Performance of Modified Chitosan Treated Tomato (*Lycopersicon esculentum*) Seedlings on the Growth and Yield of Tomato

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Performance of Modified Chitosan Treated Tomato (*Lycopersicon esculentum*) Seedlings on the Growth and Yield of Tomato

BY

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CERTIFICATE

This is to certify that thesis entitled, ***"Performance of Modified Chitosan Treated Tomato (Lycopersicon esculentum) Seedlings on the Growth and Yield of Tomato"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in SOIL SCIENCE, embodies the result of a piece of bona fide research work carried out by MD. ARIFUR RAHMAN, Registration No. 10-03793 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 been duly acknowledged.

Dated: December, 2015
Place: Dhaka, Bangladesh

Dr. Mohammad Issak
Supervisor

Dedicated to
My Beloved Parents

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ABSTRACT

A pot experiment was conducted at the net-house of Sher-e-Bangla Agricultural University, Dhaka, during the period from October 2015 to March 2016 to investigate the effect of modified chitosan on seedling morphological characters, growth and reproductive characters and yield performance of tomato cv. BARI tomato-15. The experiment was designed with five treatments using four level of modified chitosan in the seedbed soil (10 kg of soils per pot). The used treatments were T_1 (control), T_2 (50 g modified chitosan/pot), T_3 (100 g modified chitosan/pot), T_4 (150 g modified chitosan/pot) and T_5 (200 g modified chitosan/pot). The experiment was laid out in earthen pots arranged in a randomized complete block design (RCBD) with three replications. Application of modified chitosan increased seedling height, fresh and dry weight of seedlings, soil pH, organic carbon (%), organic matter (%), number of flowers/ plant, fruits/plant, fruit size and fruit yield over control. Most of the morpho-physiological, reproductive and yield attributes were increased with increasing doses of modified chitosan, whereas control plants showed the lowest value of the above parameters. Most of the morphological, growth and reproductive attributes were recorded maximum in the T_4 and the highest fruit yield was recorded in the T_5 treatments. It might be due to the morpho-physiological changes and increased number of fruits/plant. Therefore, application of modified chitosan at 150g or 200g/pot (10 kg soils) could be used for getting quality seedling, leading to maximizing the tomato fruit yield.

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SOME COMMONLY USED ABBREVIATION

FULL WORD	ABBREVIATION
And others	et al
Bangladesh Bureau of Statistics	BBS
Bangladesh Institute of Nuclear Agriculture	BINA
Completely Randomized Design	CRD
Cultivar	cv.
Degree Celcius	^{o}C
Duncans Multiple Range Test	DMRT
ed est (means That is)	i.e.
Figure	Fig.
Flower per plant	FlPP
Food and Agriculture Organization	FAO
Fruit per bud	FPB
Fruit yield per plant	FYPP
Fruiting bud per plant	FBPP
Gibberellic Acid	GA3
Gram	g
Micro gram	µg
Micro mol	µM
Milligram/litre	mgL^{-1}
Namely	Viz.
Negative logarithm of hydrogen ion	pH
Parts/million	ppm
Percentage	%
Seedbed soil organic carbon	SSOC
Seedbed soil organic matter	SSOM
Seedbed soil pH	SSpH
Seedling dry weight	SdDW
Seedling height	SdH
Single fruit weight	SFW
Species (plural number)	spp.
Variety	var.

CHAPTER I
INTRODUCTION

Tomato (*Lycopersicon esculentum*) is one of the most popular and nutritious vegetables in Bangladesh as well as in the world. It belongs to the family Solanaceae. It is widely grown not only in Bangladesh but also in many countries of the world for its taste and nutritional status. In Bangladesh, it ranks 2nd which is next to potato and top the list of canned vegetables (BBS, 2009). Although the total cultivated area and production of tomato in our country have increased gradually over the last few years but the production (2009-10) is still very low compared to the world yield as per FAO (2012). In Bangladesh it is cultivated as winter vegetable (except summer tomato which is cultivated small extent), which occupies on area of 59,000 acres of land with annual production of about 1,90,000 tons where per acre yield is 3,220 kg (BBS, 2011).

It is a rich source of minerals and vitamins. One hundred grams of tomato contain 93.1 g water, 0.7 g fiber, 3.6 g carbohydrate, 0.1 g fat, 23 kilocalorie energy, 0.07 mg vitamin A, 0.01 mg vitamin B, 31 mg vitamin C, 20 mg Ca, 1.8 mg Fe and 129 µg, carotene. With the increase of population, the demand of tomato in our country is increasing day by day. By producing more tomato we can earn a considerable amount of foreign exchange through exporting it. Further, tomato has diversified use like salad, soup and processed into valuable products like Ketchup, Sauce, Conserved Puree, Marmalade, Chutney, Jelly, Jam, Pickles, Juice, Paste, Powder and many other products (Ahmed, 1979; Bose and Som, 1990). So, by increasing tomato producing area, we can fulfill our demand but due to limitation of lands, it is not possible. The most logical way to increase the total production at the national level from our limited land resources is to increase yield/unit area and increase tomato cropping intensity.

Tomato is considered to be a day neutral plant. The crop performs better under an average monthly temperature of 20-25°C. But commercially, it may grow at temperature ranging from 15-27°C (Haque *et al.*, 1999). Plant could set fruit abundantly when the night temperature is between 15° and 20°C and the day temperature at about 22-25°C (Kalloo, 1985). In Bangladesh, congenial atmosphere remains for tomato production during November to March. So, tomato is widely grown in Bangladesh usually in winter season. High temperature during day and night above 32° and 21°C respectively was recorded as limiting factor to fruit set due to impaired complex physiological processes in the pistil which results on floral or fruit abscission (Picken, 1984).

However, in Bangladesh the yield performance of tomato varieties is very poor. So, it is urgent to increase tomato yield by proper management and cultural practices. Plant growth regulators are one of the most important factors for increasing higher yield. A large proportion of tomato reproductive structures abscise before reaching maturity, which is the primary cause of lowering yield (Mondal *et al.*, 2010). Fruit yield of tomato can be increased through reducing reproductive abscission. Hormones regulate abscission process and synthetic hormones may reduce abscission and ultimately increase the yield of soybean (Nahar and Ikeda, 2002) and tomato (Abdel *et al.*, 1996).

Application of plant growth regulator (PGR) seems to be one of the important practices in view of convenience, cost and labor efficiency. Recently, there has been global realization of the important role of PGRs in agriculture for better growth and yield of crops. Developed countries like Japan, China, Poland, South Korea etc. have long been using PGRs to increase crop yield. Like other crop plants, the physiological mechanisms of tomato growth are hormonally mediated. Additional supply of plant growth regulators (PGRs) control growth and yield in plants. Chitosan, a new plant growth regulator like GA3 that may have many uses to improve the growth, yield and yield attributes of plant. Chitosan is a natural carbohydrate polymer modified from chitin, which is derived from crustaceous shells such as crabs and shrimps. It has been reported as a high potential bio-molecule that increases plant growth and yield.

Chitosan is considered an environmental friendly product that has been widely used in agricultural applications mainly for enhancing soil characteristics which is suitable for plant growth and also stimulation of plant defense. It has been used in seed, leaf, fruit and vegetable coating, as well as a fertilizer and in controlled agrochemical release (Ibrahim *et al.*, 2015). Chitosan is a safe material has antifungal activity against many plant pathogens. Moreover, it also was reported to induce resistance against soil borne fungi. In recent years, applications of chitosan in the fields of medicine, food, chemical engineering, pharmaceuticals, nutrition, environmental protection and agriculture have received considerable attention. Chitosan was able to enhance the growth of many crops. The underlying mechanisms for this plant growth promoting action may be attributed to effects on plant physiological processes such as nutrient uptake, cell elongation, cell division, enzymatic activation and protein synthesis (Amin *et al.*, 2007). Application of chitosan enhances growth and yield attributes in rice (Liu *et al.*, 2007) and soybean (Chibu *et al.*, 2002).

Considering the above facts, the present study has been undertaken to fulfill the following objectives:

- To evaluate role of modified chitosan on growth, yield and yield attributing characters of tomato cv. BARI tomato-15.

- To find out optimum doses of the modified chitosan as seedbed organic fertilizers to increase the yield potentiality of tomato.

CHAPTER II
REVIEW OF LITERATURE

Plant growth regulators are the substances that regulate the growth of plants in a miraculous form. Many scientists are now studying the pattern of growth and development of plant treated with different plant growth regulators. Chitosan is an important growth regulator which has many different influences on growth, yield and yield contributing characteristics of Solanaceous crops. Extensive studies of the regulatory effects of chitosan on various crops have been carried out worldwide by different workers. Some of the related reports are reviewed below.

2.1 Effect of chitosan application on Seedling Characteristics

2.1.1 Seedling height

Chitosan is well known for its role in stem elongation. The effect of Chitosan on seedling height as well as plant height was studied in various parts of the world by various workers on a variety of crops. It was observed in most cases that Chitosan remarkably increases seedling height as well as plant height of different crops.

Algam *et al.* (2010) found that chitosan was able to enhance the growth of tomato plants.

Boonlertnirun *et al.* (2005) observed that the application of chitosan via seed soaking and spraying 4 times created variation in number of tillers/plant and dry matter accumulation, but did not affect plant height, 1000-grain weight and number of seeds/head of rice.

Boonlertnirun *et al.* (2006) conducted a greenhouse experiment to determine the most effective chitosan type and appropriate application method for increasing rice yield and found that the application of chitosan with different molecular weights and different application methods did not affect plant height.

Boonlertnirun *et al.* (2008) revealed that application of chitosan on rice plants did not influence the plant height significantly.

EI-Asdoudi and Ouf (1993) observed that three sprays of 50 ppm GA3 produced the tallest plant of tomato. Tomar and Ramgiry (1997) studied that tomato plants treated with GA3 showed significantly greater plant height than untreated control.

Jia'an *et al.* (2001) reported that application of 0.4 g chitosan/50 cm3 water on rice increased root length, root number, leaf length, leaf width, leaf number, seedling height and stem diameter of seedlings.

Khan *et al.* (2002) conducted an experiment and revealed foliar application of chitosan and chitin Oligomers did not affect ($p>0.05$) maize or soybean height, root length, leaf area, shoot or root or total dry mass.

Liu *et al.* (2007) sprayed one month old transplanted tomato plants with chitosan and reports that chitosan at 75 ppm had increased plant height. Three sprays of 75 ppm chitosan produced the tallest plant of tomato. Similarly Martinez *et al.* (2007) observed that seed treated with chitosan increased the plant height, stem diameter and root length in tomato.

Lu Chang-min *et al.* (2009) reported that the tomato seed were soaked in different concentration of chitosan solution which were impact on tomato seed germination and the growth of seedlings. The results showed that the tomato main root length and root activity were higher than the control that treated with water.

Supachitra *et al.* (2011) conducted an experiment to determine the plant growth stimulating effects of chitosan on Thai indica rice (Oryza sativa L.) cv. Leung PraTew 123. Rice seedlings were treated with Oligomeric chitosan with 80% degree of deacetylation at the concentration of 40 ppm by seed soaking overnight before sowing, followed by spraying on 2-week and 4-week old seedlings, respectively. The Oligomeric chitosan stimulated plant height.

Wanichpongpan *et al.* (2001) observed a positive effect of chitosan on the growth of roots, shoots and leaves of various plants including gerbera of several crop plants.

Wu *et al.* (1983) sprayed one month old transplanted tomato plants with GA3 and reports that GA3 at 50 ppm had increased plant height. Pimpini *et al.* (1988) observed that soaking seeds for 10 h in a solution of NAA (25 ppm) + GA3 (25 ppm) + IAA (25 ppm) increased plant growth of tomato in the initial stages only.

2.1.2 Seedling fresh weight

Ghoname *et al.* (2010) conducted an experimental trial in the two successive seasons of 2008 and 2009 to investigate and compare the enhancing effects of three different biostimulation compounds on growth and production of sweet pepper plants (*Capsicum annuum* L.) cv. California Wonder. Three weeks after transplanting, plants were sprayed with any of the individual chitosan (2, 4 and 6 cm/L). Data showed that all applied solutions promoted plant vegetative growth i.e. plant height, number of leaves and branches, fresh and dry weights. Within each solution treatments, there was a positive relationship between the applied concentration and the response of all plant growth parameters.

Nawar (2005) found that the highest plant length and fresh and dry weights were obtained in tomato plants grown from transplants treated with chitosan.

Ouyang and Langlai (2003) also reported that seeds of non-heading Chinese cabbage dressed with chitosan at the rate 0.4-0.6 mg/g seed and leaf spraying with 20-40 µg/ml increased fresh weight.

2.1.3 Seedling dry weight

Ali *et al.* (1997) also revealed that dry matter accumulation of soybean cv. Akishirome increased 42 days after sowing with soils supplemented with 0.1% chitosan. The results of Hidalgo *et al.* (1996) showed that tomato plants grown from seed coated with chitosan increased dry weight and stem thickness more than the untreated plants.

Chibu and Shibayama (1999) studied chitosan application on early growth of four crops: soybean, lettuce, tomato and rice. The results showed that chitosan at 0.1 or 0.5% leaf dry weight of soybean, lettuce and rice whereas chitosan at 0.1% showed positive effects on dry weight of tomato.

Gabal *et al.* (1990) noted that 100 ppm GA3 was the most suitable treatment for increasing the dry weight of fresh bean. Kamaraj *et al.* (1999) observed that higher dry weight of capitulum was also found in sunflower.

Hunt (1978) observed that relative growth rate is the increase in plant weight/unit plant weight/unit of time represents the efficiency of the plant as a producer of new material i.e. efficiency index of dry weight production.

Martinez *et al.* (2007) stated that in general, the best response was obtained when seeds were treated with 1 mg/L chitosan during four hours, as this concentration stimulated significantly plant dry weight, although the other indicators were not modified.

Zhou *et al.* (2001) reported that presoaking seed treatment of grain in varying concentrations of chitosan showed the best results on dry weights. Guan *et al.* (2009) stated that chitosan under low temperature increased shoot and root dry weight in maize plants compared to that of the control.

2.2 Effect of chitosan application on reproductive characters in tomato

2.2.1 Number of flower buds/plant

BINA (2009) applied sprunit (a growth hormone developed at Biological Science Department, Bangladesh Atomic Energy Agency) on tomato and observed increased flower production in sprint applied plant than control.

Borkowsky *et al.* (2007) reported the increased vigor of tomato plants due to Chitosan application.

2.2.2 Number of flower/plant

Bhardway *et al.* (1987) observed that crop growth rate is positively correlated with LAI and net assimilation rate. Katiyar (1980) also stated that gibberellic acid encouraged larger vegetative growth and also enhanced larger reproductive growth than the untreated control. The CGR increased at all the treatments of GA3 over control.

BINA (2005) further observed that application of NAA on rice decrease unfilled grain number which in consequence increased grain yield. BINA (2004) applied GA3 (50, 100, 150, 200 ppm) on mustard and reported that application of GA3 increased reproductive efficiency in mustard.

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

Utsunomiya *et al.* (1998) reported that the number of harvested fruits of purple passion fruit increased with soil treated with Oligomeric chitosan under high nitrogen conditions.

2.3 Effect of chitosan application on yield attributes &yield in tomato

2.3.1 Number of fruits/cluster

El-Mougy *et al.* (2006) noted that chitosan treatment increased tomato yield more than 66.7%, whereas the moderate increase was obtained with individual treatments of chitosan recorded more than 40.0% increase as compared with untreated plants.

Kananont *et al.* (2015) conducted an experiment with Fermented chitin waste (FCW) with three levels of FCW @ (0.25%, 0.50% and 1.0% (w/w)) along with CF=soil supplemented with chemical fertilizer and CMF=soil supplemented with chicken manure fertilizer. The results found that FCW @ 1% the filled grains panicle^{-1} differ significantly from 0.5% FCW, 0.25% FCW and the rest of the treatment.

2.3.2 Number of fruits/plant

Mohamed *et al.* (2011) recently reported that the much attention has been paid to chitosan as a potential polysaccharide resource. Although several efforts have been reported to prepare functional derivatives of chitosan by chemical modifications, few attained their antimicrobial activity against plant pathogens which enhance growth and yield in vegetables field.

Tomar and Ramgiry (1997) found that tomato plant treated with chitosan showed significantly greater number of fruits/plant than untreated control.

Vasudevan *et al.* (2002) suggested that application of chitosan formulations or derivate can serve as increase in root and shoot length and grain yield. It also increases in the growth of nursery-raised plants such as cucumber, pepper and tomato among others.

Utsunomiya *et al.* (1998) reported that the number of flowers and the harvested fruits of purple passion fruit increased with soil treated with Oligomeric Chitosan under high nitrogen conditions.

2.3.3 Single fruit weight

Krivtsov, G.G. *et al.* (1996) found that thousand grain weight of wheat plants was increased with application of polymeric chitosan at low concentration.

Liu Wei *et al.* (2004) studied that chitosan could improve the quality and the yield of tomato. Its 1/500 dilution could increase the weight of/fruit by 11.1% and the yield by 21.7%. It could also improve the resistance to various diseases. After applying 3 times, 1/500 dilutions efficacy against *Phytophthora infestans.*

2.3.4 Fruit length

Rahman (2006) conducted an experiment with mungbean and applied Miyobi at 30 DAS at the rate of 2.0, 3.0, 4.0 and 5.0 mg/L and reported that pod length increased in Miyobi applied plant over control and the highest pod length was recorded in 4 mg/L. Alam (2007) also reported similar result in lentil.

2.3.5 Fruit size

Alam (2007) reported that spraying of Miyobi at pre-flowering resulted enlarged pods in lentil. Hossain (2007) also reported similar result in sesame.

Begum (2006) noted that application of GABA on mustard plant at 21 DAS increased pod size over control and the highest pod size was recorded in 1.0 mg/L.

Rahman (2006) applied Miyobi on mungbean at 30 DAS at the rate of 2.0, 3.0, 4.0 and 5.0 mg/L and reported that single pod weight increased in Miyobi applied plant over control and the highest single pod weight was recorded in 5.0 mg/L.

2.3.6 Fruit yield

Asghari-Zakaria *et al.* (2009) investigate the effects of soluble chitosan on plantlets were subsequently transferred to the greenhouse and mini tuber yield parameters were evaluated. At the concentrations of 750 and 1000 mg/L of chitosan the culture medium failed to solidify. Application of 500 mg/L of soluble chitosan increased the shoot fresh weight, but its lower concentrations did not significantly affect this trait ($P < 0.05$). The 5 and 15 mg/L of soluble chitosan led to a significant increase in root fresh and dry weight whereas, higher concentrations, especially 500 mg/L, significantly decreased root fresh weight of plantlets. Application of 500 mg/L chitosan resulted in improved acclimatization of plantlets in the greenhouse as expressed by significant ($P<0.05$) increase in mini tuber number and yield, compared to the control.

Boonlertnirun *et al.* (2007) conducted a greenhouse experiments to determine the effect of chitosan on drought recovery and grain yield of rice under drought conditions. Results revealed that the chitosan applied before drought treatment gave the highest yield and yield components and also showed good recovery.

Boonlertnirun *et al.* (2008) conducted an experiment on application of chitosan in rice production. The results showed that application of chitosan by seed soaking and soil application four times throughout cropping season significantly increased rice yield over the other treatments.

Darmawan Darwis (2010) reported that the Oligo-chitosan GP have been field tried for soybean (using Mitani and Rajabasa varieties) at Indralaya District, South Sumatra. The result showed that productivity of both soybean varieties treated with Oligo-chitosan is higher than that of control. Improvement of productivity for Rajabasa and Mitani varieties is about 40%.

El-Mougy *et al.* (2006) suggested that chitosan can be used commercially for controlling tomato root rot diseases under field conditions. Boonlertnirun *et al.* (2006) reported that rice yield cultivar Suphan Buri-1 was significantly increased over the control (no chitosan) after application of polymeric chitosan at the concentration of 20 ppm. Nevertheless, the exact mechanism(s) of chitosan effects on plant growth and production is not yet determined. On the other hand, the positive effects of dry yeast application has been repeatedly reported on many vegetable crops. Moreover, Gomaa *et al.* (2005) reported that, foliar treatment with yeast significantly increased vegetative growth and tuber yield of potato plants.

FNCA (2010) presented reports and detailing their activities for 2010 and research plans for 2011-2012 where, Dr. Darmawan Darwis, National Nuclear Energy Agency (BATAN) delivered a lead speech on summary results of field tests of PGP. Oligo-chitosan Plant Growth Regulator/Promoter was produced by irradiating chitosan using gamma radiation at 75-100 kGy. Field trials were conducted on Oligo-chitosan application to soybean plant. The result showed that soybean productivity increase 40% of both varieties treated with Oligo-chitosan is higher than the control. Dr. Darmawan Darwis, National Nuclear Energy Agency (BATAN) delivered a lead speech on summary results of field tests of PGP. Oligo-chitosan Plant Growth Regulator/Promoter was produced by irradiating chitosan using gamma radiation at 75-100 kGy. Parameters such as total N, P uptake by plant, yield/production will be measured. Dr. Naotsugu Nagasawa from Japan Atomic Energy Agency (JAEA) presented a speech for all the participants where he said that it is necessary on planting and harvesting management and Oligo-chitosan affected on crop yield, length, weight etc., of sprayed and control.

Salma Sultana (2010) from BAEC, Bangladesh reported that the Oligo-chitosan was applied for its potential use as plant growth promoter. Effects of Oligo-chitosan on growth and productivity of Maize (*Zea mays* L.) plants were investigated as a lab-scale. The morphological characters of Maize were studied randomly in different pots. The foliar spraying of Oligo-chitosan (molecular weight 7,000 Da) with the concentration of 25, 50 and 75 ppm was applied. The growth and productivity of these Oligo-chitosan treated Maize plants were compared with those of control Maize plants. The effects of Oligo-chitosan on Maize's growth and productivity were investigated in terms of plant height, weight of cob and weight of seeds. The results showed that the application of Oligo-chitosan, at the concentration of 75 ppm, plays a significant role in terms of plant height, weight of cob and weight of seeds/Maize. These results suggest its potential use in agriculture purpose as growth promoter.

Synowiecki and Nadia (2003) observed that high Chitin or derivatives chitosan enzyme level improves the durability and resistance of the plant, makes it not easily infected by germs, not proliferate even infected, and cures the disease by itself. It increases the yield. Hong *et al.* (1998) also stated that using chitosan in agriculture with less use of chemical fertilizer increases the production, in different kinds of plant, by 15-20%.

Walker *et al.* (2004) observed that chitosan application resulted in yield increases of nearly 20% in two out of three tomato trials, no significant difference in yield of treatments in the organic carrot trial or in average weight of individual carrots. They found also no significant differences among cucumber, capsicum, beet-root or peas plants from any treatment, however the chitosan foliar treatment had a tendency for greater yield than the yield from other treatments. Trials conducted in tomatoes showed that foliar applications of chitosan resulted significant improvement in powdery mildew disease control which increase the yield of tomato of nearly 20%.

2.4 Effect of chitosan application on Seedbed soil

2.4.1 pH of Seedbed soil

Kananont *et al.* (2015) conducted an experiment with Fermented chitin waste (FCW) with three levels of FCW @ (0.25%, 0.50% and 1.0% (w/w)) along with CF=soil supplemented with chemical fertilizer and CMF=soil supplemented with chicken manure fertilizer. The results found that application of FCW to the soil led to an increased pH level (5.0-6.0 approx.) in the soil.

2.4.2 Organic carbon in Seedbed soil

Gooday (1990) stated that chitin and its derivatives show additional properties among carbohydrates, as nitrogen content and, therefore, a low C/N ratio. Manucharova *et al.* (2005 and 2006) observed that its addition increases both prokaryote and eukaryote microbial populations and their activities, since they are altogether involved in chitin mineralization, including populations of nitrogen fixation microorganisms, and methane, carbon dioxide and dinitrogen monoxide emissions are raised.

Oka and Pivonia (2003) stated that many of these chitinolytic organisms establish beneficial symbiotic interactions with plants, as mycorrhiza and Rhizobium spp., favoring vegetal absorption of certain nutrients and especially nitrogen fixation. For example, amendments of chitin together with fertilizers as urea have been used to improve soil microbiota, to control pathogenic organisms and to strengthen plant nutrition, all these showing better results than the controls in tomato, carnation and grazing.

2.4.3 Organic matter in Seedbed soil

Kananont *et al.* (2015) conducted an experiment with Fermented chitin waste (FCW) with three levels of FCW @ (0.25%, 0.50% and 1.0% (w/w)) along with CF=soil supplemented with chemical fertilizer and CMF=soil supplemented with chicken manure fertilizer. The results found that application of FCW to the soil led to an increased OM level in the soil.

Zhang *et al.* (2009) stated that the combined application of organic manure and chemical fertilizers increased organic matter content in soil.

CHAPTER III
MATERIALS AND METHODS

The experiment was conducted to find out the performance of summer tomato supplemented with modified chitosan treatment. A brief description about the locations of the experimental site, characteristics of soil, climate, materials, layout and design of the experiment, land preparation, manuring and fertilizing, transplanting of seedlings, intercultural operations, data recording procedure, economic and statistical analysis etc. which are presented as follows:

3.1 Experimental period

The experiment was conducted during the period from October 2015 to March 2016.

3.2 Site description

A pot experiment was carried out at the pot yard of Sher-e-Bangla Agricultural University, Dhaka. Geographically the experimental site was at 90°22" E longitudes and 23°41" N latitudes at an altitude of 8.2 meters above the sea level. Experimental site is presented in Plate 1.

3.3 Soil

The soil of the experimental pots was collected from the research farm of Sher-e-Bangla Agricultural University, Dhaka. The collected soil belonging to the agro-ecological zone of ‘The Madhupur Tract’, AEZ-28 (FAO, 1988). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and had organic carbon 0.45%. The characteristics of the experimental soil are presented in Appendix II (B).

Plate 1. The Experimental site where the experiment were took place.

3.4 Climate and weather

The mean highest and mean lowest temperatures in the 6 months are 31.6°C & 18.17°C respectively. The monthly total rainfall, temperature during the study period was shown in Appendix I.

3.5 Experimental materials

3.5.1 Plant materials

Tomato cv. BARI tomato-15 was used as the plant materials for this study which were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur.

3.5.2 Modified Chitosan

The raw material (Shrimp shell byproduct) of the modified chitosan was collected from the Khulna region of Bangladesh. The modified chitosan was prepared by using traditional methods with some modifications.

3.5.3 Treatments

The single factor experiment was compared with five concentrations of chitosan viz. 0 g chitosan powder/pot (T_1), 50 g chitosan powder/pot (T_2), 100 g chitosan powder/pot (T_3), 150 g chitosan powder/pot (T_4) and 200 g chitosan powder/pot (T_5) which were applied during seedbed soil preparation.

3.6 Experimental design and raising of seedlings

The experiment was done with 10 earthen pots for seedling raising and other 60 earthen pots which are used after transplanting the seedlings. Seedbed soil was prepared with no fertilizer but different doses of modified chitosan powder. There were 10 seedbeds with this 5 different doses of chitosan powder as mentioned in the article 3.5.3. BARI tomato-15 seeds were sown to 5 seedbeds which soils were treated with 0 g, 50 g, 100 g, 150 g & 200 g chitosan powder. After 15 DAS, 20 DAS and 25

DAS some healthy seedlings were collected for progressive change of seedling height and seedling fresh weight.

3.7 Transplanting of seedlings

Healthy and uniform seedlings of BARI tomato-15 were collected from the seedbed and were transplanted in the experimental pots in the afternoon of 12 November, 2015. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage to the roots. Two seedlings were sown in each pot. Finally, they were thinned to one seedling after 20 days of transplanting.

3.8 Preparation of pots and fertilizer applications

Silty clay soils were collected from the research farm of Sher-e-Bangla Agricultural University, Dhaka. The collected soil was well pulverized and dried in the sun. Plant propagules, inert materials, visible insects and pests were removed from this soil. The dry soil was thoroughly mixed with well rotten cowdung. This prepared medium was used in filling the pots after well mixing with the given amounts of urea, triple superphosphate, muriate of potash, gypsum and cowdung (Table 1). Earthen pots of 30 cm diameter and 35 cm height were used for the experiment. The pots were filled with 12 kg of soils.

Table 1. Amount of Fertilizer and manure application in different times after transplanting in each pot.

Fertilizer and manures	Basal Doses	10 DAT	25 DAT	40 DAT
Urea	-	4 g	4 g	4 g
TSP	6.5 g (During land preparation)	-	-	-
MoP	2.6 g	-	2g	2g
Cowdung	400 g	-	-	-

TSP: Triple super phosphate
MP: Muriate of potash
DAT: Days after transplanting

Plate 2. Just after transplanting of seedling

3.9 Intercultural operations

Weeding and soil loosening were done as and when necessary. Water was supplied as and when needed to ensure sufficient moisture for the normal growth of the plants. Plant protection measures were taken at 31 and 55 DAT against fruit and shoot borer by spraying Kormil 72 MZ WP @ 0.25%, Malathion @ 2.5 ml/L. To prevent the plants from fungal infection, Dithane M-45 was applied @ 2 g/L at 15 days interval. After 30 DAT, each plant was staked with cross section of bamboo sticks to keep them erect and to protect from damage by storm and high speedy winds.

3.10 Harvesting

First harvest of ripen tomato started at 75 days after sowing. At initial ripening stage, tomato was harvested at 5 days interval for one time and after a few days, tomato was harvested at 2 days interval for five times. All the harvests were completed by March 2016.

3.11 Collection of data

The data were recorded at various characterized which was present are as follows.

3.11.1 Morphological parameters

Plant height

Plant height was taken to be the length between the bases of the plant to the tip of the main stem at harvest.

3.11.2 Reproductive characters

Number of bud/plant

The number of effective flower clusters/plant was counted of the sampled plant at 80 DAT. The effective flower cluster denotes as when it bears at least one fruit.

Number of flowers/plant

The total number of flowers produced on every plant of the given genotypes through the crop life was recorded.

3.11.3 Yield and yield contributing characters

Number of fruits/cluster

Fruits of selected plants of each replication were counted and then the average number of fruits for each plant was determined.

Single fruit weight

Total numbers of harvested fruits during the period from first to final harvest in the sample plant were recorded and measured individual fruit weight through divided by the total number of fruits to total weight.

Fruit yield/plant

The fresh fruits of selected plants weighed at each harvest and the summation is considered fruit yield/plant.

3.12 Statistical analysis

The collected data were analyzed statistically following the analysis of variance (ANOVA) technique and the mean differences were adjudged by LSD test using the statistical computer package program, Statistix 10.

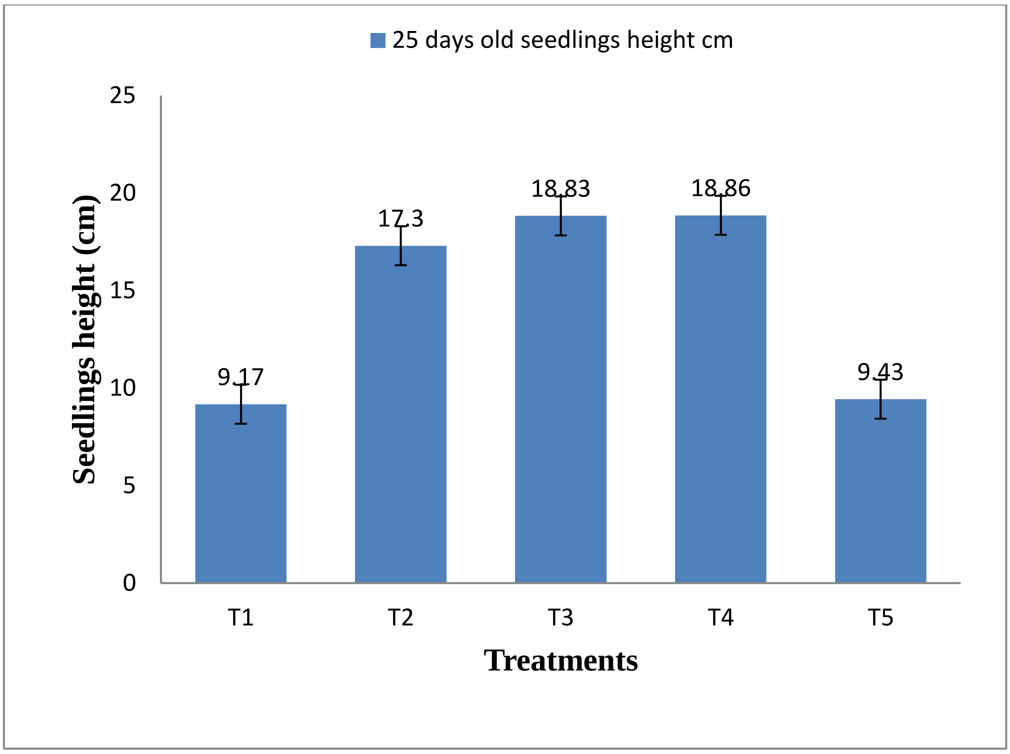
CHAPTER IV

RESULTS AND DISCUSSION

4.1 Role of modified chitosan on seedlings morphological characteristics

4.1.1 Seedling height

A remarkable effect was observed on tomato seedlings using modified chitosan in the seedbed. Tomato seedlings height was significantly varied with the application of different doses of modified chitosan. Seedlings height was clearer with time dependent manner. The minimum seedlings height was found in the control treatment T1 (9.17 cm) at 25 days after sowing (DAS), having no use of modified chitosan in the seedbed. On the other hand, maximum seedlings height was found in the T4 (18.86 cm) treatment having seedbed application of modified chitosan. Seedlings height was increased in a dose dependent manner up to the 150 g modified chitosan/pot. However, seedlings height was not increased in the higher doses but germination was delayed and slight lethal effect was found in the higher dose having 200 g modified chitosan/pot soil. Seedlings height in the treatments T3 and T4 were statistically identical. Similarly, the seedlings height in the treatments T2 and T3 were statistically identical (Figure 1).

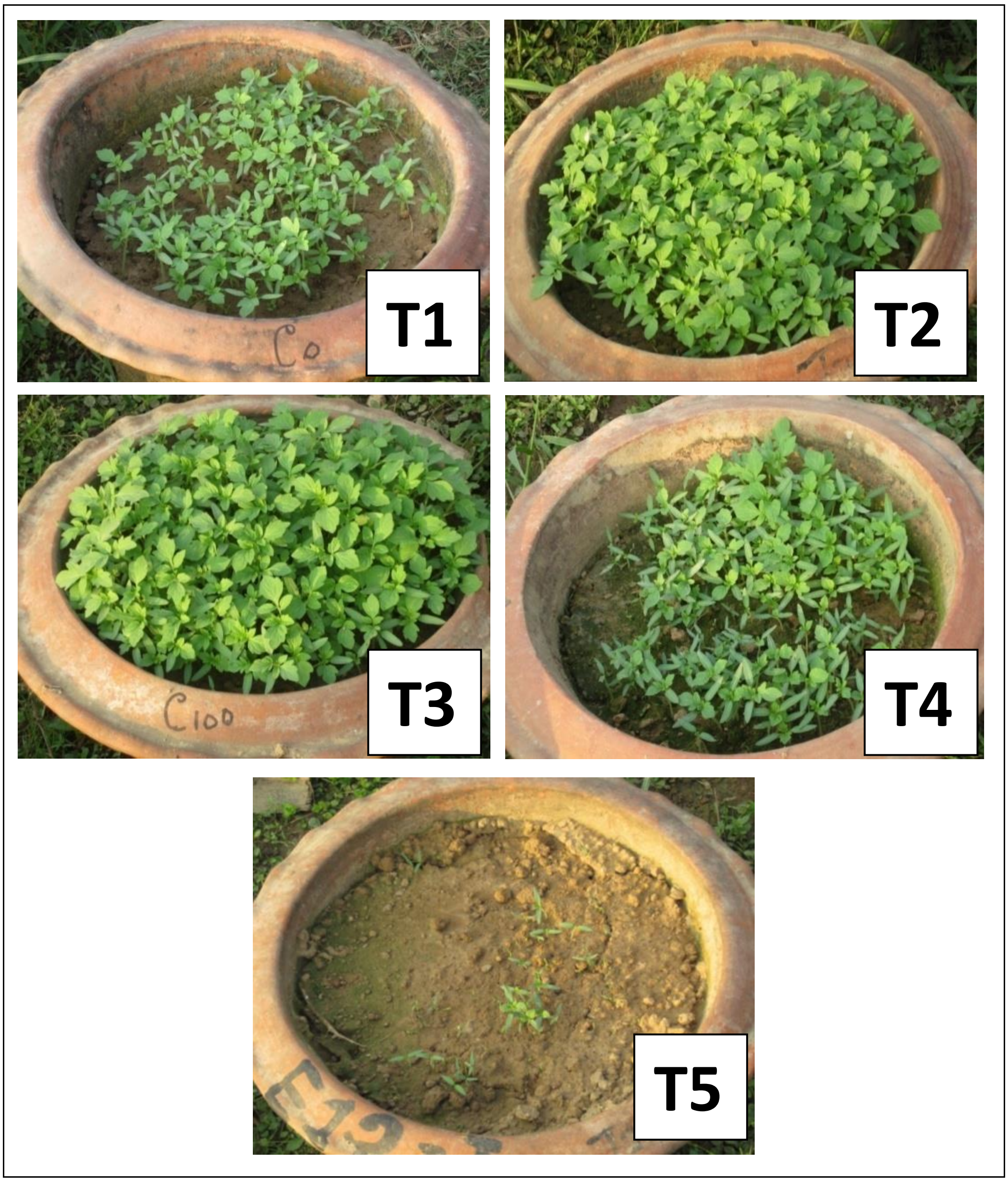


T1=0 g modified chitosan applied in the seedbed
T2=50 g modified chitosan applied in the seedbed
T3=100 g modified chitosan applied in the seedbed
T4=150 g modified chitosan applied in the seedbed
T5=200 g modified chitosan applied in the seedbed

Fig. 1. Modified chitosan-induced tomato seedlings height (cm) at 25 days after sowing

T1=0 g modified chitosan applied in the seedbed
T2=50 g modified chitosan applied in the seedbed
T3=100 g modified chitosan applied in the seedbed
T4=150 g modified chitosan applied in the seedbed
T5=200 g modified chitosan applied in the seedbed

Plate 3. Modified chitosan-induced tomato seedlings at 10 days after sowing.



T1=0 g modified chitosan applied in the seedbed
T2=50 g modified chitosan applied in the seedbed
T3=100 g modified chitosan applied in the seedbed
T4=150 g modified chitosan applied in the seedbed
T5=200 g modified chitosan applied in the seedbed

Plate 4. Modified chitosan-induced tomato seedlings in the seedbed at 15 days after sowing.

T5	T4	T3	T2	T1

T1=0 g modified chitosan applied in the seedbed
T2=50 g modified chitosan applied in the seedbed
T3=100 g modified chitosan applied in the seedbed
T4=150 g modified chitosan applied in the seedbed
T5=200 g modified chitosan applied in the seedbed

Plate 5. Modified chitosan-induced tomato seedlings at 25 day after sowings.

4.1.2 Seedling fresh weight and oven dry weight of ten (10) tomato seedlings at 15 Days after sowing and 20 days after sowing

Figure 2 (a, b) shows the effect the modified chitosan on tomato seedlings at 15 and 20 days after sowing. It is clear that there were significant differences among the treatments on fresh weight and oven dry weight of tomato seedlings. Fresh weight and oven dry weight were increased in a dose dependent manner up to the using of 100 g modified chitosan/pot of seedbed soil (12 kg soil/pot) then the fresh weight and oven dry weight were decreased with increasing the dose of the modified chitosan up to the using of 200 g of modified chitosan/pot of seedbed soil. Application of higher doses of modified chitosan in the seedbed delayed the germination of seeds, strongly reduced the growth of seedlings, and finally produced slightly dwarf seedlings but vigorous in nature. Our results suggest that modified chitosan could play a key role to the vigorous tomato seedlings production. These results might be due to some growth promoting hormones and nutritional supplementations of the soil environment.

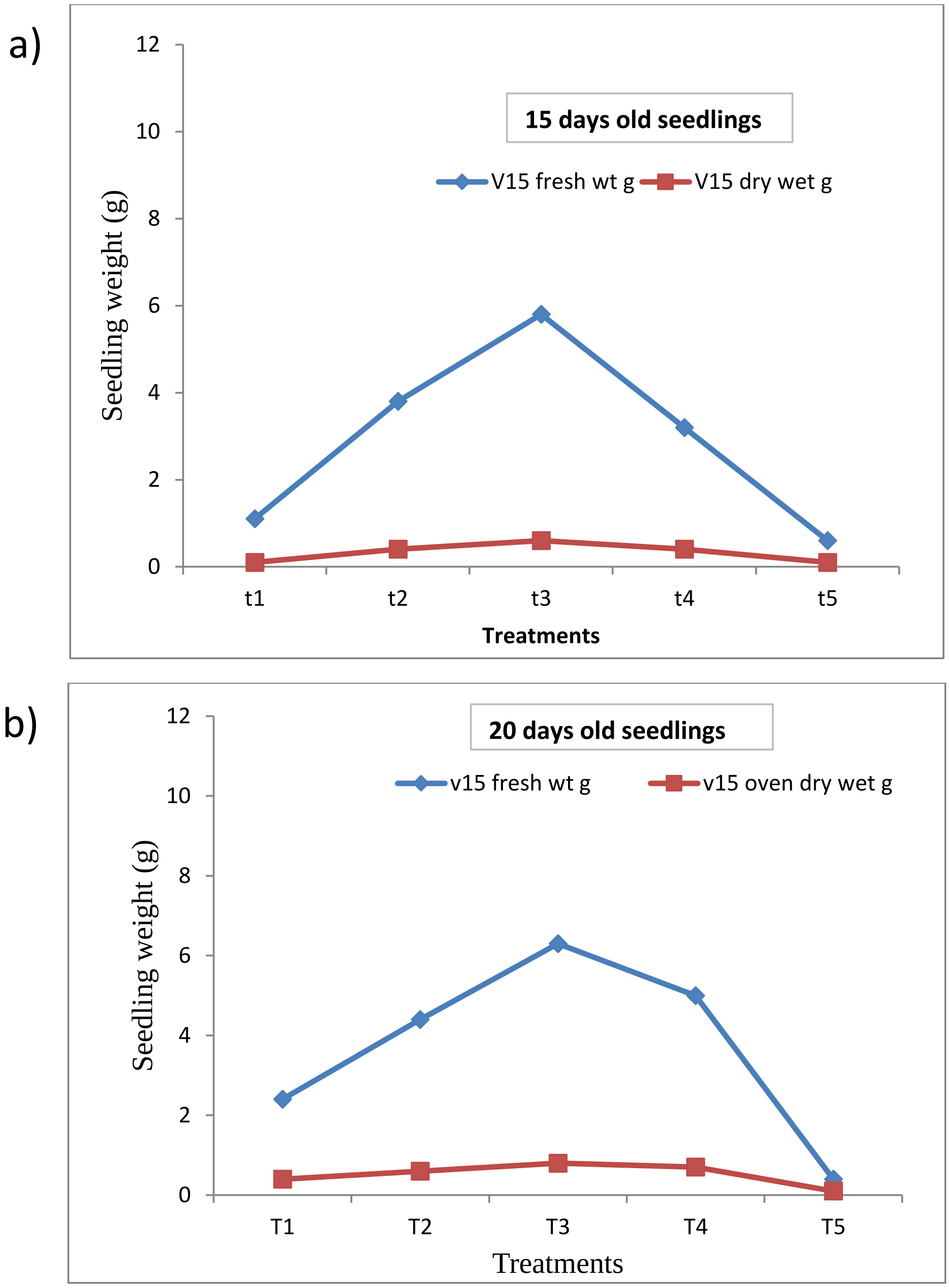
4.1.3 Fresh weight of ten (10) tomato seedlings at the transplanting time (25 days after sowing)

Very strong and significant variation was observed in the fresh weight of tomato seedlings at the transplanting time (25 days after sowing). Maximum fresh weight was found in the treatment T3 (7.93 g) using 100 g modified chitosan in the seedbed soils which was statistically different than any other treatments. The fresh weight production trend was T3≥T2≥T4≥T5≥T1. The fresh weight production was significantly varied between the treatments T2 (6.60 g) and T4 (5.73 g) using 50 g and 150 g of the modified chitosan in the seedbed soils. Here, higher doses of the modified chitosan reduced the fresh weight production of tomato seedlings and these might be due to some toxicity or over stressed by the materials (modified chitosan) used in the seedbed (Figure 3 and table 2).

4.1.4 Oven dry weight of ten (10) tomato seedlings at the transplanting time (25 days after sowing)

Similar to the fresh weight production a very strong and significant variation was also observed in the dry weight of tomato seedlings at the transplanting time (25 days after sowing). Maximum oven dry weight was found in the treatment T3 (1.10 g) using 100 g modified chitosan in the seedbed soils which was statistically identical with the treatments T2 (0.93 g) using 50 g modified chitosan in the seedbed soils. Similar to the fresh weight production, the oven dry weight production trend of the tomato seedlings was T3≥T2≥T4≥T5≥T1. The oven dry weight production in the treatment T4 was 0.80 g using 150 g of modified chitosan in the seedbed soils which was statistically identical with the treatment T2 using 50 g of the modified chitosan in the seedbed soils. There was no significant difference in the oven dry weight production between the control treatment T1 and the treatment T5 using 200 g of the modified chitosan in the seedbed soils. The higher doses of the modified chitosan under T5 treatments reduced or strongly suppressed the dry mass production capacity of the tomato seedlings. These might be due to some toxic effects of the booster doses or over stressed by the materials (modified chitosan) used in the seedbed (Figure 3 and Table 2).

a)



T1=0 g modified chitosan applied in the seedbed
T2=50 g modified chitosan applied in the seedbed
T3=100 g modified chitosan applied in the seedbed
T4=150 g modified chitosan applied in the seedbed
T5=200 g modified chitosan applied in the seedbed

Fig. 2 (a, b) Fresh weight and oven dry weight of ten (10) tomato seedlings at 15 days after sowing and 20 days after sowing.

Table 2. Effect of different levels of modified chitosan treated seedlings on seedling fresh weight at 25 DAS and seedling oven dry weight at 25 DAS

Doses of chitosan (g)	Seedling fresh weight at 25 DAS	Seedling oven dry weight at 25 DAS
T1 = 0 g modified chitosan	3.0000d	0.5167d
T2 = 50 g modified chitosan	6.6000b	0.9333b
T3 = 100 g modified chitosan	7.9333a	1.1000a
T4 = 150 g modified chitosan	5.7333c	0.8000c
T5 = 200 g modified chitosan	0.7333e	0.1167e
LSD (0.05)	0.3670	0.1237
CV (%)	4.06	9.47
Standard Error	0.1592	0.0536

In a column figures having same letter (s) do not differ significantly at $P \leq 0.05$

4.2 Role of modified chitosan on the reproductive characters of tomato

4.2.1 Number of flower buds/plant

The effect of different doses of modified chitosan on flower buds or clusters/plant was non-significant. There are no significant pairwise differences among the treatments (Table 3). However, modified chitosan treated tomato seedlings (T2, T3, T4, T5) produced more number of flower buds or clusters/plant compare to the control treatment T1. Minimum number of flower buds or clusters/plant was found in the treatment T1 (5.67) having non-treated seedlings with modified chitosan. Maximum flower buds were found in the treatment T4 (7.67) using 150 g modified chitosan in the seedbed soils. Second highest flower buds were found in the treatment T5 (6.67) using 200 g modified chitosan in the seedbed. These results indicate that the seedlings, treated with higher doses give a higher number of flower bud/plant. Similar result was found Liu *el al.* (2007) that effective flower cluster number is increased due to the chitosan application in tomato.

4.2.2 Number of flowers/plant

The effect of different doses of chitosan had significant effect on number of flowers/plant in tomato (Table 3). Result showed that flower number was greater in chitosan applied plants than control. Results further revealed that flower number was increased with increasing doses of chitosan till 150 g followed by a decline. The highest number of flowers/plant was recorded in 150 g chitosan (32.00) followed by 100 g chitosan (29.00) with same statistical rank. In contrast, control plants produced the fewest flowers/plant (25.00). The result is supported by BINA (2010), who reported that application of chitosan increased flower number over control in mungbean.

Table 3. Effect of different levels of chitosan on reproductive characters in tomato cv. BARI tomato-15.

Treatments	Flower bud/ plant (no.)	Flowers/ plant (no.)
T1 =0 g modified chitosan	5.67	25.00c
T2 =50 g modified chitosan	6.00	26.67bc
T3 =100 g modified chitosan	6.00	29.00b
T4 =150 g modified chitosan	7.67	32.00a
T5 =200 g modified chitosan	6.67	30.67ab
F test	NS	**
LSD (0.05)	4.32	3.04
CV (%)	23.95	5.83
Standard error	1.25	1.32

In a column figures having same letter (s) do not differ significantly at $P \leq 0.05$;

****** indicates significant at 1% level of probability

'NS' indicates the values are not significant

4.3 Role of modified chitosan treated seedlings on yield & yield attributes of tomato

4.3.1 Number of fruits/cluster

Number of fruits/cluster was increased in the modified chitosan treated seedlings (T2, T3, T4, T5) than non-treated seedlings (T1). Although increasing trend of the number of fruits/cluster was found in the treatments but there was no significant differences among the treatments. Number of fruits/cluster was increased in a dose dependent manner in the modified chitosan treated seedlings. Minimum number of fruits/cluster was found in the treatment T1 (2.85) whereas maximum number of fruits/cluster was found in the treatment T5 (3.84) (Table 4).

4.3.2 Number of fruits/plant

A significant variation was observed in the number of fruits/plants among the treatments. The minimum number of fruits/plant was found in the control treatment T1 (16.00) which was statistically identical with the treatments T2, T3 and T4. The maximum number of fruits/plant was found in the treatments T5 (25.33) which were statistically identical with the treatments T2, T3 and T4. Among the modified chitosan treated seedlings fruits number/pants were increased in a dose dependent manner. This result indicates that modified chitosan treated tomato seedlings produced more number of flower buds that could be the important message to increase the number of fruits/plants (Table 4). Increased plant products in tomato with increasing the doses of chitosan as a result of stimulating immunity of plants (Wanichpongpan *et al.*, 2001; New *et al.* 2004).

Table 4: Effect of modified chitosan treated tomato seedlings on the number of fruits/clusters and number of fruits/plants

Treatments	Number of fruits/clusters	Number of fruits/plants
T1 = 0 g modified chitosan	2.85	16.00b
T2 = 50 g modified chitosan	3.04	18.33ab
T3 = 100 g modified chitosan	3.17	18.33ab
T4 = 150 g modified chitosan	3.41	21.67ab
T5 = 200 g modified chitosan	3.84	25.33a
F test	NS	**
LSD (0.05)	1.68	7.8125
CV (%)	18.80	20.82
Standard error	0.49	3.39

In a column figures having same letter (s) do not differ significantly at $P \leq 0.05$;

****** indicates significant at 1% level of probability

‘NS’ indicates the values are not significant

4.3.3 Single fruit weight

Single fruit weight of tomato was varied significantly due to the seedbed application of modified chitosan. The effect of different doses of modified chitosan on single fruit weight was also statistically significant (Table 5). The highest single fruit weight was observed in the treatment T3 using 100 g modified chitosan in the seedbed, which was statistically identical with the treatments T4 and T5 using 150 g and 200 g modified chitosan respectively. Minimum single fruit weight was found in the treatment T1 which was statistically identical with the treatments T2, T4 and T5. These results indicate that seedlings produced using modified chitosan could be increase the tomato fruits yield.

4.3.4 Fruits yield

Fruit yield was significantly influenced by the modified chitosan treated tomato seedlings. Fruit yield/plant was increased due to the modified chitosan treated seedlings compare to the control treatment. The highest fruit yield was recorded in the treatment T5 (2.16 kg/plant) using 200 g modified chitosan treated seedlings. Second highest fruit yield was recorded in the treatment T3 using 100 g modified chitosan treated seedlings which was statistically identical with the treatment T4. The minimum fruit yield was recorded in the treatment T1 (0.84 kg/plant) which were statistically identical with the treatment T2 (1.13 kg/plant). However, fruits yield increased 34.52%, 97.62%, 61.90% and 157.14% in the treatments T2, T3, T4, and T5 compare to the control treatment T1. Here, treatment T5 shows the tremendous increment of the fruits yield

Table 5. Effect of different levels of modified chitosan treated seedlings on yield attributes & yield in tomato cv. BARI tomato-15

Doses of chitosan (g)	Single fruit weight (g)	Fruits yield (kg/plant)	Fruits yield increased over control, T1 (%)
T1 = 0 g modified chitosan	50.87b	0.84e	-
T2 = 50 g modified chitosan	52.54b	1.13d	34.52
T3 = 100 g modified chitosan	77.93a	1.66b	97.62
T4 = 150 g modified chitosan	63.62ab	1.37c	61.9
T5 = 200 g modified chitosan	68.73ab	2.16a	157.14
F Test	**	**	
LSD (0.05)	12.789	0.2024	-
CV (%)	10.83	7.52	-
Standard Error	5.54	0.0878	-

In a column figures having same letter (s) do not differ significantly at $P \leq 0.05$;

****** indicates significant at 1% level of probability

'NS' indicates the values are not significant

4.4 Role of chitosan on seedbed soil environment

4.4.1 pH of seedbed soil

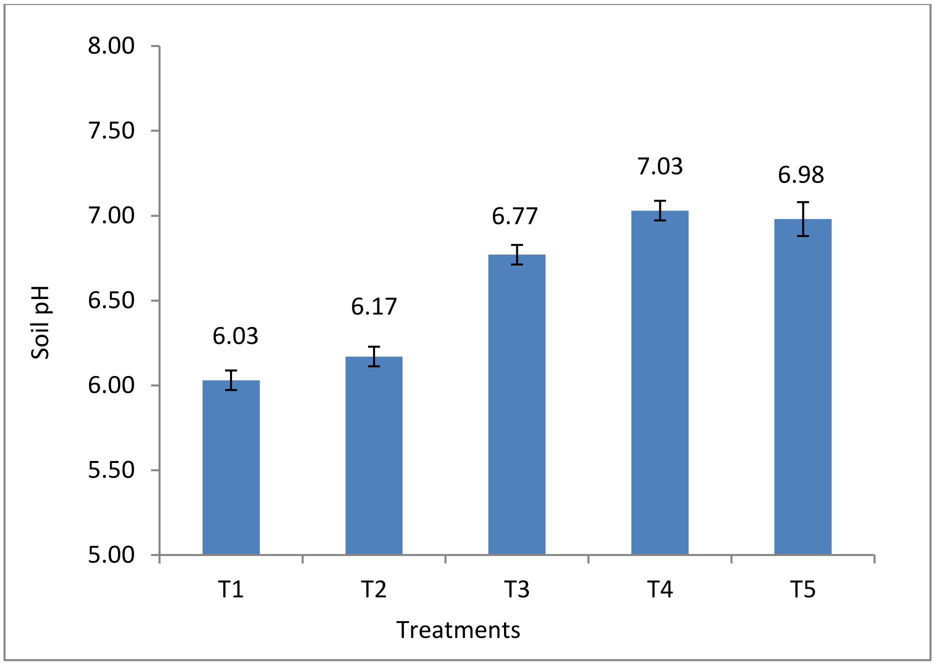
A significant variation was found in the tomato seedbed soil pH at 25 days after sowing due to the different treatment combinations (Table 6). The pH value of the tomato seedbed soil was ranged from 6.03 to 7.03 (Fig. 4). The highest pH value (7.03) was recorded in T_4 treatment having 150 g modified chitosan/pot seedbed (approximately 10 kg soils). On the other hand, seedbed soil pH of the control treatment T1 was 6.03 having no modified chitosan in the seedbed soils. The pH of the control seedbed soil (T_1) was the lowest; it might be due to the non-application of the modified chitosan in the seedbed soils. Application of modified chitosan might be neutralized the seedbed soils, which might be improved the seedbed soil environment due to the increment of soil pH levels. Many causes could be involved in the improvement of seedbed soil environment due to the application of the modified chitosan in the seedbed soils. Nutrient supplementation will be increased due to the increment of pH levels which will improve the biological and physico-chemical properties of soil.

4.4.2 Organic matter in Seedbed soil

Organic matter content of tomato seedbed soil showed significant differences among treatments. Organic matter content of tomato seedbed soil was varied from 1.54% to 1.73% respectively among the treatments (Fig. 5). Maximum organic matter content (1.73 %) was found in the treatment T4 having150 g modified chitosan in the soils, which was statistically identical with the treatments T3 (1.72%) and T5 (1.69%). Whereas minimum organic matter content (1.54%) was found in the treatment T1 having no modified chitosan application and it was statistically identical with the treatment T2 (1.55%) having modified chitosan application at 50 g per pot of soils (10 kg soils). Increasing organic matter content for the sustainable agriculture is a big challenge to the Bangladesh soils, however, the modified chitosan application could play a crucial role to increase the organic matter content in soils.

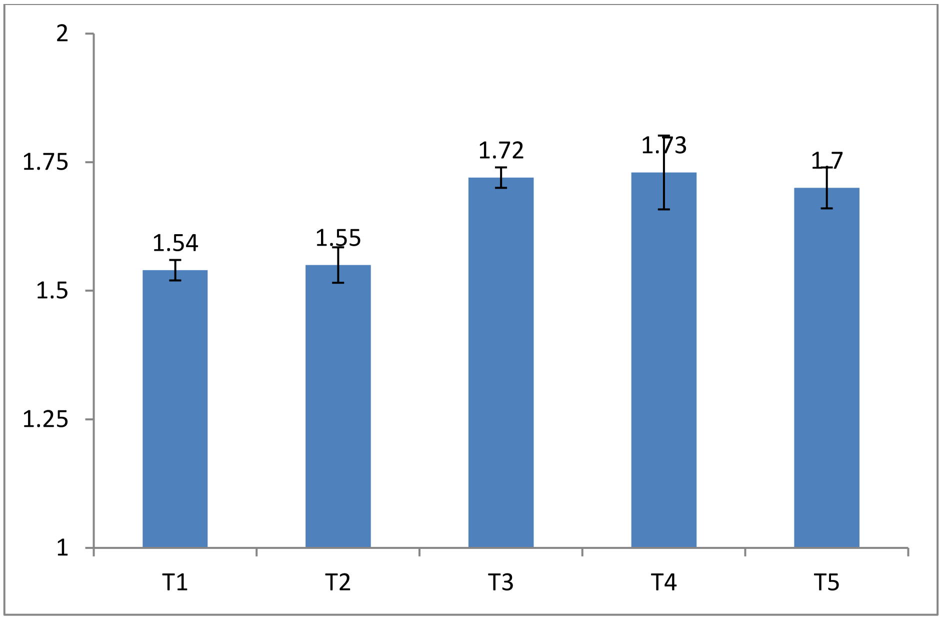
4.4.3 Organic carbon in Seedbed soil

Modified chitosan application in the seedbed soil tends to increment of organic carbon content. The organic carbon content was increased with increasing the level of modified chitosan in the seedbed soils. Maximum organic carbon content (1.14 %) was found in the treatment T5 having applications of 200 g of modified chitosan in the seedbed which was statistically identical with the treatments T3 (1.11%) and T4 (1.05%). However, minimum carbon content (0.94%) was found in the treatment T1 which was statistically identical with the treatment T2 (Table 5). The organic carbon content was increased in a dose dependent manner, it might be due to the use of modified chitosan containing high amount of organic carbon level. This result suggests that modified chitosan application might be increase the level of organic matter in soils and would be helpful to improve the sustainable soil health.



T1=0 g modified chitosan applied in the seedbed
T2=50 g modified chitosan applied in the seedbed
T3=100 g modified chitosan applied in the seedbed
T4=150 g modified chitosan applied in the seedbed
T5=200 g modified chitosan applied in the seedbed

Fig. 4. Seedbed soil pH induced by the modified chitosan in case of BARI tomato-15



T1=0 g modified chitosan applied in the seedbed
T2=50 g modified chitosan applied in the seedbed
T3=100 g modified chitosan applied in the seedbed
T4=150 g modified chitosan applied in the seedbed
T5=200 g modified chitosan applied in the seedbed

Fig. 5. Organic matter content of seedbed soil against different doses of chitosan in case of BARI tomato-15

Table 6. Chemical properties of the seedbed soils at 25 days after sowing

Treatments	Seedbed Soil pH	Seedbed Soil %OC	Seedbed Soil %OM
T1 = 0 g modified chitosan	6.03c	0.94c	1.54b
T2 = 50 g modified chitosan	6.17c	0.96bc	1.55b
T3 = 100 g modified chitosan	6.77b	1.05ab	1.72a
T4 = 150 g modified chitosan	7.03a	1.11a	1.73a
T5 = 200 g modified chitosan	6.98b	1.14a	1.69a
F Test	**	*	**
LSD (0.05)	0.1239	0.0696	0.0750
CV%	1.01	3.12	2.42
Standard Error	0.054	0.03	0.032
Initial seedbed soil	**6.05**	**0.62**	**1.07**

In a column figures having same letter (s) do not differ significantly at $P \leq 0.05$;

****** indicates significant at 1% level of probability

* indicates significant at 5% level of probability

'NS' indicates the values are not significant

4.5 Analytical composition of the modified chitosan

The modified chitosan was analyzed to observe the N, P, K, S, Ca, Mg, Zn, and Boron content levels. The modified chitosan supplied 4.06% N; 0.64% P; 0.28% K; 0.09% S; 2.43% Ca; 0.36% Mg, 92.03 ppm Zn and 152 ppm B, respectively. The organic carbon levels and the organic matter contents were 7.52% and 12.96% respectively. The modified chitosan was alkaline in nature and the pH level was 8.73 (Table 6). Analytical results revealed that supplementation of group of an essential elements (macro and micro elements) will be available due to the application of modified chitosan in the tomato seedbed soils. With the alkaline behavior of the supplied materials increased the pH level of the seedbed soils. Many factors could be involved in the supper growth, development and yield increment behavior of the tomato seedlings. The above mentioned nutritional supplementations and some other growth promoting hormones could be involved in the mechanisms.

Table 7. Composition of the modified chitosan powder which was used in the 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 %
pH of the Modified Chitosan	8.73

CHAPTER IV

SUMMARY AND CONCLUSION

A pot experiment was conducted in the net house of Sher-e-Bangla Agricultural University, Dhaka, during the period from October 2015 to March 2016 to investigate the effect of modified chitosan on seedlings morphological characters, growth and yield and yield attributes of tomato cv. BARI tomato-15. The experiment comprised of four levels of modified chitosan and the treatments were T1 (control), T2 (50 g modified chitosan/pot having 10 kg soils), T3 (100 g modified chitosan/pot having 10 kg soils), T4 (150 g modified chitosan/pot having 10 kg soils) and T5 (200 g modified chitosan/pot having 10 kg soils). The experiment was laid out in pots arranged in a completely randomized design with three replications.

Application of modified chitosan had a profound influence on morphological, reproductive, yield attributes and fruit yield in tomato. The modified chitosan enhances soil characteristics in such a level that induced the tomato seedlings growth and boosts up the yield. All the traits were significantly increased in a dose dependent manner by the different treatments. The tallest seedlings at 25 days after sowing and the highest seedbed soils pH at 25 after sowing was observed in the T4 (150 g chitosan/seedbed) treatment and the shortest seedling with lowest seedbed soil pH was recorded in T1 (control) treatment. The use of T4 (200 g chitosan/seedbed) not only gives higher growth and yield but also improves the soil organic matter, maintains soil health and keeps the soil and environment free from pollutions. On the other hand, tomato seedbed soil from modified chitosan treatments showed greater organic matter content than untreated seedbed soils that also boosts up the growth of tomato seedlings.

In reproductive characters, all the treatments showed maximum number of flowers over control. Results revealed that number of flower bud/plant and number of flowers/plant increased with increasing the level of modified chitosan. The highest flower bud/plant and number of flowers/plant was recorded in T4 (150 g chitosan/seedbed) and the lowest was recorded in T1 (control) plant.

For yield attributes, results showed that fruit number increased with increasing the doses of modified chitosan. The yield of tomato was significantly different with the application of different treatments. The highest fruit yield was recorded in the treatment T5 (200 g Chitosan/seedbed) due to the maximum branching and maximum flowering and fruiting. The lowest fruit yield was recorded in control plant due to the minimum number of fruits/plant and the smaller size of fruits. This result indicates that seedlings produced with modified chitosan applications increased the fruits yield of BARI tomato-15.

Based on the experimental results, it can be concluded that,

i. Application of modified chitosan in the tomato seedbed soil had a significant influence on plant growth characters, yield attributes and fruit yield in tomato

ii. Application of modified chitosan @ 150 g and/or 200 g per pot soils (10 kg soils) had the superiority over other treatments (0g, 50g, and 100g chitosan/pot).

Recommendations

From the above experimental findings, it is apparent that the application of 150 g or 200g chitosan/pot soil (10 kg soils) performed better on yield and yield parameters of tomato cv. BARI tomato-15. In order to recommend the practices for the vegetable growers, the following aspects would be considered in future:

i) Similar experiments need to be conducted in different locations and seasons of Bangladesh to draw a final conclusion regarding the modified chitosan applications for the fruit yield increment of tomato.

ii) Varietal trials need to be investigated.

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APPENDICES

Appendix I. Monthly average of air temperature, Relative Humidity and Total rainfall of the experimental site during the period from October 2015 to April 2016

Month	Air Temperature (^{o}C)		Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
October, 2015	31.6	20.8	63	1
November, 2015	30.3	18	70	1
December, 2015	26.7	13	73	0
January, 2016	26.0	13.2	72	1
February, 2016	32.9	19.2	61	1
March, 2016	35.8	22.5	65	60
April, 2016	37.9	23.1	62	67

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

Appendix II. Characteristics of soil of the experimental field

A. Morphological characteristics of of the experimental field

Morphological features	Characteristics
Location	Experimental field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Sallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical characteristics of initial soil

characteristics	Value
% Sand	27
% Silt	43
% Clay	30
Textural class	Silty-clay
pH	6.05
Organic carbon (%)	0.62
Organic matter (%)	1.07

Sourse: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

Appendix III. ANOVA Table

Source	d.f.	MS											
		SdH	**SdFW**	**SdDW**	**FBPP**	**FlPP**	**FPB**	**FPP**	**SFW**	**FYPP**	**SSpH**	**SSOC**	**SSOM**
Rep	2	0.048	0.008	0.025	5.6	5.267	0.069	40.467	7.277	0.003	0.006	5.000E-04	0.002
Treatment	4	77.031**	25.28**	0.449**	1.9NS	24.5**	0.469NS	39.567NS	384.403**	0.771**	0.537**	7.167E-03*	0.026**
Error	8	0.409	0.038	0.004	2.35	2.6	0.354	17.217	46.136	0.012	0.004	1.367E-03	0.002

SdH: Seedling height, SdDW: Seedling dry weight, FBPP: Fruiting bud per plant, FlPP: Flower per plant, FPB: Fruit per bud, SFW: Single fruit weight, FYPP: Fruit yield per plant, SSpH: Seedbed soil pH, SSOC: Seedbed soil organic carbon, SSOM: Seedbed soil organic matter.

In a column figures having same letter (s) do not differ significantly at $P \leq 0.05$;

****** indicates significant at 1% level of probability

* indicates significant at 5% level of probability

'NS' indicates the values are not significant.