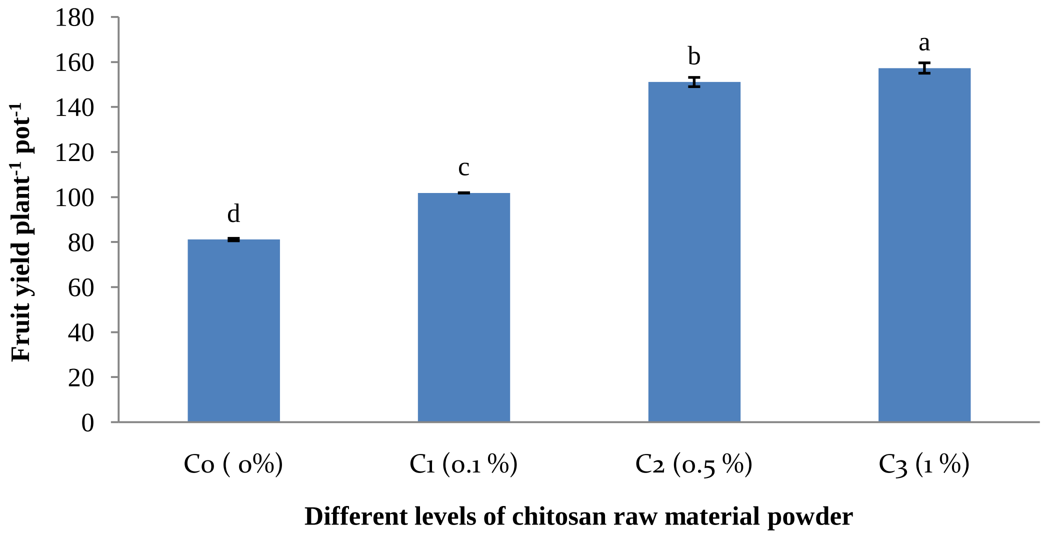


Here; V_1: BARI sweet pepper 1 and V_2: BARI sweet pepper 2.

Figure 15. Effect of variety on fruit yield plant^{-1} pot^{-1} of sweet pepper

Effect of different levels of chitosan raw material powder on fruit yield plant^{-1} pot^{-1} of sweet pepper

Yield plant^{-1} pot^{-1} of sweet pepper showed significant differences for different levels of chitosan raw material powder application (Figure 16). Experimental result showed that, the highest fruit yield plant^{-1} pot^{-1} (157.29 g) was recorded in C_3. Whereas the lowest fruit yield plant^{-1} pot^{-1} (81.14 g) was recorded in C_0. Mondal *et al*. (2012) reported that the application of chitosan in early growth stage had tremendous effect on the growth and development in okra. Kowalski *et al.* (2006) stated that chitosan has also been used to increase yield and tuber quality of micro propagated greenhouse-grown potatoes.



Here: C_0= 0% chitosan raw material powder, C_1= 0.1% chitosan raw material powder, C_2= 0.5% chitosan raw material powder and C_3= 1% chitosan raw material powder.

Figure 16. Effect of different levels of chitosan raw material powder on fruit yield plant^{-1} pot^{-1} of sweet pepper

Combined effect of variety and different levels of chitosan raw material powder on fruit yield plant^{-1} pot^{-1} of sweet pepper

Cultivation of different varieties along with different levels of chitosan raw material powder treated pot varied significantly due to their combined effect in terms of fruit yield plant^{-1} pot^{-1} of sweet pepper (Table 9). Experimental results showed that, the highest fruit yield plant^{-1} pot^{-1} (188.43 g) was recorded in V_2C_3. Whereas the lowest fruit yield plant^{-1} pot^{-1} (74.14 g) was recorded in V_1C_0.

Table 9. Combined effect of variety and different levels of chitosan raw material powder on no. of fruits plant^{-1}, individual fruit weight plant^{-1} and fruit yield plant^{-1} pot^{-1} of sweet pepper

Treatments	Number of fruits plant^{-1}	Individual fruit weight plant^{-1}	Fruit yield plant^{-1} pot^{-1}
V_1C_0	1.00 g	74.14 a	74.14 f
V_1C_1	1.59 e	63.96 b	100.71 d
V_1C_2	2.71 d	46.05 d	125.00 c
V_1C_3	2.87 c	44.15 d	126.14 c
V_2C_0	1.14 f	77.13 a	88.14 e
V_2C_1	1.57 e	65.55 b	103.00 d
V_2C_2	3.14 b	56.36 c	177.14 b
V_2C_3	3.29 a	57.41 c	188.43 a
$LSD_{0.05}$	0.07	3.63	5.63
CV(%)	2.83	5.56	4.25

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. Here; V_1: BARI sweet pepper 1, V_2: BARI sweet pepper 2, C_0= 0% chitosan raw material powder, C_1= 0.1% chitosan raw material powder, C_2= 0.5% chitosan raw material powder and C_3= 1% chitosan raw material powder.

4.9 Chemical properties of pot soils after harvesting

These data were statistically analyzed. Only pot soil from different treatments were collected harvesting. Then chemical compositions of soil like soil pH, organic carbon, organic matter and total nitrogen percentage were determined and compared with initial soil parameters.

pH and organic carbon (%)

Form the table 10 it was noticed that application of different level of chitosan raw material powder influenced soil pH and total nitrogen percentage from initial level (5.8 and 0.04 %). Among different treatments, C_3 treatment (1 % chitosan raw material powder) increasing soil pH (6.5) and total nitrogen (0.12 %) comparable control treatment due to reason that chitosan raw material powder has higher pH which influenced the soil pH whereas application of chitosan raw material powder increasing the nutrient supplying capacity to the soil result in increasing total nitrogen percentage in the pot soil.

Table 10. Effects of different treatments on pH and % total nitrogen of pot soil after harvesting of sweet pepper

Treatments	**pH**		**% total nitrogen**	
	Initial	**After**	**Initial**	**After**
C_0	5.8	5.60 d	0.04	0.02 d
C_1	5.8	6.00 c	0.04	0.05 c
C_2	5.8	6.30 b	0.04	0.11 b
C_3	5.8	6.50 a	0.04	0.12 a
$LSD_{(0.05)}$	0	0.18	0	0.003
CV(%)	0	1.97	0	2.34

Here: C_0= 0% chitosan raw material powder, C_1= 0.1% chitosan raw material powder, C_2= 0.5% chitosan raw material powder and C_3= 1% chitosan raw material powder.

Organic carbon and organic matter

Chitosan raw material powder contents 7.52 % organic carbon and 12.96 % organic matter. From the table 11 it was noticed that, the application of different level of chitosan raw material powder influenced organic carbon percentages and organic matter comparable to control treatment. The maximum organic carbon (0.76 %) and organic matter (1.31 %) were recorded in C_3 treatment comparable to control treatment. More the application of chitosan raw material powder more the organic carbon and organic matter present in the soil. Higher amount of organic carbon and organic matter influences nutrient uptake as a result higher plant growth and yield were obtained.

Table 11. Effects of different treatments on pH and % total nitrogen of pot soil after harvesting of sweet pepper

Treatments	Organic carbon (%)		Organic matter (%)	
	Initial	After	Initial	After
C_0	0.5	0.50 c	0.87	0.87 d
C_1	0.5	0.63 b	0.87	1.09 c
C_2	0.5	0.75 a	0.87	1.20 b
C_3	0.5	0.76 a	0.87	1.31 a
$LSD_{(0.05)}$	0	0.02	0	0.03
CV(%)	0	2.62	0	2.16

Here: C_0= 0% chitosan raw material powder, C_1= 0.1% chitosan raw material powder, C_2= 0.5% chitosan raw material powder and C_3= 1% chitosan raw material powder.

CHAPTER V

SUMMARY AND CONCLUSION

Our experimental results suggested that different varieties and different levels of chitosan raw material powder greatly influenced the growth and yield of sweet peppers. The highest fruit yield $plant^{-1}$ pot^{-1} (139.18 g) was recorded in V_2 (BARI sweet pepper 2) treatment. Application of different levels of chitosan helps to develop plant growth and influenced soil nutrient characteristics. But all chitosan levels don't have same ability to contribute to yield and development of sweet peppers. In this experiment 1 % chitosan raw material powder (C_3) played a major role for the plant growth and yield of sweet peppers. The highest number of fruits $plant^{-1}$ (3.07), fruit yield $plant^{-1}$ pot^{-1} (157.29 g), soil pH (6.5), soil total nitrogen content (0.12 %), organic carbon (0.76 %) and organic matter (1.31 %) were recorded in C_3 treatment comparable to control treatment. Sweet pepper cultivation in absence of chotosan raw material powder (C_0) gradually decreasing yield and soil characteristics and the lowest fruit yield $plant^{-1}$ pot^{-1} (74.14 g) was recorded in $V_1C_{0.}$ Increasing chitosan levels influenced plant growth and development and the highest fruit yield $plant^{-1}$ pot^{-1} (188.43 g) was recorded in BARI sweet pepper 2 cultivation along with application of 1 % chitosan raw material powder (V_2C_3).

Recommendation

As we conducted our experiment, with only 4 levels of chitosan raw material powder and two sweet pepper variety, it is difficult to recommended the appropriate dose of chitosan raw material powder for the influenced of growth and development of sweet peppers. However according to the findings of our study we are suggesting the following recommendations:

i. Among the four chitosan levels (0 %, 0.1 %, 0.5 % and 1 % chitosan raw material powder) 1 % performed best and influenced the growth, yield and soil characteristics in sweet pepper cultivation.
ii. Varietal trials need to be investigated.
iii. However, more experiment should be conducted at different chitosan levels with more varieties to draw a final conclusion regarding the effect of

chitosan raw material powder applications for the increasing growth and yield of sweet peppers.

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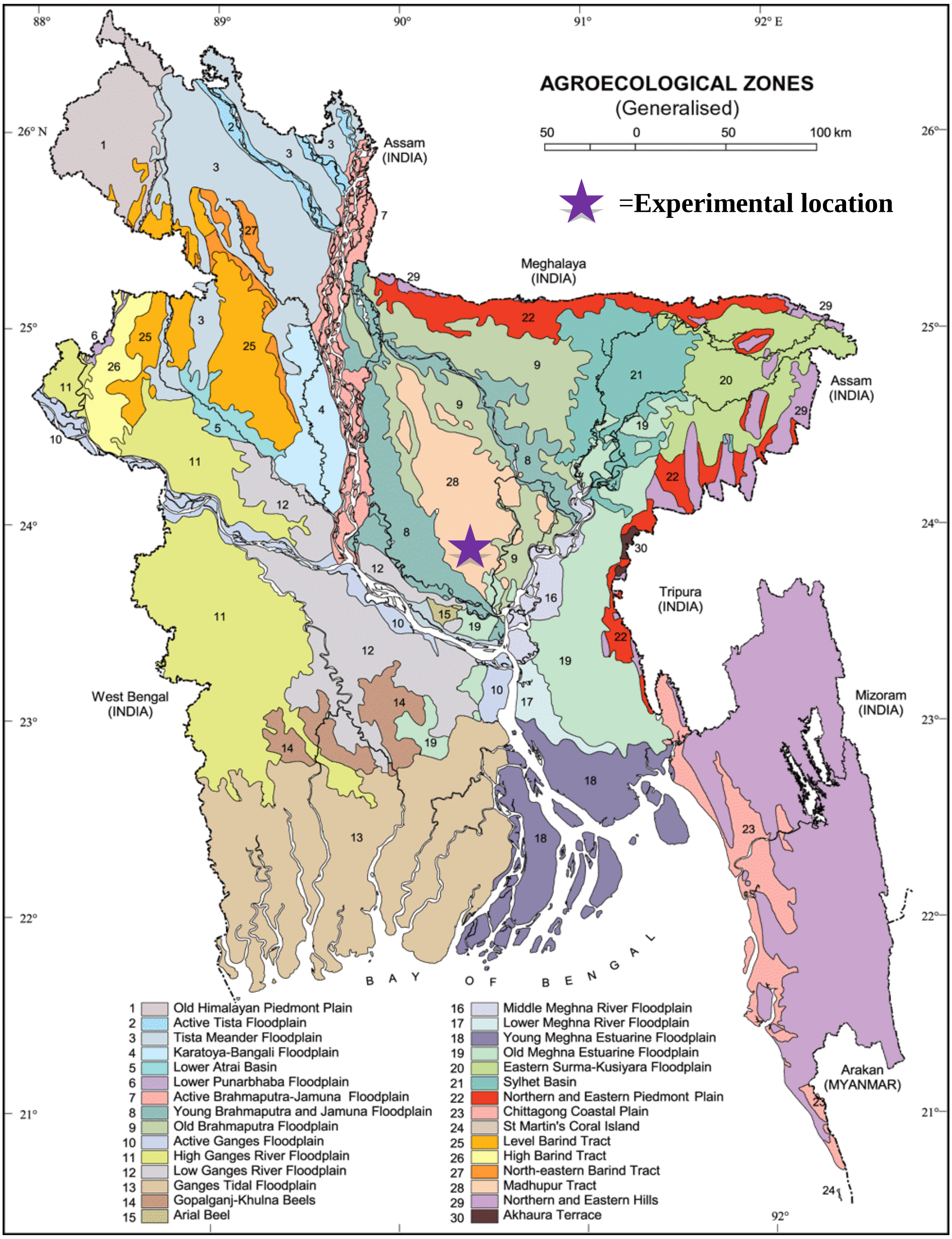
APPENDICES

Appendix I. Map showing the experimental location under study



Appendix II. Monthly meteorological information during the period from November, 2019 to April 2020

Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2019	October	31.2	23.9	76	52
	November	29.6	19.8	53	00
	December	28.8	19.1	47	00
	January	25.5	13.1	41	00
2020	February	25.9	14	34	7.7
	March	31.7	20.2	60	73
	April	32.7	23.8	74	168

(Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix III. Analysis of variance of the data of plant height of sweet pepper at different DAT

Mean square of plant height at			
Source	**Df**	35 DAT	50 DAT
Replication	6	0.143	0.083
Variety (V)	1	397.458**	575.682**
Chitosan (C)	3	110.591**	65.158**
V×C	3	60.597**	11.083**
Error	42	0.143	0.083

**: Significant at 0.01 level of probability

Appendix IV. Analysis of variance of the data of number of no. of primary branches plant^{-1} of sweet pepper at different DAT

Mean square of no. of primary branches plant^{-1} at				
Source	**Df**	35 DAT	50 DAT	65 DAT
Replication	6	1.1774	7.00779	0.11979
Variety (V)	1	16.2553**	0.09085**	0.45322**
Chitosan (C)	3	0.4074**	1.38445**	0.16365**
V×C	3	0.0091**	0.00829**	0.00574**
Error	42			

** : Significant at 0.01 level of probability

Appendix V. Analysis of variance of the data of number of no. of secondary branches plant^{-1} of sweet pepper at different DAT

Mean square of no. of secondary branches plant^{-1} at				
Source	**Df**	35 DAT	50 DAT	65 DAT
Replication	6	14.0000	11.2412	0.02529
Variety (V)	1	57.6904**	25.8407**	3.47932**
Chitosan (C)	3	2.3256**	7.7073**	0.68002**
V×C	3	0.0042**	0.0070**	0.00395**

** : Significant at 0.01 level of probability

Appendix VI. Analysis of variance of the data of no. leaves plant^{-1} of sweet pepper at different DAT

Mean square of no. leaves plant^{-1} at			
Source	**Df**	35 DAT	50 DAT
Replication	6	0.202	0.220
Variety (V)	1	273.510**	144.033**
Chitosan (C)	3	239.499**	601.761**
V×C	3	54.609**	208.468**
Error	42	0.164	0.163

**: Significant at 0.01 level of probability

Appendix VII. Analysis of variance of the data of no. flowers plant^{-1} of sweet pepper at different DAT

Mean square of no. flower plant^{-1} at				
Source	**Df**	50 DAT	60 DAT	70 DAT
Replication	6	0.014	0.094	0.09
Variety (V)	1	67.791**	12.835**	1410.52**
Chitosan (C)	3	137.977**	430.301**	56.81**
V×C	3	26.206**	153.049**	12.28**
Error	42	0.124	0.046	0.05

**: Significant at 0.01 level of probability

Appendix VIII. Analysis of variance of no. of fruits plant^{-1}, individual fruit weight plant^{-1} and fruit yield plant^{-1} pot^{-1} of sweet pepper

Mean square of				
Source	**Df**	Number of fruits plant^{-1}	Individual fruit weight plant^{-1}	Fruit yield plant^{-1} pot^{-1}
Replication	6	0.0085	1.34	36.8
Variety (V)	1	0.8502**	692.83**	14950.4**
Chitosan (C)	3	13.7407**	1996.91**	19424.8**
V×C	3	0.1692**	111.50**	2949.4**
Error	42	0.0037	11.35	27.3

** : Significant at 0.01 level of probability

Appendix IX. Analysis of variance of the data of pH, percentage of total nitrogen, percentage of organic carbon and percentage of organic matter

Mean square of					
Source	**Df**	**pH**	**% total nitrogen**	**Organic carbon (%)**	**Organic matter (%)**
Treatment	3	0.43200**	5.71E-03**	0.04172**	0.09719**
Error	52	0.01444	3.222E-06	0.00028	0.00054

**: Significant at 0.01 level of probability

PLATES

Plate 1. Lay out of the experiment

Plate 2. Picture showing number of fruits plant^{-1}