RESIDUAL EFFECT OF CHITOSAN RAW MATERIAL POWDER ON YIELD PERFORMANCE OF OKRA (*Abelmoschus esculentus* L.) UNDER TOMATO-OKRA CROPPING SYSTEM

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BY

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This is to certify that thesis entitled, "Residual Effect of Chitosan Raw Material Powder on Yield Performance of okra (Abelmoschus esculentus L.) Under Tomato-Okra Cropping System" 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 MST. FATIMATUJ ZAHARA Registration number 19-10038 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2021

Dhaka, Bangladesh

(Prof. Dr. Mohammad Issak)

Supervisor

DEDICATED

TO

MY BELOVED PARENTS

LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviations	Full word
%	Percent
@	At the rate
<	Less than
=	Equal
>	Greater than
≤	Less than or equal
^0C	Degree Centigrade
AEZ	Agro-Ecological Zone
ANOVA	Analysis of variance
Anon.	Anonymous
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BRRI	Bangladesh Rice Research Institute
CEC	Cation exchange capacity
CHT	Chitosan
cm	Centimeter
Cm L^{-1}	Centimeter per litre
Cm^3	Centimeter cube
CV	Coefficient of Variation
cv.	Cultivar (s)
EC	Electrical conductivity
et al.	And others
etc.	et cetera
FAO	Food and Agriculture Organization
GA_3	Gibberelic acid
g	Gram

LIST OF ABBREVIATIONS AND SYMBOLS (Contd.)

Abbreviations	Full word
H_2O_2	Hydrogen per oxide
H_2SO_4	Sulphuric acid
H_3BO_3	Boric acid
Ha^{-1}	Per hectare
j.	Journal
$K_2Cr_2O_7$	Potassium dichromate
kg	Kilogram
LSD	Least Significant Difference, Latin Square Design
Mg L^{-1}	Milligram per litre
No.	number
N	Normality
N	Nitrogen
NS	Non-Significant
NaOH	Sodium hydroxide
NH_4^+	Ammonium ion
NO_3^-	Nitrate ion
NPK	Nitrogen, Phosphorus, Potassium
OC	Organic carbon
pH	Potential of hydrogen ion
ppm	Parts per million
SOM	Soil organic matter
SAU	Sher-e-Bangla Agricultural University
Var.	Variety

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Dhaka, Bangladesh
June, 2021 **The Author**

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RESIDUAL EFFECT OF CHITOSAN RAW MATERIAL POWDER ON YIELD PERFORMANCE OF OKRA (*Abelmoschus esculentus* L.) UNDER TOMATO-OKRA CROPPING SYSTEM

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ABSTRACT

An experiment was conducted at the central farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, during the kharif 1 season (May to September, 2019) to examine the residual effect of chitosan raw material powder on yield performance of okra under tomato-okra cropping system. BARI Dheros-1 was used as test crop. The experiment was carried out in the Randomized Complete Block Design (RCBD) with the four replications. The experiments were consist of five treatments having four levels of CHT raw material powder. The treatments were T_1 = 0% CHT raw material powder (control), T_2 = 0.1% CHT raw material powder applied in the previous expt., T_3 = 0.2% CHT raw material powder applied in the previous expt., T_4 = 0.3% CHT raw material powder applied in the previous expt. and T_5 = 0.4% CHT raw material powder applied in the previous expt. .Yield and yield contributing characters positively responded with increasing rate of CHT raw material powder. The fruit yield significantly increased in T_4 treatment 7.31 t ha^{-1} (45.08% yield increased over the control) compared to T_1 control treatment 5.04 t ha^{-1}. But T_3 treatment shows statistically identical fruit yield 6.36 t ha^{-1} (26.19% yield increased over the control) compare to the T_1 control 5.04 t ha^{-1}. The residual effect of the chitosan raw material powder has a positive effect on the increase of total nitrogen, the highest N value 0.112 % was recorded in T_5 treatments and lowest value was observed in T_1 control treatment. From the three layer of soil the maximum value of the soil pH 6.74, 6.66 and 6.53 of 0-30 cm, 30-60 cm and 60-90 cm respectively, organic carbon content 0.70%, 0.66% and 0.60% of 0-30 cm, 30-60 cm and 60-90 cm respectively, and organic matter content 1.21%, 1.14%, and 1.03% of 0-30 cm, 30-60 cm and 60-90 cm respectively in the post-harvest soils were found in the T_5 treatment and lowest values were observed in the control treatment. Above discussion revealed that the yield and yield contributing characters of okra and some chemical properties of soil were improved due to the residual effect of CHT raw material powder. Residual nitrogen value indicates that the CHT raw material powder has a slow releasing nitrogen supplementation, soil organic carbon and soil pH. These results suggest that the residual effect of CHT raw material powder could play an important role to improve the sustainable soil health.

CHAPTER I
INTRODUCTION

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INTRODUCTION

Okra (*Abelmoschus esculentus* L.) known as lady's finger is a heat loving plant of Malvaceae family and is one of the most important and a popular vegetable in Bangladesh which originated in tropical Africa (Purseglove, 1987). It is locally named as "Dherosh" or "Bhindi". During the summer season it plays a significant role in vegetable market when the supply of vegetables is limited. In tropical and sub-tropical parts of the world it is cultivated as an annual vegetable crop but it grows year round in our country and commercially cultivated mainly in summer. It delivers vitamin A, B, C, protein, amino acids, minerals and iodine (Hossain *et al*., 2006). In Bangladesh, vegetable production is not uniform round the year. Total area under cultivation in Bangladesh is 28647 acres and total production of green fruits is about 54183 metric tons where per acre yield is 1891 kg (BBS, 2019). In spite of all our attempt to increase okra yield in the country, its yield is much lower (3.1 t ha^{-1}) than that of other agriculturally developed countries (FAO, 2007). Even though significant annual increase in fertilizer use, its yield has stagnated and even declined in some cases. Vegetables are plenty in winter but are in short in summer. Abundance of vegetables in Bangladesh is primarily concentrated in the winter season. Due to lower production the shortage of vegetables be prevalent from June to September (rainy season). Around 70% of vegetable is produced during Rabi season and the rest 30% in Kharif season of the total vegetable production, (Hossain, 1992).

Tomato (*Solanum lycopersicon* Mill.) is one of the most significant edible and nutritious vegetable crops in Bangladesh. It belongs to solanaceae family. It is widely grown not only in Bangladesh but also in many countries of the world for its taste and nutritional status. 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. The demand of tomato in our country is increasing day by day with the increase of population. We can earn a considerable amount of foreign exchange through exporting it by producing more tomato. Further, tomato has also different 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). In Bangladesh it is accomplished as winter vegetable (except summer tomato which is cultivated small extent), which occupies on area of 69697 acres of land with annual production of about 387653 metric tons where per acre yield 5562 kg (BBS, 2019). The lower yield attribute viz., unavailability of quality seeds of improved varieties, improper management of fertilizers, irrigation, disease control and lack of suitable pruning practices is the main reason of low yield potentiality of this crops (Haque *et al*., 1999).

The chemical properties of a soil and the correct balance of the available nutrients in the soil is highly important. Chemical properties of soils, such as soil pH, organic matter, available phosphorus and nitrogen availability play as an index of soil quality. Soil pH is a measure of soil acidity or alkalinity. It influences not only crop yields, crop suitability, but also activity of soil microorganism and availability of micronutrients (Martinez, 2014). With low pH are there easily a phosphate deficiency and aluminum and manganese toxicity. Phosphorus acts as one of the limiting nutrients for crop production. For enhancing crop growth phosphorus and potassium are taken up through plant roots from soil solution (Cakmak, 2010).

Soil organic matter (SOM) is the main form of C which is found in the soil (Brady and Weil, 2008) and can influence chemical, physical and biological soil attributes, be a source of C and energy for microorganisms and affect greenhouse gas emissions (Batjes and Sombroek, 1997). SOM is a mixture of molecules from plants, animals and microorganisms (Simpson *et al*., 2002) with different compositions, levels of availability, and functions in the environment (Carter, 2001).

SOM is an important indicator of soil quality and agricultural sustainability, since management practices can cause it to undergo rapid change (Mielnickuk, 2008). Such change can be evaluated using the total soil C content, it's chemical and physical fractions or by a combination of these factors (Blair *et al*., 1997). However, minor changes in total C content are hard to detect (Blair *et al*., 1995). Labile C, resulting from soil oxidation with $K_2Cr_2O_7$ at different acidity levels or by physical fractionation of SOM, as well as the microbial biomass can be used as indicators of sustainability for agricultural systems (Araújo and Melo, 2010; Dieckow *et al*., 2005; Chan *et al*., 2001). The amount of carbon stored in the soil is a component of soil organic matter. Nitrogen is a plant nutrient available to the plant mainly in the NH_4^+ and NO_3^- forms. In the soil, it is present in many other complex forms which are broken down to NH_4^+ and NO_3^- ions. The total nitrogen content of the soil is an important property to measure as part of the characterization of soil nitrogen.

Chitosan is a linear polysaccharide that can be obtained from the deacetylation of chitin, a long-chain polymer of N-acetyl-glucosamine present and easily extracted from fungal cell wall and crustaceans shells. From a partial viewpoint, the shells of marine crustaceans such as crabs and shrimps are very affordable for a commercial production of chitin. Recent advances in fermentation technologies suggest that the cultivation of selected fungi can provide an alternative source of chitin and chitosan (Badawy *et al*., 2011).

Chitosan is one of the most studied polysaccharides nowadays. It has a wide number of applications because of its biocompatibility, biodegradability and abundance in nature. The chitosan is an active molecule that observed many possible applications in agriculture with the aim of reducing or replacing more environmentally damaging chemical pesticides. Chitosan applications would find interesting opportunities particularly in organic farming because it is a good alternative even in conventional farming. In agriculture, chitosan is used primarily as a natural seed treatment and plant growth enhancer and also as an ecologically friendly biopesticidal substance that boosts the innate ability of plants to defend themselves against fungal infections (Linden *et. al*., 2000). Plants with high content of chitin show better disease resistance (Khan *et al*., 2003). With high affinity and non-toxicity, it has no harmful effects on human beings and livestock. Chitosan regulates the immune system of plants by inducing the excretion of resistant enzymes. Moreover, chitosan activates the cells besides the improvement of its disease and insect resistant ability (Doares *et al*., 1995). Chitosan has strong effects on agriculture such as acting as the carbon source for microbes in the soil. It accelerates the transformation process of organic matter into inorganic matter. Moreover, it helps the root system of plants to absorb more nutrients from the soil. Chitosan is absorbed by the roots after being decomposed by bacteria in the soil and chitin secreted by the roots (Somashekar and Ricard, 1996, Brian *et al*., 2004). Application of chitosan in agriculture, even without chemical fertilizer can increase the microbial population by large numbers and transforms organic nutrient into inorganic nutrient which is easily absorbed by the plant roots (Bolto *et al*., 2004). The chitosan powder, the acetylated form of chitosan, is the raw material prepared from the shrimp shell by products by the sequential process of grinding, drying and finally by sieving. Chitosan may be used as an alternative source of N which increases efficiency of applied N (Saravanan *et al*., 1987). Chitosan and its residue improve soil health and soil productivity but only use of nitrogenous fertilizer for a long period causes deterioration of physical condition and organic matter status and reduces crop yield. The residual modified chotosan is applied for efficient growth of crop, decline in organic carbon is arrested and the gap between potential yield and actual yield is bridged to large extent (Rabindra *et al*., 2005). Soil application of chitosan raw material powder is a new concept to us to improve the chemical properties of soils. Therefore, the research was designed to examine the residual effect of chitosan raw material powder on the yield performance of okra.

The objectives of the study are as follows:

1. To observe residual effect of chitosan raw material powder on yield performance of okra;

2. To examine residual effect of chitosan raw material powder on soil pH, %OM content and total N content in soil.

CHAPTER II
REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Chitosan is a new plant growth regulator may have many uses to modify the growth, yield and yield attributes of okra. Chitosan has good film forming performance and excellent biocompatibility, and is also safe and non-toxic. It is a natural, safe and cheap biopolymer product of chitin deacetylation, widely used because of its interesting features. Application of chitosan in agriculture, even without chemical fertilizer, can increase the microbial population by large numbers, and transforms organic nutrient into inorganic nutrient, which is easily absorbed by the plant roots. It is alkaline in nature and increases soil pH. Chitosan have potential in agriculture with regard to controlling plant diseases. Some or the relevent reports are reviewed below.

2.1 Effect of chitosan application on growth, yield and quality characters

2.1.1 Growth and yield promoter

Plant growth promoters are important factors for higher yield of vegetables to meet the population demand and earn a considerable amount of foreign exchange through exporting it.

Muley *et al.* (2019) evaluated on potato plants as foliar spray of Chitosan and oligo-chitosan. They found that improvement in shoot height and number of nodes after foliar spray of chitosan and oligo-chitosan at 50–75 mg L^{-1}. Overall results indicated that chitosan (75 mg L^{-1}) and oligo-chitosan (50 mg L^{-1}) can augment plant growth and induce defense mechanism for drought stress tolerance in potato.

Esyanti *et al.* (2019) revealed that physiological parameters, such as increment of height and leaves number, and chlorophyll content indicated an improved growth process in chitosan treated plants compared to the control. Plant resistance to Phytophthora infection was also investigated following chitosan application to highly (CM334), moderately (LABA), weakly (LADO) resistant and susceptible (15080) cultivars.

Rahman *et al.* (2018) conducted a field experiment on strawberry plant. Foliar applications of chitosan on strawberry significantly increased plant growth and fruit yield (up to 42% higher) compared to untreated control. Increased fruit yield was attributed to higher plant growth, individual fruit weight and total fruit weight plant^{-1} due to the chitosan application. Surprisingly, the fruit from plants sprayed with chitosan also had significantly higher contents (up to 2.6-fold) of carotenoids, anthocyanins, flavonoids and phenolics compared to untreated control. Total antioxidant activities in fruit of chitosan treated plants were also significantly higher (ca. 2-fold) ($p< 0.05$) than untreated control.

Islam *et al.* (2018) showed that four levels of oligochitosan were used with control to optimize the level for obtaining maximum yield in tomato and chilli. It was observed that in case of tomato 50 ppm chitosan level was found optimum in terms of yield (2.48 kg plant^{-1}). On the other hand, in case of chilli, 75 ppm chitosan level was found optimum in yield (333.01 g plant^{-1}).

Sultana *et al*. (2017) was undertaken to study the effect of oligo-chitosan (O. chitosan) on growth, yield attributes and economic yield in tomato and egg-plant under Bangladesh conditions. Three levels of oligo-chitosan concentration viz. 0 (control), 60 and 100 ppm. O-chitosan was sprayed five times after sowing. The present results revealed that plant height and number of flowers plant^{-1} increased with increasing concentration of chitosan till 100 ppm. Treatments with 60 and 100 ppm O-chitosan were effective in increasing total yield plot G_1 of tomato (41.67 and 38.30 kg, respectively) than control (22.79 kg). In tomato, the acidity and protein content has been significantly ($p<0.05$) decreased from plant treated with 60 ppm chitosan whereas 100 ppm chitosan treatment significantly ($p<0.05$) increased protein content in eggplant. The powerful antioxidant (phenolic content) component has been found to be increased ($p<0.05$) significantly with chitosan treatment in eggplant but decreased only with lower dose in tomato. It was concluded that foliar application of oligo-chitosan at early growth stage enhances growth and functional components of tomato and eggplant.

Dar *et al.* (2015) conducted a pot experiment to investigate the effect of foliar application of Co-60 gamma irradiated chitosan (IC) with soil applied phosphorus supplement on growth, biochemical and quality attributes of fenugreek. Four concentrations of irradiated chitosan were used (0, 40, 80 and 120 mg L^{-1}) individually as well as in combination with single dose of phosphorus 40 kg ha^{-1}. The results were found that contents of photosynthetic pigments and activity of nitrate reductase, carbonic anhydrase enzymes were also significantly enhanced.

Wang *et al.* (2015) examined an experiment with Chitosan oligosaccharides (COS) effects under lab condition on wheat (*Triticum aestivum* L.). Seed dressing and foliar spraying at different growth stages with Chitosan oligosaccharides (COS) were applied to four wheat cultivars, which were divided into irrigated and rainfed varieties. In the irrigated wheat cultivars, grains per spike from the COS seed dressing were significantly improved, and the spike number from COS spraying at tillering stage (Tf_1) and returning-green (Tf_2) stage increased significantly.

El-Khair (2015) carried out this work during the two successive summer seasons of 2013 and 2014 at a Private Vegetable Farm on sweet potato. Chitosan solution 0.075% increased growth, average tuber weight, total yield, starch and total sugar in tuber roots, whereas chitosan 0.125% increased chlorophyll a, total (a+b) in leaf tissues, N, P and

K uptake by shoots and marketable yield and also recorded minimum values of weight loss and decay (%) in tuber roots during storage period.

Mondal *et al.* (2013) were conducted in two consecutive years under sub-tropical condition (24°75' N and 90°50' E) during the period from December to April, 2010-2011 and 2011-2012, to investigate the effect of foliar application of chitosan (a growth promoter), on morphological, growth, yield attributes and seed yield of maize plants. The experiment comprised five levels of chitosan concentrations viz., 0 (control), 50, 75, 100 and 125 ppm. The chitosan was sprayed three times of 35, 50 and 65 days after sowing. Results revealed that foliar application of chitosan at early growth stages improved the morphological (plant height, leaf number plant^{-1}, leaf length and breadth, leaf area plant^{-1}), physiological (total dry mass plant^{-1}, absolute growth rate and harvest index) parameters and yield components thereby increased seed yield of maize. The highest seed yield was recorded in 100 and 125 ppm of chitosan in maize. Therefore, foliar application of chitosan at 100 ppm may be used at early growth stage for getting maximum seed yield in maize.

Mondal *et al*. (2012) were conducted in two consecutive years at the pot-yard and experimental field on the okra (BARIdherosh-1) plant. The experiment was comprised of five levels of chitosan concentrations viz., 0 (control), 50, 75, 100 and 125 ppm. The chitosan was sprayed three times at 25, 40 and 55 days after sowing. Results revealed that most of the morphological (plant height, leaf number plant^{-1}), growth (total dry mass plant^{-1}, absolute growth rate, relative growth rate), biochemical parameters (nitrate reductase and photosynthesis) and yield attributes (number of fruits plant^{-1} and fruit size) were increased with increasing concentration of chitosan until 25 ppm, resulted the highest fruit yield in okra (27.9% yield increased over the control).

Chookhongkha *et al.* (2012) conducted an experiment on Chili plant by using Murashige and Skoog (MS) medium amended with 20 ppm chitosan solution with low (80−100 kDa), medium (200−300 kDa), and high (600−900 kDa) molecular weight (MW), 0.5% acetic acid, or without chitosan (control). As a result, the significantly greatest seed yield indicated by fruit fresh weight plant^{-1}, fruit numbers plant^{-1}, seed numbers fruit^{-1}, and seed weight plant^{-1} was observed in the plants grown in the soil mixed with 1.0% high MW of chitosan.

2.1.2 Plant height

Rahman (2015) conducted a pot experiment at the net-house on 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^{-1}), T_3 (100 g modified chitosan pot^{-1}), T_4 (150 g modified chitosan pot^{-1}) and T_5 (200 g modified chitosan pot^{-1}). Application of modified chitosan increased seedling height, fresh and dry weight of seedlings, soil pH, organic carbon (%), organic matter (%), number of flowers plant^{-1}, fruits plant^{-1}, fruit size and fruit yield over control.

Salachna *et al*. (2014) obtained that the molecular weight of the compound, the chitosan-treated plants had more leaves and shoots, flowered earlier, formed more flowers and corms. The application of medium- and high-molecular-weight chitosan resulted in higher plants with a higher relative chlorophyll content (SPAD) in potted fressia. The highest increase in the corm weight was observed as a result of treating plants with high-molecular-weight chitosan.

Mondal *et al.* (2013) carried out pot and field experiment with two varieties of mung bean, namely BINA mung-7 and BINA mung-8. Five concentrations of chitosan viz., 0, 25, 50, 75 and 100 ppm were applied twice Results show that plant height, branch and leaf number and LA plant^{-1} both at pot and field conditions increased with the increasing chitosan concentration till 50 ppm. The higher plant height, branch and leaf number and LA plant^{-1} were recorded in between 50 and 100 ppm of chitosan. Leaf number and LA were greater in chitosan treated plants than control might be due to increased number of branches plant^{-1}.

Abu-Muriefah *et al.* (2013) revealed that foliar-applied chitosan, in particular 200 mgl-l, increased plant growth, yield and its quality as well as physiological constituents in plant shoot under stressed or non-stressed conditions as compared to chitosan-untreated plants.

Abdel-Mawgoud *et al.* (2010) showed that chitosan application improved plant height, number of leaves, fresh and dry weights of the leaves and yield components (number and weight) in strawberry plant.

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

Boonlertnirun *et al.* (2005) found that the application of chitosan via seed soaking and spraying 4 times created variation in number of tillers plant^{-1} and dry matter accumulation, but did not affect plant height, 1000-grain weight and number of seeds head^{-1} of rice.

EI-Asdoudi and Ouf (1993) found that three sprays of 50 ppm GA_3 produced the tallest plant of tomato. Tomar and Ramgiry (1997) also found that tomato plants treated with GA_3 showed significantly greater plant height than untreated control.

2.1.3 Plant weight

Ghoname *et al.* (2010) completed an experimental trial in the two successive seasons on 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^{-1}). 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.

Debiprasad *et al.* (2010) examined that application of 120 kg N ha^{-1} through chemical fertilizer with the combination of organic fertilizer increased 1000-grain weight of rice.

Guan *et al.* (2009) revealed that chitosan under low temperature increased shoot and root dry weight in maize plants compared to that of the control.

Boonlertnirun *et al*. (2008) reported that application of chitosan by varying application methods did not affect 1,000-grain weight of rice. The maximum seed weight was gained from seed soaking in chitosan solution before planting and then applying in soil whereas chitosan application by seed soaking in chitosan solution before planting and then foliar spraying showed the minimum seed weight. Nevertheless, no significant difference was found among treatments.

Martinez *et al.* (2007) conducted an experiment on tomato plant. They stated that the best response was obtained when seeds were treated with 1 mg L^{-1} chitosan during four hours, as this concentration stimulated significantly plant dry weight, although the other indicators were not modified.

Boonlertnirum *et al.* (2006) conducted in pot experiment with rice (Suphan Buri) variety. The results indicated that application of polymeric chitosan by seed soaking before planting followed by four foliar sprayings throughout cropping season significantly increased ($P<0.05$) the tiller numbers per plant and dry matter accumulation but decreased unfilled grains.

Ouyang and Langlai (2003) also revealed that seeds of non-heading Chinese cabbage dressed with chitosan at the rate 0.4-0.6 mg g^{-1} seed and leaf spraying with 20-40 μg ml^{-1} increased fresh weight.

Zhou *et al.* (2001) explained that pre-soaking seed treatment of grain in varying concentrations of chitosan showed the best results on dry weights.

Chibu and Shibayama (1999) concluded that 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.

Krivtsovm *et al.* (1996) conducted a field experiment and found that thousand grain weight of wheat plants was increased with application of polymeric chitosan at low concentration.

2.2 Effect of chitosan application on reproductive characters

2.2.1 Number of flower buds plant^{-1}

Mondal *et al.* (2016) reported that reproductive parameters (number of effective flower clusters and flowers plant^{-1}, and reproductive efficiency) also increased in chitosan applied plants and thereby increased the prime yield component, number of fruits plant^{-1} of summer tomato. The higher fruit yield was recorded in 50 and 75 mg L^{-1} of chitosan in summer tomato with being the highest in 75 mg L^{-1} (35.61 t ha^{-1}).

Limpanavech *et al.* (2008) carried out an experiment on Dendrobium orchid. They used six types of chitosan molecules, P-70, O-70, P-80, O-80, P-90, and O-90. According to analysis of variance (ANOVA) followed by Duncan's multiple range test (DMRT), chitosan O-80 at all concentrations tested, 1, 10, 50, and 100 ppm could induce early flowering and increase the accumulative inflorescence number during the 68 weeks of the experimental period, when compared to the non-chitosan-treated controls.

Islam (2007) conducted an experiment with Miyobi on rice at the rate of 1.0, 2.0, 3.0 and 4.0 mg L^{-1} and observed that with increasing hormone concentration panicle length also increased and the highest panicle length was observed in 4.0 mg L^{-1} Miyobi application.

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

Ohta *et al.* (2001) also explained 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) explained that the number of flowers and the harvested fruits of purple passion fruit increased with soil treated with Oligomeric. Chitosan under high nitrogen conditions.

Tomar and Ramgiry (1997) showed that tomato plant treated with chitosan showed significantly greater number of fruits plant^{-1} than untreated control.

2.2.2 Effective tillers hill^{-1} and length of panicle

Sultana *et al.* (2015) carried out a field experiment on rice plant. This experiment was carried out by using four different concentrations of oligomeric chitosan that is 0, 40, 80 and 100 ppm and four times foliar spray after germination. From this experiment it was found that the number of tillers plant^{-1}, the number of panicle length of rice show significant differences in case of foliar sprayed chitosan plants and control plants.

Lu *et al.* (2002) revealed that the number of panicle in rice plant was increased after watering with chitosan at the rate of 0.4 g: 50 cm^3 (Chitosan: water).

2.3. Residual effect of chitosan application on chemical properties (pH, organic carbon and organic matter) of soil

Sultana *et al.* (2020) conducted a field experiment on BRRI dhan29. Residual effect of the raw material of CHT powder @ 4.0 t ha^{-1} (applied in the previous experiment) + 2/3rd of recommended N fertilizer and T_5 =Residual effect of the raw material of CHT powder @ 0 t ha^{-1} + recommended N (control). The total nitrogen content, soil pH, organic carbon and organic matter status in the post-harvest-soils were increased due to the residual effect of the powder in rice growing soils. The maximum value of the pH (7.01), organic carbon content (0.72%), and organic matter content (1.24%) in the post-harvest soils were found in the treatment T_4 and lowest values were observed in the control treatment (T_5).

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 revealed that @ 1% FCW the pH differ significantly from 0.5% FCW, 0.25% FCW and the rest of the treatment. The pH ranges from 5.01 to 5.93 among the treatment. @ 1% FCW the highest pH was obtained (5.93) and lowest pH was obtained (5.01) with CF = soil supplemented with chemical fertilizer.

Farooq and Nawaz, (2014); Matsumoto *et al*. (1999); Yaron, (1987) and Khaleel *et al*. (1981) showed that FCW application to the soil also led to an increased organic matter in the soil. OM improves the physical, chemical and biological properties of soil, as well as giving a better soil aggregation, available water content and enhanced cation exchange capacity, leading to improved soil fertility. The results found that @ 1% FCW the organic matter differ significantly from 0.5% FCW, 0.25% FCW and the rest of the treatment. Organic matter level ranges from 1.82 to 2.35 among the treatment. @ 1% FCW the highest organic matter level was obtained (2.35) and lowest organic matter level was obtained (1.82) with CF = soil supplemented with chemical fertilizer.

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

Hu *et al.* (2006) showed that with increasing of chitosan acid solution, the water stable aggregate and permeability coefficient of soil increased, however, bulk destiny, CEC and pH of the soil were reduced, the soil EC decreased firstly and then raised. The changes of physical and chemical properties appeared stable when the dose of chitosan exceeded 0.45% (chitosan mass concentration relative to dry soil) on the soil.

Manucharova *et al.* (2005 and 2006) evaluated 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. Gooday (1990) reported that chitin and its derivatives show additional properties among carbohydrates, as nitrogen content and, therefore, a low C/N ratio.

2.4. Effect of chitosan application on disease control

Pandey *et al.* (2018) explained that chitosan is emerging as a potential agent used in enhancing defence mechanism of plant, as growth promoter, as antimicrobial agent, as a soil conditioner. Beside this chitosan is used as carrier for improving nutrient delivery, increasing water use efficiency and as absorbent of heavy metals.

Orzali *et al.* (2017) explained that chitosan is active molecule that finds many possibilities for application in agriculture, including plant disease control. It showed to be effective against seed borne pathogens when applied as seed treatment. It can form physical barriers (film) around the seed surface, and it can vehicular other antimicrobial compounds that could be added to the seed treatments.

Hassan and Chang (2017) showed that chitosan controls pathogenic microorganisms by preventing their growth and sporulation, reducing spore viability and germination and by disrupting their cell membrane. Secondly, it induce of different defense responses in host plants by inducing and/or inhibiting different biochemical activities during the plant pathogen interaction. Chitosan has been assayed for controlling numerous pre and post-harvest diseases of many crops.

Li *et al.* (2013) evaluated that in vitro antibacterial effect of chitosan and its ability in protection of watermelon seedlings from bacterial fruit blotch. Results showed that three types of chitosan, in particular, chitosan A at 0.40 mg mL^{-1} significantly inhibited the growth of *Acidovorax citrulli.* The disease index of watermelon seedlings planted in soil and the death rate of seedlings planted in perlite were significantly reduced by chitosan A at 0.40 mg mL^{-1} compared to the pathogen control.

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.

Hien *et al*. (2010) reported that the elicitation and growth promotion effect of oligochiotsan for sugarcane and rice. Results obtained that oligochitosan with moleculer weight (Mw) 6000-10,000 exhibited the most effective elicitation and growth promotion for plant. The optimum oligochitosan concentrations by spraying were 30 and 15 ppm for sugarcane and rice, respectively. The disease index of *Ustilgo scitaminea* and *Collectotrichum falcatum* on sugarcane was reduced respectively to 44.5% and 72.3% compared to control (100%).

El Hadrami *et al.* (2010) reported that chitin and chitosan is active against viruses, bacteria and other pests. Fragments from chitin and chitosan are known to have eliciting activities leading to a variety of defense responses in host plants in response to microbial infections, including the accumulation of phytoalexins, pathogen-related (PR) proteins and proteinase inhibitors, lignin synthesis, and callose formation.

Meng *et al*. (2010) explained that chitosan and oligochitosan strongly inhibited spore germination and mycelial growth of *Alternaria kikuchiana* Tanaka and *Physalospora piricola* Nose. Relatively, chitosan and oligochitosan showed more obvious inhibitory effect on mycelial growth than spore germination. These results suggested that chitosan and oligochitosan triggered different mechanism for pathogenicity inhibition and disease control.

Oka and Pivonia (2003) revealed 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.

Ben-Shalom *et al*. (2003) evaluated that the effects of chitosan and chitin oligomers on grey mould caused by *Botrytis cinerea* in cucumber plants. It was found that chitosan controlled the grey mould caused by *B. cinerea* (0.45 disease index) compared with control (3.5 disease index). Results showed that spraying of chitosan 1h before inoculation with *Botrytis* conidia decreased grey mould incidence by 65%. Spraying chitosan 4 or 24 h before inoculation reduced disease development by 82% and 87%, respectively. However, spraying chitosan on the leaves 1h after inoculation decreased grey mould only by 52%.

Rodiguez *et al*. (2002) showed that treating seeds of rice (*Oryza sativa* L.) with chitosan and hydrolyzed chitosan for induction of defense response against blast disease caused by *Pyricularia grisea*. Results revealed that seedlings obtained from seeds applied with chitosan and hydrolyzed chitosan (oligochitosan) showed stronger resistance to blast disease compared with non-applied plants (positive control).

Bell *et al.* (1998) conducted an experiment with chitin and chitosan on disease incidence and severity of *Fusarium* yellows of celery and on populations of *Fusarium oxysporum*. Field experiments were conducted at two locations with a history of severe *Fusarium* yellows. Disease incidence and severity were significantly reduced by pre-plant chitin amendments to soil. Chitosan applied as a root dip alone did not reduce disease incidence but significantly ($P < 0.05$) reduced disease severity when used with a tolerant celery cultivar.

2.5 Effect of chitosan application on post-harvest management

Khatri *et al*. (2020) conducted an experiment with the combination of Aloe vera gel and chitosan, as edible coatings, in extending the post-harvest shelf-life of tomato fruits (*Solanum lycopersicum* Mill.). They revealed that A. vera gel and chitosan treatment showed the best efficiency in delaying the ripening process and extended the fruit shelf-life up to 42 days.

Reddy *et al*. (2000) showed that Chitosan sprays significantly reduced post-harvest fungal rot and maintained the keeping quality of the fruit compared with control. The incidence of decay decreased with increased chitosan concentration and increased with storage period and temperature. Chitosan sprays at 6 g l^{-1} concentration performed twice, 10 days apart, protected the fruit from decay and kept the fruit quality at an acceptable level throughout the storage period of 4 weeks in fruit stored at 3°C.

Esyanti *et al*. (2019) observed that physical characteristics of bananas ripening. Results showed that fruits coated with chitosan nanoparticles 0.2% has a slower skin discolouration by 2-3 days compared to control treatment.

Lustriane *et al*. (2018) evaluated that the effect of different concentrations of chitosan and chitosan nanoparticles as edible coating in extending shelf life and maintaining the quality of banana fruits (*Musa acuminata* AAA group). The fruit treated with 1.15% chitosan, 1.25% chitosan and chitosan nanoparticles then store at ambient temperature (25±1°C). The shelf-life of banana, starch content, weight loss, pulp to peel ratio, total soluble solid, surface morphology of banana peel and sensory evaluation were analysed.

Parvin *et al*. (2018) evaluated that the effect of irradiated chitosan coating on post-harvest preservation of tomato. Irradiated chitosan (40 kGy) solution of various concentrations (500, 750, 1000, 1500 and 2000 ppm) were applied on post-harvest preservation of tomato. The results revealed that 1500 ppm chitosan solution performed better in extending the shelf-life of tomato as compared to the control and other treated samples.

Kaur *et al*. (2018) carried out a laboratory experiment to study the "Effect of Post-harvest treatments for enhancing shelf life of 'Litchi' (*Litchi chinensis* Sonn.)". There were eight treatments used in which one control and remaining treatments consist Chitosan (1%), Ascorbic Acid (5%), Ascorbic Acid (10%), Citric Acid (5%), Citric Acid (10%), Oxalic Acid (5%) and Oxalic Acid (10%). The Chitosan 1% treatment will serve as a good alternative for prolonging shelf life.

Zahoorullah *et al*. (2017) explored that the effect of Chitosan coatings that were applied by double immersion of fruits in the film-forming solutions for 5 min, depending on treatments: (i) Chitosan at 1.5% (w/v) in lactic acid 1% (v/v); (ii) Chitosan at 1.5% (w/v) in lactic acid 1% (v/v) and Tween 80 at 0.1% (w/v); and (iii) Chitosan at 1.5% (w/v) in acetic acid 1% (v/v). (iv) Uncoated. The effectiveness of the treatments in extending fruit shelf-life was evaluated by determining ripening stages, weight loss, firmness, pH, total sugars, reducing sugars, non- reducing sugars.

Camatari *et al*. (2017) demonstrated that chitosan showed significant effect on weight loss, peel color, texture, aroma and time which correlated well for suitability of fruit consumption. The formulation containing 0.25% of chitosan and 0.5% of cassava starch showed most favorable results as it presented a post-harvest shelf life of 3 days more than the control fruits and lower rates of CO_2 production.

Romanazzi *et al*. (2017) found that chitosan application has shown promising disease control, at both pre harvest and postharvest stages. Chitosan coating forms a semipermeable film on the surface of fruit and vegetables, thereby delaying the rate of respiration, decreasing weight loss, maintaining the overall quality, and prolonging the shelf life.

Ibrahim *et al*. (2014) conducted an experiment to investigate the effects of gamma irradiated and un-irradiated chitosan coating on different quality parameters (ripening, biochemical and organoleptic) and shelf life extension of pineapple over a storage period of 18 days at ambient environment (30 ± 1°C /75 ± 5% RH). The overall results showed the superiority of irradiated chitosan (15 kGy) in extending the shelf life of pineapple and potentiality to be used on fresh produce to maintain quality and extending shelf life.

Chien *et al*. (2007) carried out an experiment with edible chitosan on sliced mango. These were treated with aqueous solutions of 0%, 0.5%, 1% or 2% chitosan. Results showed that chitosan coating retarded water loss and the drop in sensory quality, increasing the soluble solid content, titratable acidity and ascorbic acid content. It also inhibited the growth of microorganisms.

Bautista-Baños *et al*. (2006) reported that both soil and foliar plant pathogens fungal, bacterial and viral may be controlled by chitosan application. Chitosan has been shown to increase the production of glucanohydrolases, phenolic compounds and synthesis of specific phytoalexins with antifungal activity, and also reduces macerating enzymes such as polygalacturonases, pectin metil esterase etc. In addition, chitosan induces structural barriers for example inducing the synthesis of lignin-like material. For some horticultural and ornamental commodities, chitosan increased harvested yield. Due to its ability to form a semipermeable coating, chitosan extends the shelf life of treated fruit and vegetables by minimizing the rate of respiration and reducing water loss.

Chien and Chou (2006) examined that the antifungal activity of chitosan A (MW = 92.1 kDa) and B (MW = 357.3 kDa), with 94.2% N-deacetylation at various concentrations against fungi including *Penicillium digitatum*, *Penicillium italicum*, *Botrydiplodia lecanidion* and *Botrytis cinerea*. The effectiveness of these chitosans to control the post-harvest quality of Tankan fruit. Chitosan treatment significantly reduced ($P < 0.05$) the percentage decay of Tankan fruit during storage at 24°C. After 42 days of storage at 13 °C, chitosan-coated Tankan fruits were firmer, exhibited less decay and weight loss, and showed higher titratable acidity, ascorbic acid, and total soluble solids than the control fruit.

2.6 Others reviews about chitosan application in Agriculture

Shahrajabian *et al.* (2021) found that Chitin and chitosan can be used in plant defense systems against biological and environmental stress conditions and as a plant growth promoter it can increase stomatal conductance and reduce transpiration or be applied as a coating material in seeds. Finally, it can remediate polluted soils through the removal of cationic and anionic heavy metals and the improvement of soil properties.

Oliveira *et al*. (2021) explained that chitosan has great versatility of modifications and formulations for industrial applications, such as controlled release, surface modification, and preparation of nanoparticles. This chapter gives a comprehensive review of the advantages and recent developments in the formulation of chitosan nanoparticles as an alternative for sustainable agriculture.

Mujtaba *et al*. (2020) Chitosan molecules can be easily modified for adsorption and slow release of plant growth regulators, herbicides, pesticides, and fertilizers, etc. Chitosan as a carrier and control release matrix that offers many benefits including; protection of biomolecules from harsh environmental conditions such as pH, light, temperatures and prolonged release of active ingredients from its matrix consequently protecting the plant's cells from the hazardous effects of burst release.

Priyaadharshini *et al*. (2019) showed that the treatment with chitosan causes reduction in stomatal conductance thereby limiting the photosynthesis, transpiration rate and raise in leaf temperature than unsprayed plants in case of pearl millet under water deficit condition.

Mohamed (2018) conducted a greenhouse experiment on one-year old sour orange seedlings. Results showed that most of the vegetative growth indices, plant height %, stem diameter %, leaves number, area, fresh and dry weight and relative water content(RWC) %, leaf carbohydrates and protein % were significantly decreased with increasing drought level and that chitosan and putrescine application resulted in enhancement gradually of the previous parameters by increasing concentrations applied.

Zong *et al*. (2017) revealed that Chitosan (CTS) induces plant tolerance against several abiotic stresses, including salinity and drought exposure. The results showed that Cd stress significantly decreased plant growth, leaf chlorophyll contents and increased the malondialdehyde (MDA) level in rape leaves.

Rosul (2014) explained that applying carboxymethyl chitosan could strongly improve the abilities of transportation of N in functional leaves and stem-sheaths of rice and key enzyme activities of nitrogen metabolism and contents of total N and protein N in brown of rice comparing to CK. Applying 0.5% concentration of carboxymethyl chitosan resulted in the highest rice grain protein and which was 19.8% higher comparing to CK.

Berger *et al*. (2013) carried out an experiment which results revealed the potential of rock biofertilizer mixed with earthworm compound inoculated with free living diazotrophic bacteria and *C. elegans* (Fungi chitosan) for plant production and nutrient uptake. The biofertilizer, such as may be an alternative for NPK fertilization that slows the release of nutrients, favouring longterm soil fertility.

Van *et al*. (2013) carried out a greenhouse experiment with chitosan nanoparticles on biophysical characteristics and growth of Robusta coffee (*Coffea canephora Piere var Robusta*) in green. The results showed that size effect of chitosan nanoparticles in the range from 420 to 970 nm on biophysical characteristics and growth parameters of the coffee seedlings was not different significantly.

Farouk and Amany (2012) found that foliar applied chitosan, in particular 250 mg l^{-1}, increased plant growth, yield and its quality as well as physiological constituents in plant shoot under stressed or nonstressed conditions as compared to untreated plants. Treatment with chitosan, in particular, 250 mg l^{-1} and their interactions with stress conditions increased all the above mentioned parameters in either non-stressed or stressed plants. It is suggested that the severity of cowpea plants damaged from water stress was reduced by 250 mg l^{-1} chitosan application.

Mondal *et al*. (2011) conducted a pot experiment on Indian spinach. The experiment comprised five levels of Chitosan concentrations viz., 0 (control), 25, 50, 75 and 100 ppm. The Chitosan was sprayed two times of 15 and 25 days after sowing. Results indicated that application of Chitosan @ 75 ppm is optimum for maximizing plant growth and development of Indian spinach.

Boonlertnirun *et al*. (2007) carried out an experiment 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 1000-seed yield and also showed good recovery on yield.

Bartnicki-Garcia (1969) explained that chitosan (b-1, 4-linked glucosamine) is a deacetylated derivative of chitin found in the composition of cell walls of many fungi. From data in previous reports, two biological roles can be ascribed to this compound. First, at defined concentrations, it presents antifungal properties as shown by its inhibitory action on the mycelial growth of a number of pathogenic fungi, including root pathogens, such as *Fusarium oxysporum* and *Pithium phanidermatum.*

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The experiments were accomplished at the field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from May 2019 to September 2019. This chapter deals with a brief description on experimental site, climate, soil, and land preparation, layout of the experimental design, intercultural operations, data recording and their analyses.

3.1 Site description

The experiments were carried out at the field of Sher-e-Bangla Agricultural University, Dhaka.

3.2 Geographical location

The location of the experimental site was situated at 23°77′N latitude and 90°33′E longitude at an altitude of 8.6 meter from the mean sea level.

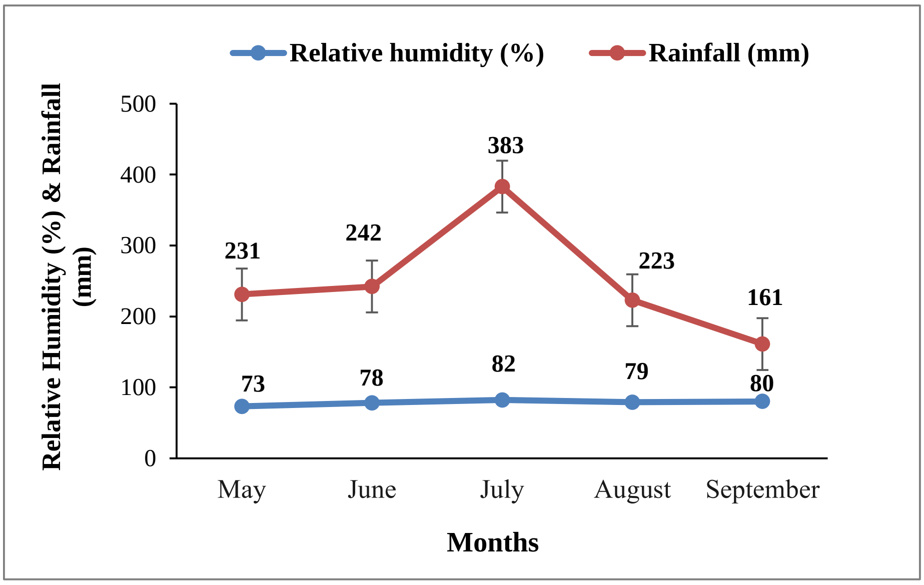
3.3 Agro-ecological region

The experiment was conducted under “The Modhupur Tract”, AEZ-28 (Anon., 1988a) of Agro-ecological zone of Bangladesh. 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., 1988b). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.4 Climate

The experimental area was under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the Rabi season (October-March). The experiment was carried out in the month of May to September (Kharif 1 season) 2019. The monthly average minimum and maximum temperature and relative humidity during the crop period was 18.2^{o}C to 29.9^{o}C and 73% to 82% respectively. The monthly average minimum and maximum rainfall was 161mm and 383 mm. All the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment were noted from the Bangladesh Meteorological Department, Sher-e-Bangla Nagar, Dhaka-1207. The weather data during the study period of the experimental site is shown in Appendix II.

A)



B)

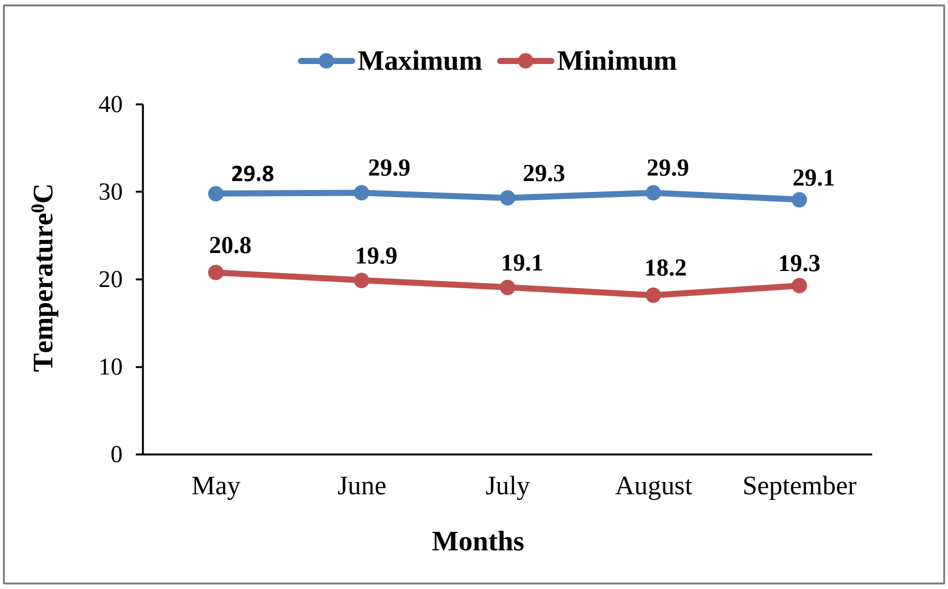


Figure 1. Monthly record of relative humidity, rainfall (average) and temperature of the experimental site during the experimental time

3.5 Soil

The soil belongs to the general soil type, Shallow Red Brown Terrace under Tejgaon soil Series. Top soils were Silty clay loam in texture, olive-grey with common fine to medium distinct dark yellowish brown mottles. Initial Soil pH was 6.05 and had organic carbon 0.60% and organic matter content is 1.03%. The experimental area was flat having available irrigation and drainage system. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples were collected from 0-30 cm, 30-60 cm and 60-90 cm depths from the experimental field. The chemical analyses were done in the laboratory of the Department of Soil Science of Sher-e-Bangla Agricultural University, Dhaka-1207.

Table 1: Morphological characteristics of the soil of experimental field

Morphological features	Characteristics
Location	Soil science field ,SAU, Dhaka
AEZ	Madhupur tract (28)
Soil series	Tejgaon
Topography	Fairly leveled
Land type	High land
General soil type	Shallow red brown terrace soil
Flood level	Above flood level
Drainage	Well drained

Table 2: Physical and chemical characteristics of initial soil

Characteristics	Value
% Sand	18
% Silt	50
% Clay	32
Textural class	Silty-clay loam
pH	6.05
Organic carbon (%)	0.60
Organic matter (%)	1.03
Total N (%)	0.03

Table 3: Chemical properties of initial (Tomato growing) soil

Treatments	Soil Layer (cm)	Soil organic carbon (%)	Soil organic matter (%)	Soil pH
T_1	0-30	0.73	1.26	6.23
	30-60	0.68	1.17	
	60-90	0.62	1.07	
T_2	0-30	0.86	1.48	6.36
	30-60	0.76	1.31	
	60-90	0.68	1.17	
T_3	0-30	0.93	1.60	6.52
	30-60	0.85	1.46	
	60-90	0.74	1.27	
T_4	0-30	1.02	1.75	6.56
	30-60	0.91	1.57	
	60-90	0.81	1.39	
T_5	0-30	1.13	1.94	6.64
	30-60	0.99	1.70	
	60-90	0.88	1.51	

3.6 Experimental details

3.6.1 Crop/Planting material

BARI Dherosh-1 was used as the test crop. The variety BARI Dherosh-1 was developed in 1996 by Bangladesh Agriculture Research Institute (BARI), Joydebpur, Gajipur, Bangladesh. Plant height is 200-250 cm. Fruits are green with 5 marked ridges and 14-15 cm long. Each plant produces 25-30 fruits. The growth duration is about 150 days.

Experimental Treatments

Table 4: Five treatments dose of chitosan raw material powder

Treatment	1st Crop (Tomato) Rabi Season	2nd Crop (Okra) Kharif 1
T_1	0% Chitosan raw material powder (control)	-
T_2	0.1% Chitosan raw material powder (applied in the previous expt.)	-
T_3	0.2% Chitosan raw material powder (applied in the previous expt.)	-
T_4	0.3% Chitosan raw material powder (applied in the previous expt.)	-
T_5	0.4% Chitosan raw material powder (applied in the previous expt.)	-

3.6.2 Preparation of chitosan raw material powder

Chitosan raw material powder was prepared using shrimp shell by products that was collected from the Khulna region of Bangladesh and sieving the powder using <2 mm sieves to prepare the usable CHT raw material powder following a new traditional method. The prepared chitosan raw material powder was used in the 1st experimental crop (Tomato) on 26 November, 2018 during the final land preparation.

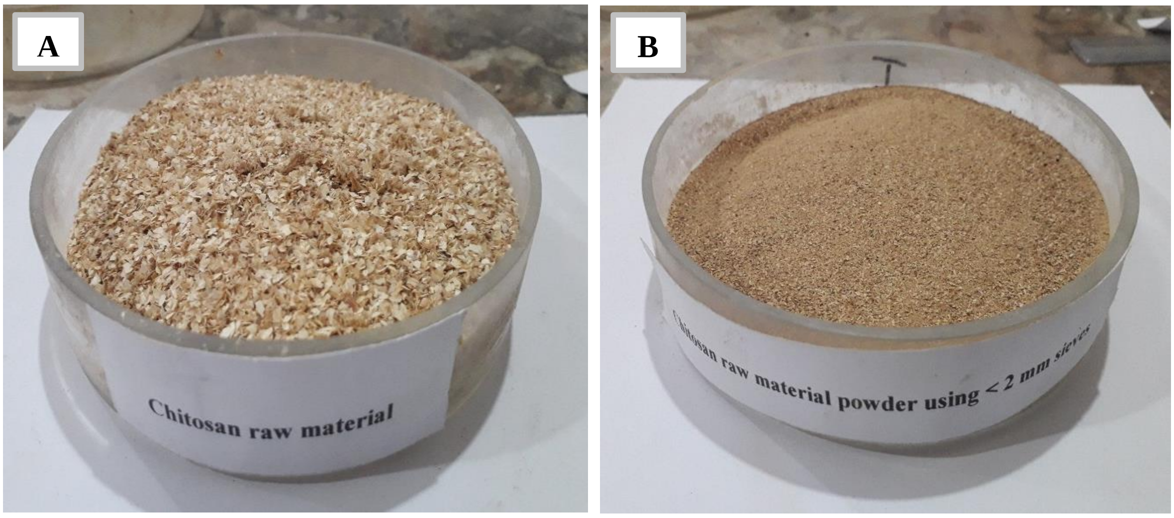


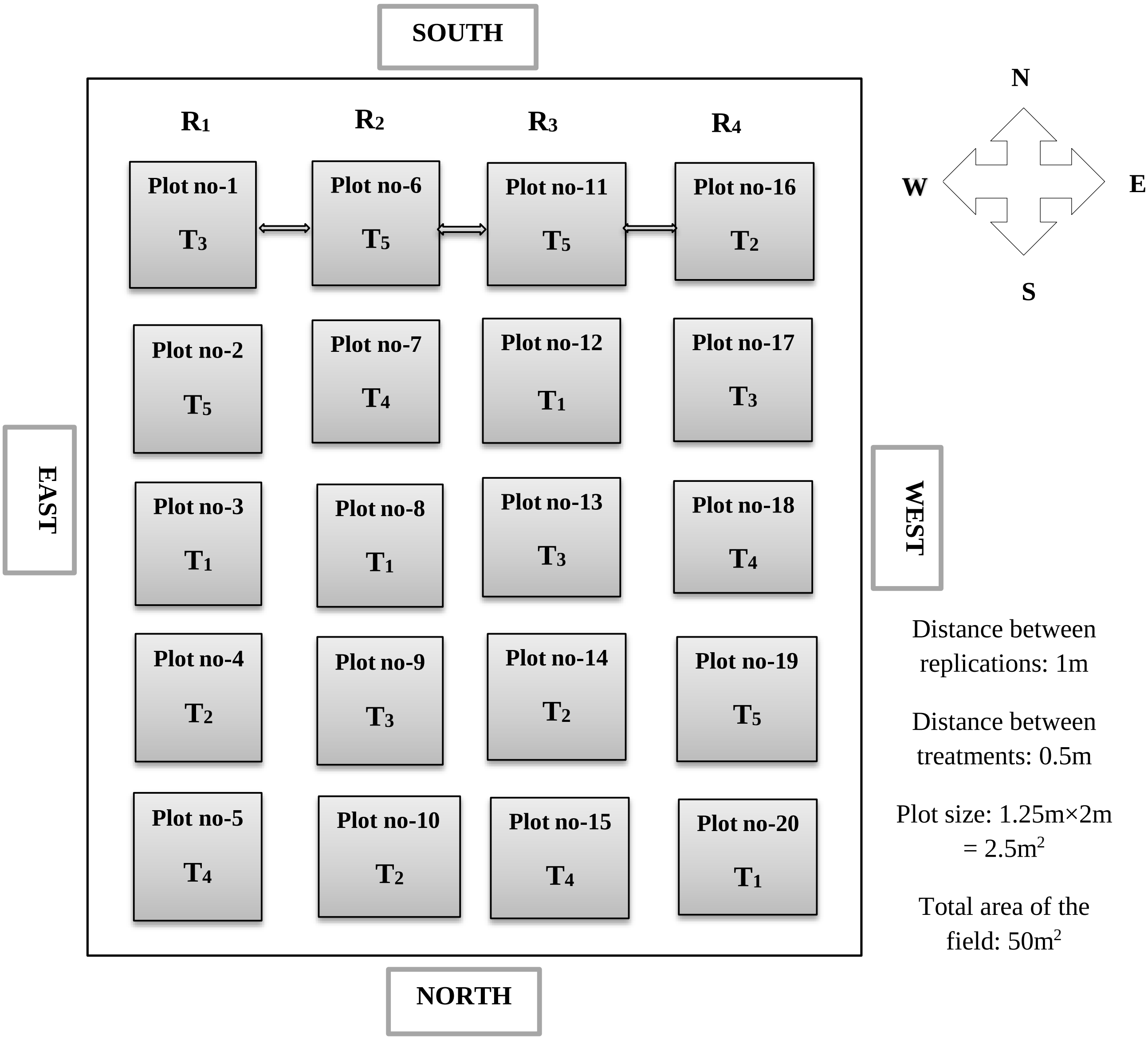
Plate 1. Chitosan raw material and Chitosan raw material powder using <2 mm sieves

Table 5. Chemical composition of the CHT raw material powder

Name of the nutrients	Nutrient content	Methods name
pH	8.19	Glass Electrode Method (Max Cremer, 1906)
Organic Carbon (OC)	18.39%	Wet Oxidation Method (Walkley and Black, 1934)
Organic Matter (OM)	31.70%	Organic carbon x 1.724 (Van Bemmelen factor)
Total Nitrogen (N)	7.42-11.41%	Micro-Kjeldahl Metod (Kjeldahl, J. (1883)
Phosphorus (P)	0.45%	Spectrophotometric Molybdovanadate Method (Boltz, D. F., and Mellon, M. G. 1948)
Potassium (K)	0.14%	Flame Photometric Method (Deal, S. B.1954)
Sulphur (S)	0.10%	Spectrophotometric Method (Jones, A. S., & Letham, D. S. 1956)
Boron (B)	17.94 ppm	
Calcium (Ca)	75 ppm	Atomic Absorption Spectrophotometric Method (Trudeau, D. L., & Freier, E. F. 1967).
Magnesium (Mg)	2.7 ppm	
Zinc (Zn)	0.096%	

3.6.3 Experimental design

The experiment was organized in a Randomized Complete Block Design (factorial). Number of treatment was 5 and number of replication was 4. The size of the plot was 2.5 m^2 (1.25m × 2m). Total plots in the experimental field were 20. The treatments were randomly distributed to each block. The distance between two adjacent replications (block) was 1m and row-to-row distance was 0.5 m. The inter block and inter row spaces were used as footpath and irrigation or drainage channel. The layout of the experiments has been shown in Figure 2.



Replications:	Treatment Combinations:
R_1: Replication 1	T_1 = {0% CHT raw material powder (control)}
R_2: Replication 2	T_2 = {0.1% CHT raw material powder (applied in the previous expt.)}
R_3: Replication 3	T_3 = {0.2% CHT raw material powder (applied in the previous expt.)}
R_4: Replication 4	T_4 = {0.3% CHT raw material powder (applied in the previous expt.)} and
	T_5 = {0.4% CHT raw material powder (applied in the previous expt.)}

Figure 2. The layout of the experimental field

3.7 Seed collection

BARI Dherosh-1 Seeds were collected from BARI, Joydebpur, Gazipur, Bangladesh. Healthy seeds were collected for seed sowing.

3.8 Preparation of experimental land

The experimental field was prepared on May 26, 2019 with the help of spade; later on May 28, 2019 the land was irrigated and leveled by laddering. Residues of previous crop and all kinds of weeds were removed from the field. After the final land preparation the field layout was made on May 28, 2019 according to experimental plan. By using wooden plank all plots were cleaned and finally levelled for seed sowing.

3.9 Seed sowing

The seeds were sown on the plot on May 29, 2019 for raising seedlings. 8 Seeds were sown in every individuals plot at the depth of 3cm of soil. Maintaining the distance (row to row 45cm and plant to plant 30cm).

3.10 Intercultural operations

After germination of the seedlings, different intercultural operations were performed for better growth and development, which are as follows.

3.10.1 Weeding and hoeing

The plot was covered with some weeds after the germination of seedlings. Hand weeding and hoeing was done in every individuals plot. Weeding and hoeing was done at 27 days after sowing of seeds and second weeding at 20 days after first weeding.

3.10.2 Irrigation

Irrigation water was added to each plot as and when required.

3.10.3 Plant protection measures

Plants were successfully controlled by applying SEVIN^{R} 85 sp @ 1ml 1 liter^{-1} of water by the infested of Aphids (*Aphis gossypii*), Shoot and fruit borer (*Earias vittela* and *Earias insulana*), and okra fruit borer (*Helicoverpa armigera*). These are the most serious pest of okra plant.

3.11 General observation of the experimental field

Infestation by weeds, insects and diseases and also by the pest could be minimized by the regular observation of the experimental field. Regular black ants were observed at the flowering time of the okra plant that controlled properly by the reducing of aphid population. No bacterial and fungal disease was observed in the field.

3.12 Harvesting

The okra fruit were harvested 5-6 days after flowering, when the fruit was bright green in colour, the fruit was fleshy, seeds were small and mucilage content was high. There were 19 harvest occurred by every 1 day's intervals. First harvesting was done on July 30, 2019. After every harvesting of fruit different growth and yield attributes data were collected.

3.13 Recording of data

During the experiment the followings data were recorded these are given below:

A. Plant growth characters

i. Plant height (cm)

B. Yield and yield components

i. Average number of flower plant^{-1}
ii. Fruits plant^{-1}
iii. Number of flower dropping plot^{-1}
iv. Total fruits plot^{-1}
v. Average fruit length (cm)
vi. Fresh weight of single fruit (g)
vii. Oven dry weight of single fruit (g)
viii. Fresh weight (g) of fruit plot^{-1}
ix. Fruit oven dry weight plot^{-1} (g)
x. Yield (t ha^{-1})

3.14 Procedure of data collection

A. Crop growth characters

i. Plant height (cm)

Plant height was measured from the ground level to the top of the tallest branch of the plant and mean value was calculated. Plant height recorded at final harvest.

B. Yield and yield components

i. Average number of flower plant^{-1}

The number of flower plant^{-1} was counted from randomly selected plant and their average was taken as the total number of flower plant^{-1}.

ii. **Fruits plant^{-1}**

Fruits plant^{-1} was measured by the total number of fruits (g) by dividing it's single fruit weight.

iii. **Number of flower dropping plot^{-1}**

Number of flower dropping plot^{-1} was counted by regular observation of plot.

iv. **Total fruits plot^{-1}**

The total fruits plot^{-1} was measured by multiplication of fruits plant^{-1} and no. of plant plot^{-1}.

v. **Average fruit length (cm)**

Average fruit length plant^{-1} was measured by using measuring scale.

vi. **Fresh weight of single fruit (g)**

Single fruit fresh weight was measured by using weight meter.

vii. **Oven dry weight of single fruit (g)**

Fruit oven dry weight was measured by using oven at 170^{o}c temperature for 24 hr. then the dried fruit were measured by using weight meter.

viii. **Fresh weight (g) of fruit plot^{-1}**

Single fruit fresh weight plot^{-1} was measured by multiplication of average single fruit fresh weight and no. of plant plot^{-1}.

ix. Fruit oven dry weight plot^{-1} (g)

Fruit oven dry weight plot^{-1} was measured by multiplication of average single fruit oven dry weight and no. of plant plot^{-1}.

x. Yield plot^{-1} (kg ha^{-1})

Fruit yield (kg ha^{-1}) plot^{-1} was calculated by using the following formula:

$$\text{Yield kg ha}^{-1} = \frac{\text{Yield plot}^{-1}\text{ (kg)}}{\text{Area of plot (m}^2\text{)}} \times 10000 \text{ m}^2$$

xi. Yield plot^{-1} (t ha^{-1})

Fruit yield (t ha^{-1}) plot^{-1} was calculated by using the following formula:

$$\text{Yield t ha}^{-1} = \frac{\text{Yield plot}^{-1} \text{ x } 10000}{\text{Area of plot (m}^2\text{) x } 1000}$$

xii. Yield increased over control (%)

Yield increased over control was calculated by the following formula:

$$\text{Yield increased over control (\%)} = \frac{\text{Treatment yield} - \text{Control yield}}{\text{Control yield}} \text{ X } 100$$

3.15 Chemical analysis of soil samples

Soil samples were collected from 0-30 cm, 30-60cm, and 60-90cm of soil layer from the experimental field on 19 October, 2019 (one cropping season after application of chitosan raw material powder). Chemical properties of soil samples were analyzed in the laboratory of Department of Soil Science of Sher-e-Bangla Agricultural University, Dhaka-1207.

3.15.1 Soil pH

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

3.15.2 Organic C

Organic carbon in soil was determined by wet oxidation method of Walkley and Black (1934). 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. Dilute the mass in the flask with about 150-200 mL of distilled water by mixing conc. H_3PO_4 and 2 mL of diphenylamine indicator. The organic carbon was calculated by the following formula:

$$\% \text{ Organic carbon} = \frac{(B-T) \times N}{W} \times 0.003 \times 1.3 \times 100$$

Therefore, % Organic matter = % Organic carbon x 1.724

Where, B = Blank, T = Treatment, N = Normality, W = weight of soil, 1.724 = Van Bemmelen factor.

3.15.3 Total Nitrogen (%)

Nitrogen in soil was determined by Micro-Kjeldahl method of Kjeldahl, J. (1883). Soil Samples were digested with conc. H_2SO_4, 30% H_2O_2 and catalyst mixture (K_2SO_4: $C_USO_4.5H_2O$: Selenium powder in the ratio 100:10:1 respectively). Nitrogen in the digest was determined by distillation with NaOH followed by titration of the distillate absorbed in H_3BO_3 with 0.01 N H_2SO_4 (Jackson 1973). Total nitrogen was calculated by the following formula:

$$\% \text{ of total N in soil} = \frac{(T-B) \times N \times 0.014 \times D}{W} \times 100$$

Where, T = Treatment, B = Blank, N = Normality, D = Dilution factor, W = Weight of soil.

3.16 Statistical Analysis

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

CHAPTER IV
RESULTS AND DISCUSSION

CHAPTER IV

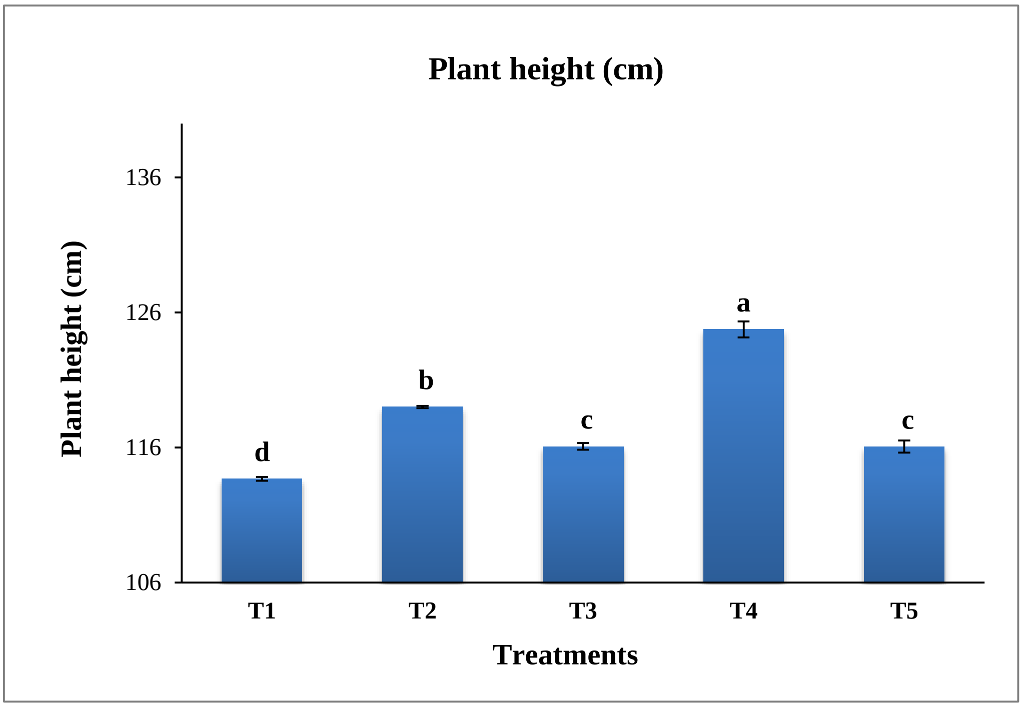
RESULTS AND DISCUSSION

This chapter interprets the presentation and explanation of the results obtained due to Residual effect of chitosan raw material powder on yield performance of okra under tomato-okra cropping system. The results of this paper have been presented, explained and compared as far as available with the results of the researchers.

4.1 Plant height (cm)

The residual effect of chitosan raw material powder on plant height was significantly different from one another in all of the treatments used in the experiment (Figure 3). The maximum plant height (124.75 cm) was found in the T_4 treatment which was significantly greater than that found in the T_1 treatment. T_3 treatment was statistically identical to T_5 treatment and the minimum plant height (113.67 cm) was found in the T_1 treatment. All treatments of the plant height may be organized as $T_4>T_2>T_3>T_5>T_1$.

These results were supported by Mondal *et al*., (2012) who accomplished pot and field experiments with the five levels of chitosan concentrations viz., 0 (control), 50, 75, 100 and 125 ppm. Results revealed that most of the morphological character (plant height) were increased with increasing concentration of chitosan until 25 ppm in case of okra cv. BARI dherosh-1.



T_1 = {0% CHT raw material powder (control)}

T_2 = {0.1% CHT raw material powder (applied in the previous expt.)}

T_3 = {0.2% CHT raw material powder (applied in the previous expt.)}

T_4 = {0.3% CHT raw material powder (applied in the previous expt.)} and

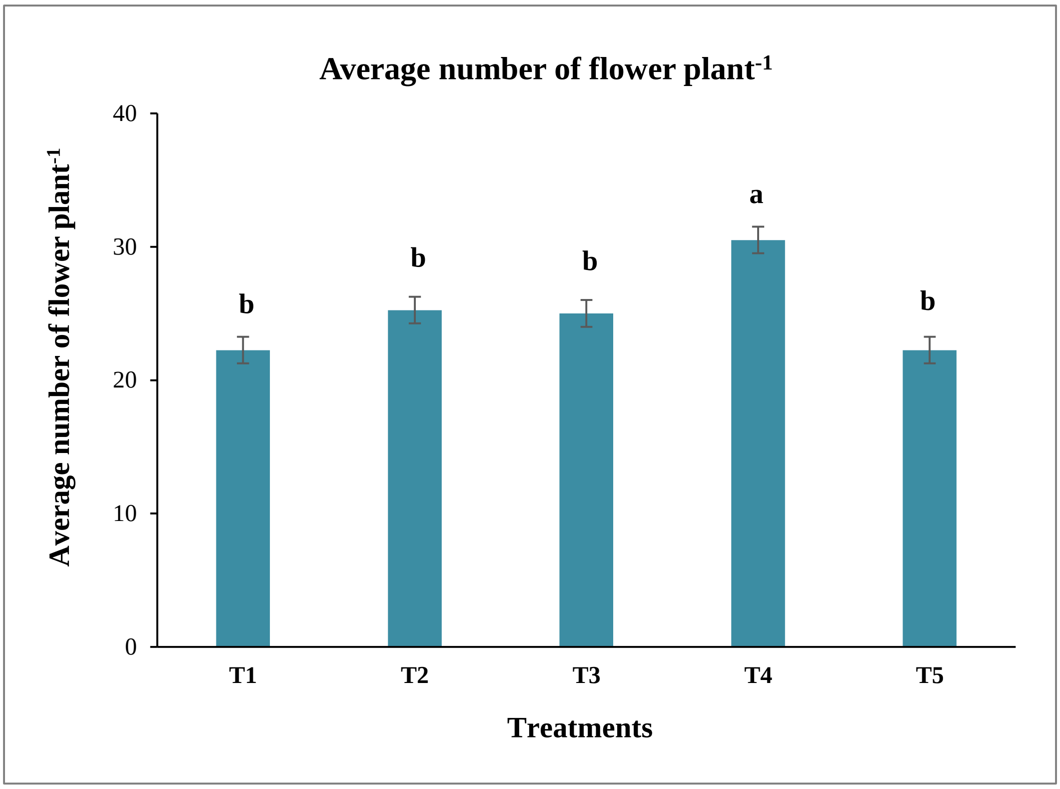
T_5 = {0.4% CHT raw material powder (applied in the previous expt.)}

Figure 3. Graphical representation of residual effect of different doses of chitosan raw material powder on plant height (cm) of okra (BARI Dheros-1). Mean was calculated from four replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD

4.2 Average number of flower plant^{-1}

The residual effects of chitosan raw material powder on different treatments on number of flower plant^{-1} (Figure 4). It was revealed that number of flower plant^{-1} were significantly different among the all treatments. The maximum number of flower plant^{-1} (30.50) was found in T_4 treatment which is statistically significant from T_1 treatment and T_5 treatment. On the other hand T_2 treatment, T_3 treatment and T_5 treatment were statistically identical to T_1 treatment. The minimum number of flower plant^{-1} (22.25) was found in T_1 treatment and T_5 treatment. According to the number of flower plant^{-1} all treatments may be organized as $T_4>T_2>T_3>T_1>T_5$. It was recognized that, the effect of residual chitosan raw material powder application in soil shows the positive effect on number of flower plant^{-1}.

These results were supported by Parvin *et* al., (2019) who carried out a pot experiment with tomato (*Lycopersicon esculentum* Mill.). The experiment was laid out in completely randomized design (CRD) with four replications and twelve treatments combinations viz., T_0 = Control, T_1= Soil application of chitosan (SAC) @80 ppm, T_2= SAC @120 ppm, T_3= Foliar spraying of chitosan (FSC) @60 ppm, T_4= FSC @80 ppm, T_5= FSC @100 ppm, T_6= Combination of T_1 and T_3, T_7= Combination of T_1 and T_4, T_8= Combination of T_1 and T_5, T_9= Combination of T_2 and T_3, T_{10}= Combination of T_2 and T_4, and T_1 = Combination of T_2 and T_5. Results revealed that there were significant variations among the treatments on number of flower clusters of tomato.



T_1 = {0% CHT raw material powder (control)}

T_2 = {0.1% CHT raw material powder (applied in the previous expt.)}

T_3 = {0.2% CHT raw material powder (applied in the previous expt.)}

T_4 = {0.3% CHT raw material powder (applied in the previous expt.)} and

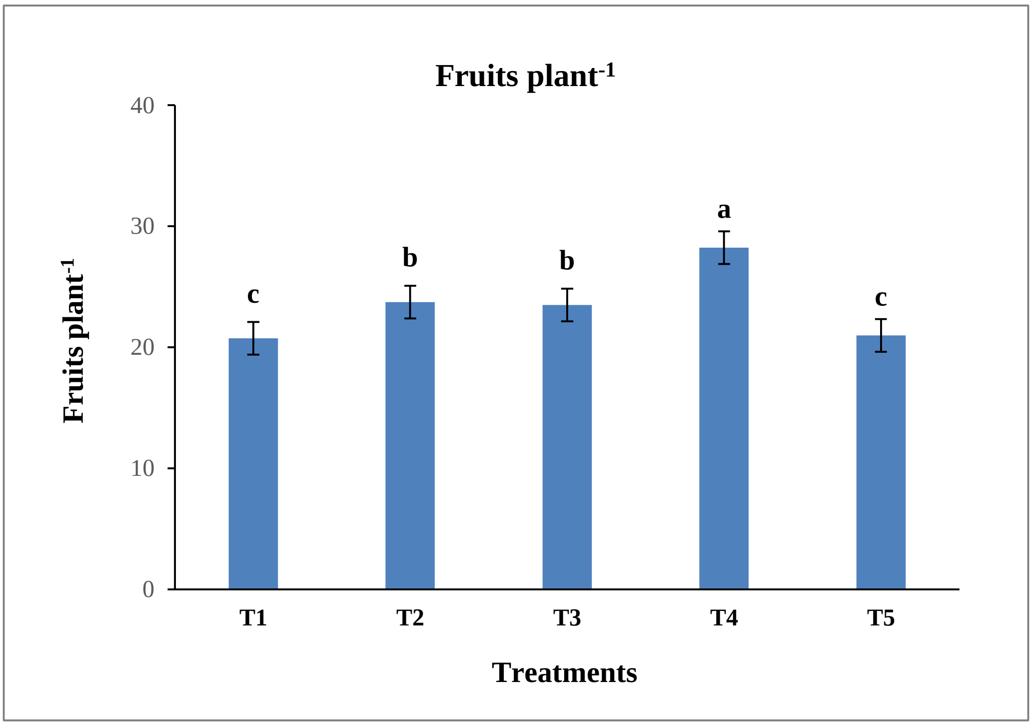
T_5 = {0.4% CHT raw material powder (applied in the previous expt.)}

Figure 4. Graphical representation of residual effect of different doses of chitosan raw material powder on number of flower plant^{-1} of okra (BARI Dheros-1). Mean was calculated from four replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD

4.3 Fruits plant^{-1}

The residual effects of chitosan raw material powder on different treatments on fruits plant^{-1} (Figure 5). It was found that fruits plant^{-1} were statistically significant among the all treatments. The maximum fruits plant^{-1} (28.25) was found in T_4 treatment which is statistically significant from T_1, T_2, T_3 and T_5 treatment. On the other hand T_2 treatment was statistically identical to T_3 treatment and T_5 treatment were statistically identical to T_1 treatment. The minimum fruits plant^{-1} (20.75) was found in T_1 treatment. According to the fruits plant^{-1} all treatments may be arranged as $T_4>T_2>T_3>T_5>T_1$. It was recognized that, the effect of residual chitosan raw material powder application in soil shows the positive effect on fruits plant^{-1} among the different treatment doses.

These results were supported by Kamruzzaman (2016) who conducted a field experiments with two individual rice variety i.e. BRRI dhan28 and BRRI dhan29. To investigate residual effect of modified chitosan (CHT) powder on nitrogen management and yield performance of Boro rice. The experiments were comprised of five treatments having four levels of modified CHT powder. Results found that yield and yield contributing characters of rice improved due to the residual effect of modified CHT powder



T_1 = {0% CHT raw material powder (control)}

T_2 = {0.1% CHT raw material powder (applied in the previous expt.)}

T_3 = {0.2% CHT raw material powder (applied in the previous expt.)}

T_4 = {0.3% CHT raw material powder (applied in the previous expt.)} and

T_5 = {0.4% CHT raw material powder (applied in the previous expt.)}

Figure 5. Graphical representation of residual effect of different doses of chitosan raw material powder on fruits plant^{-1} of okra (BARI Dheros-1). Mean was calculated from four replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD

4.4 Number of flower dropping plot^{-1}

Number of flower dropping plot^{-1} was found to be significantly different in all of the treatments used in the experiment (Table 6). The highest number of flower dropping (2.25) was found in the T_1 treatment which was significantly greater than the T_2 treatment, T_3 treatment, T_4 treatment and T_5 treatment. On the other hand T_3 treatment was statistically identical to T_5 treatment and the lower number of flower dropping (1) was found in the T_4. According to the number of flower dropping plant^{-1} all treatments may be organized as $T_1>T_5>T_3>T_2>T_4$.

Table 6. Residual effect of different doses of chitosan raw material powder on yield contributing characters of okra (BARI Dheros-1) at harvest

Treatments	Number of flower dropping plot^{-1}
T_1	2.25a
T_2	1.50bc
T_3	1.75ab
T_4	1.00c
T_5	2.00ab
SE(±)	0.31
CV (%)	25.75
LSD value	0.01

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD. SE (±) = Standard Error; CV (%) = Percent of Coefficient of Variance & LSD = Least Significant Difference.

T_1 = {0% CHT raw material powder (control)}

T_2 = {0.1% CHT raw material powder (applied in the previous expt.)}

T_3 = {0.2% CHT raw material powder (applied in the previous expt.)}

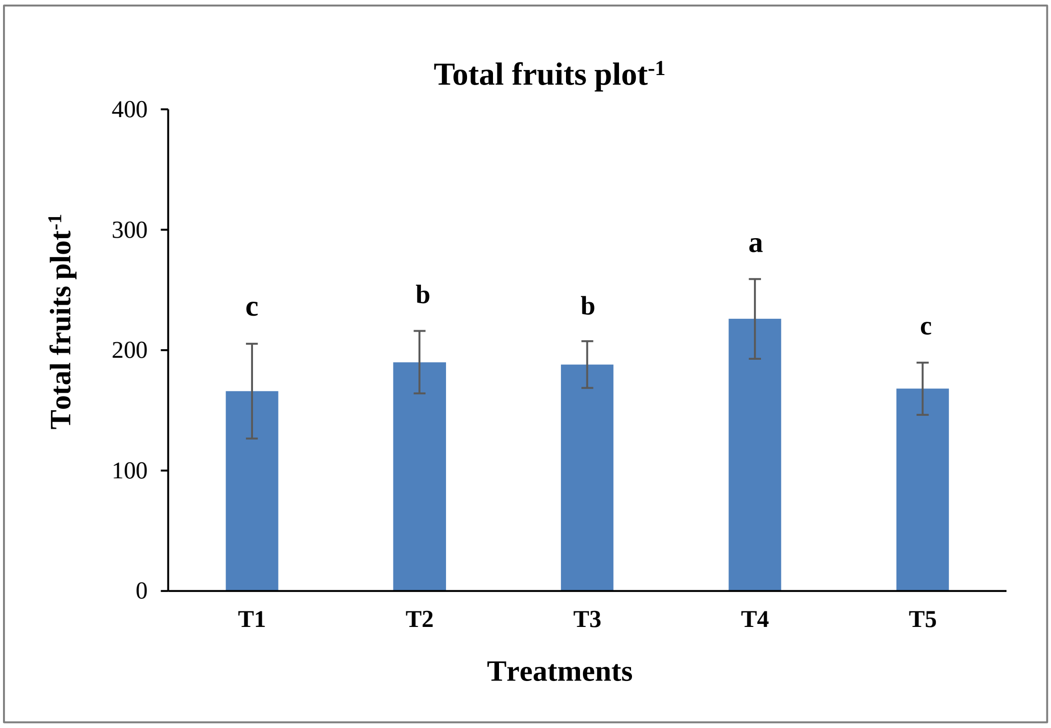
T_4 = {0.3% CHT raw material powder (applied in the previous expt.)} and

T_5 = {0.4% CHT raw material powder (applied in the previous expt.)}

4.5 Total fruits plot^{-1}

In case of total fruits plot^{-1} was found statistically significant among the all treatments (Figure 6). The maximum total fruits plant^{-1} (226) was found in T_4 treatment which is statistically significant from T_1 treatment and T_5 treatment. On the other hand T_2 treatment was statistically identical to T_3 treatment and T_5 treatment were statistically identical to T_1 treatment. The minimum total fruits plot^{-1} (166) was found in T_1 treatment. According to the total fruits plant^{-1} all treatments may be organized as $T_4>T_2>T_3>T_5>T_1$.

Similar results were also reported by Rahman (2015) who carried out a pot experiment with tomato cv. BARI tomato-15.



T_1 = {0% CHT raw material powder (control)}

T_2 = {0.1% CHT raw material powder (applied in the previous expt.)}

T_3 = {0.2% CHT raw material powder (applied in the previous expt.)}

T_4 = {0.3% CHT raw material powder (applied in the previous expt.)} and

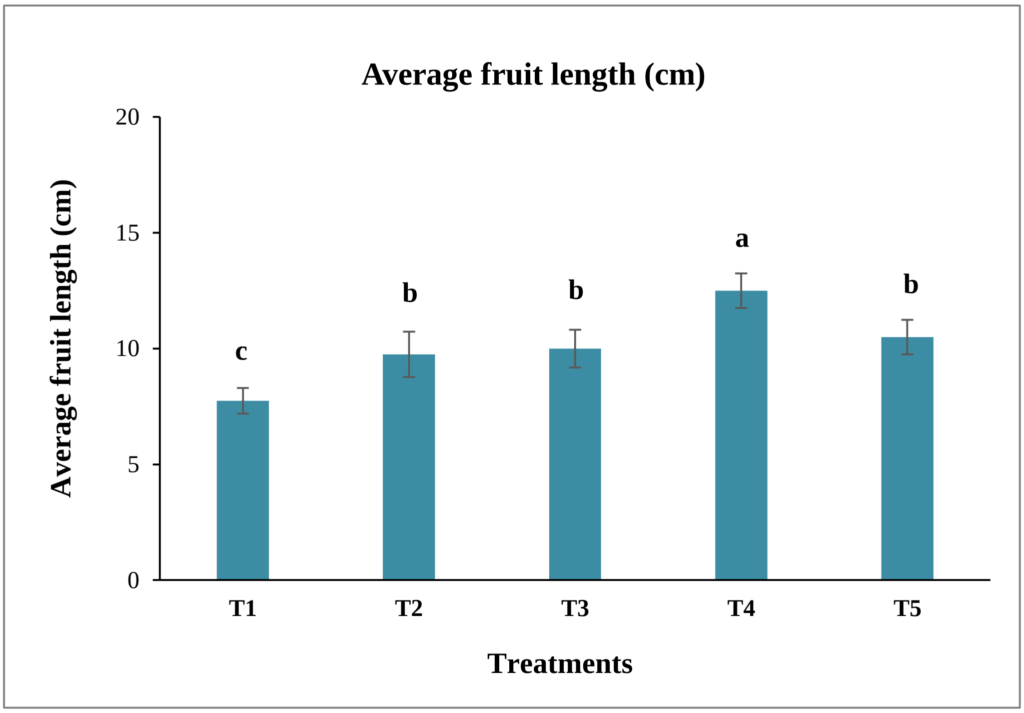
T_5 = {0.4% CHT raw material powder (applied in the previous expt.)}

Figure 6. Graphical representation of residual effect of different doses of chitosan raw material powder on total fruits $plot^{-1}$ of okra (BARI Dheros-1). Mean was calculated from four replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD

4.6 Average fruit length (cm)

Fruit length (cm) was found to be significantly different with each other treatments and showed in (Figure 7). The maximum fruit length plant^{-1} (12.50 cm) was obtained in the T_4 treatment which was significantly different from T_1. Treatment T_2 and T_3 were statistically identical to T_5 treatment. The minimum fruit length (7.75 cm) was found with T_1 treatment. According to the fruit length the treatments may be arranged as $T_4 > T_5 > T_3 > T_2 > T_1$.

Similar results were reported by Mondal *et al*., (2012) who carried out pot and field experiments with okra cv. BARI dherosh-1. Used five levels of chitosan concentrations were, 0 (control), 50, 75, 100 and 125 ppm. From this experiment result found that yield attributes fruit size were increased with increasing concentration of chitosan until 25 ppm.



T_1 = {0% CHT raw material powder (control)}

T_2 = {0.1% CHT raw material powder (applied in the previous expt.)}

T_3 = {0.2% CHT raw material powder (applied in the previous expt.)}

T_4 = {0.3% CHT raw material powder (applied in the previous expt.)} and

T_5 = {0.4% CHT raw material powder (applied in the previous expt.)}

Figure 7. Graphical representation of residual effect of different doses of chitosan raw material powder on average fruit length (cm) of okra (BARI Dheros-1) Mean was calculated from four replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD

4.7 Fresh weight of single fruit (g)

Fresh weight of single fruit (g) was found to be significantly different in all of the treatments used in the experiment (Table 7). The highest fresh weight of single fruit (13.07 g) was obtained in the T_4 treatment which was significantly different from T_1, treatment. T_2 treatment was statistically similar to T_3 treatment and T_3 treatment was statistically similar to T_5 treatment. The lowest fresh weight of single fruit (10.40 g) was found in the T_1. According to the fresh weight of single fruit all treatments may be arranged as $T_4>T_2>T_3>T_5>T_1$.

Table 7. Residual effect of different doses of chitosan raw material powder on fresh weight of single fruit and oven dry weight of single fruit of okra (BARI Dheros-1) at harvest

Treatments	Fresh weight of single fruit (g)	Oven dry weight of single fruit (g)
T_1	10.40d	0.99c
T_2	12.12b	1.50ab
T_3	11.47bc	1.36abc
T_4	13.07a	1.83a
T_5	10.67cd	1.18bc
SE(±)	0.43	0.22
CV%	5.30	22.37
LSD value	0.0003	0.02

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD. SE (±) = Standard Error; CV (%) = Percent of Coefficient of Variance & LSD = Least Significant Difference.

T_1 = {0% CHT raw material powder (control)}

T_2 = {0.1% CHT raw material powder (applied in the previous expt.)}

T_3 = {0.2% CHT raw material powder (applied in the previous expt.)}

T_4 = {0.3% CHT raw material powder (applied in the previous expt.)} and

T_5 = {0.4% CHT raw material powder (applied in the previous expt.)}

4.8 Oven dry weight of single fruit (g)

Oven dry weight of single fruit (g) found to be significantly different among the treatments (Table 7). The highest single fruit oven dry weight (1.83 g) was found in the T_4 treatment which was significantly different from T_1 treatment. On the other hand T_3 treatment was statistically identical to both T_2 treatment and T_5 treatment. The lowest single fruit oven dry weight (0.99 g) was found in the T_1. According to the single fruit oven dry weight all treatments may be organized as $T_4>T_2>T_3>T_5>T_1$.

4.9 Fresh weight (g) of fruit plot^{-1}

In case of fresh weight (g) of fruit plot^{-1} was found to be significantly different in all of the treatments used in the experiment (Table 8). The maximum fruit fresh weight plot^{-1} (104.60 g) was found in the T_4 treatment which was significantly different from T_1 treatment. T_2 treatment was statistically identical to T_3 treatment on the other hand T_3 treatment was statistically identical to T_5 treatment. The minimum fruit fresh weight plot^{-1} (83.20 g) was found in the T_1. According to the fruit fresh weight plot^{-1} all treatments may be organized as $T_4>T_2>T_3>T_5>T_1$.

4.10 Fruit oven dry weight plot^{-1} (g)

The fruit oven dry weight plot^{-1} was found to be significantly different among the treatments (Table 8). The higher fruit oven dry weight plot^{-1} (14.60 g) was found in the T_4 treatment which was significantly different from T_1 treatment. On the other hand T_3 treatment was statistically identical to both T_2 treatment and T_5 treatment. The lowest fruit oven dry weight plot^{-1} (7.90 g) was found in the T_1. According to the fruit oven dry weight plot^{-1} all treatments may be organized as $T_4>T_2>T_3>T_5>T_1$.

Table 8. Residual effect of different doses of chitosan raw material powder on fresh weight of fruit plot^{-1} and fruit oven dry weight plot^{-1} of okra (BARI Dheros-1) at harvest

Treatments	Fresh weight (g) of fruit plot^{-1}	Fruit oven dry weight plot^{-1} (g)
T_1	83.20d	7.90c
T_2	97.00b	12.00ab
T_3	91.80bc	10.84abc
T_4	104.60a	14.60a
T_5	85.40cd	9.40bc
SE(±)	3.46	1.73
CV%	5.30	22.37
LSD value	0.0003	0.02

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD. SE (±) = Standard Error; CV (%) = Percent of Coefficient of Variance & LSD = Least Significant Difference.

T_1 = {0% CHT raw material powder (control)}

T_2 = {0.1% CHT raw material powder (applied in the previous expt.)}

T_3 = {0.2% CHT raw material powder (applied in the previous expt.)}

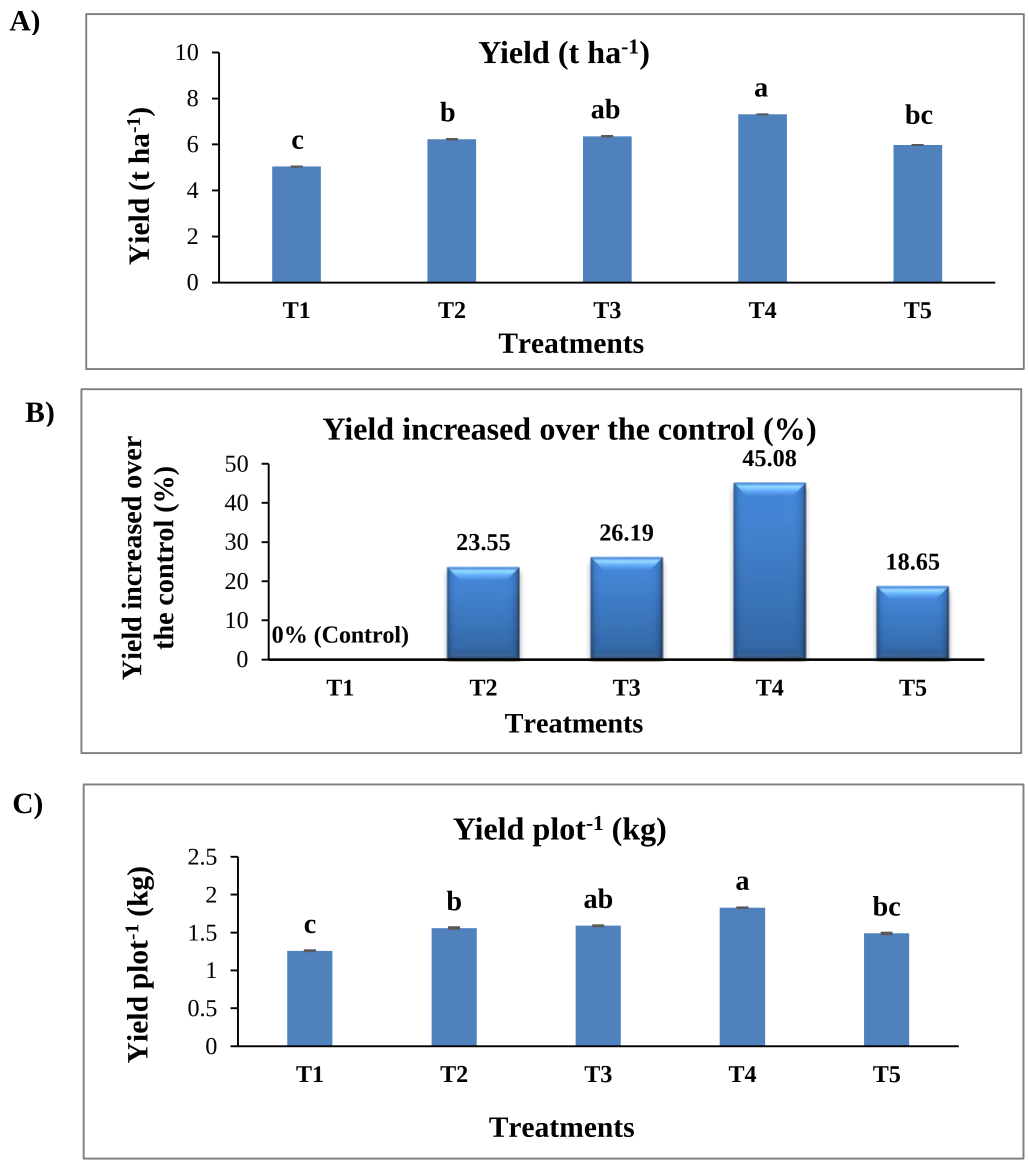
T_4 = {0.3% CHT raw material powder (applied in the previous expt.)} and

T_5 = {0.4% CHT raw material powder (applied in the previous expt.)}

4.11 Yield (t ha^{-1})

The effects of different treatments on fruit yield was significantly enhanced by the residual effect of chitosan raw material powder treatment (Figure 8). The maximum fruit yield (7.31 t ha^{-1}) was accomplished in the T_4 treatment (45.08% yield increased over the control) which was significantly greater than that accomplished in the T_1 treatment. On the other hand T_5 treatment (18.65% yield increased over the control) was statistically similar to T_1treatment and T_2 treatment (23.55% yield increased over the control) was statistically identical to T_3 treatment (26.19% yield increased over the control). Here, it's found that, statistically identical yield from T_2 treatment in comparison to T_3 treatment. Moreover the fruit yield did not differ significantly between T_1 and T_5 treatments. The minimum fruit yield (5.04 t ha^{-1}) was accomplished in the T_1 treatment. According to the fruit yield all treatments may be organized as $T_4>T_3>T_2>T_5>T_1$. It was found that, as the rate of residual chitosan raw material powder application in soil increases fruit yield of okra.

These results were supported by Mondal *et al.,* (2012) who carried out pot and field experiments with the five levels of chitosan concentrations viz., 0 (control), 50, 75, 100 and 125 ppm. From this experiment results explored that number of fruits $plant^{-1}$ were increased with increasing concentration of chitosan until 25 ppm and the highest fruit yield in okra (27.9% yield increased over the control). Therefore, foliar application of chitosan at 100 or 125 ppm may be used at early growth stage to achieve a maximum fruit yield in okra.



T_1 = {0% CHT raw material powder (control)}

T_2 = {0.1% CHT raw material powder (applied in the previous expt.)}

T_3 = {0.2% CHT raw material powder (applied in the previous expt.)}

T_4 = {0.3% CHT raw material powder (applied in the previous expt.)} and

T_5 = {0.4% CHT raw material powder (applied in the previous expt.)}

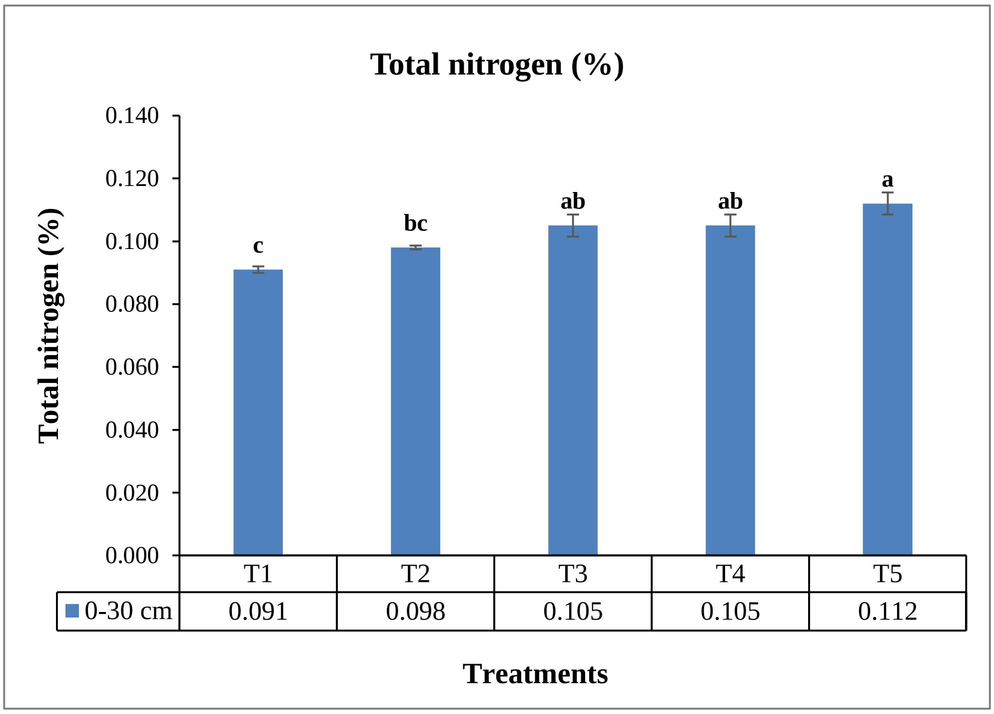
Figure 8. Residual effect of different doses of chitosan raw material powder on fruit yield of okra (BARI dheros-1). Mean was calculated from four replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD

4.12 Soil Properties

4.12.1 Residual effect of chitosan raw material powder on total N content (%) at post-harvest soil:

The total N status of the post-harvest soil of experiment that was affected by the different treatments of chitosan raw material powder and ranged from 0.091% to 0.112% (Figure 9). It was found that N status of soil was statistically different among the treatments. The highest N value (0.112%) was recorded in T_5 treatment which was significantly greater than the T_1 treatment. However T_4 and T_3 treatments were found statistically identical to T_5 treatment. The lowest N value (0.091%) was recorded in T_1 treatment. In respect of the N values all treatments may be organized as $T_5>T_4>T_3>T_2>T_1$. From this study it can be concluded that, the residual effect of chitosan raw material powder application was significantly increased the value of total N compare to the control treatment. These results indicate that the total nitrogen content is high enough due to the application of chitosan raw material powder.

These results were supported by Sultana *et al*., (2020) who carried out an experiment with the raw material of CHT powder with one control. There were four replications using four different doses of the raw material of CHT powder. The treatments were as follows: T_1= 0.5 t ha^{-1}, T_2 = 1.0 t ha^{-1}, T_3 = 2.0 t ha^{-}1, T_4 = 4.0 t ha^{-1} and T_5 = 0 t ha^{-1}. The second experiment was conducted in the same plot using the following treatments were T_1= Residual effect of the raw material of CHT powder @ 0.5 t ha^{-1} (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T_2 = Residual effect of the raw material of CHT powder @ 1.0 t ha^{-1} (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T_3 = Residual effect of the raw material of CHT powder @ 2.0 t ha^{-1} (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T_4 = Residual effect of the raw material of CHT powder @ 4.0 t ha^{-1} (applied in the previous experiment) + 2/3rd of recommended N fertilizer and T_5 = Residual effect of the raw material of CHT powder @ 0 t ha^{-1} + recommended N (control). The results revealed that the total nitrogen content in the post-harvest-soils were increased due to the residual effect of the powder in rice growing soils.



T_1 = {0% CHT raw material powder (control)}

T_2 = {0.1% CHT raw material powder (applied in the previous expt.)}

T_3 = {0.2% CHT raw material powder (applied in the previous expt.)}

T_4 = {0.3% CHT raw material powder (applied in the previous expt.)} and

T_5 = {0.4% CHT raw material powder (applied in the previous expt.)}

Figure 9. Residual effect of different doses of chitosan raw material powder on total nitrogen content (%) of okra growing soils. Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD

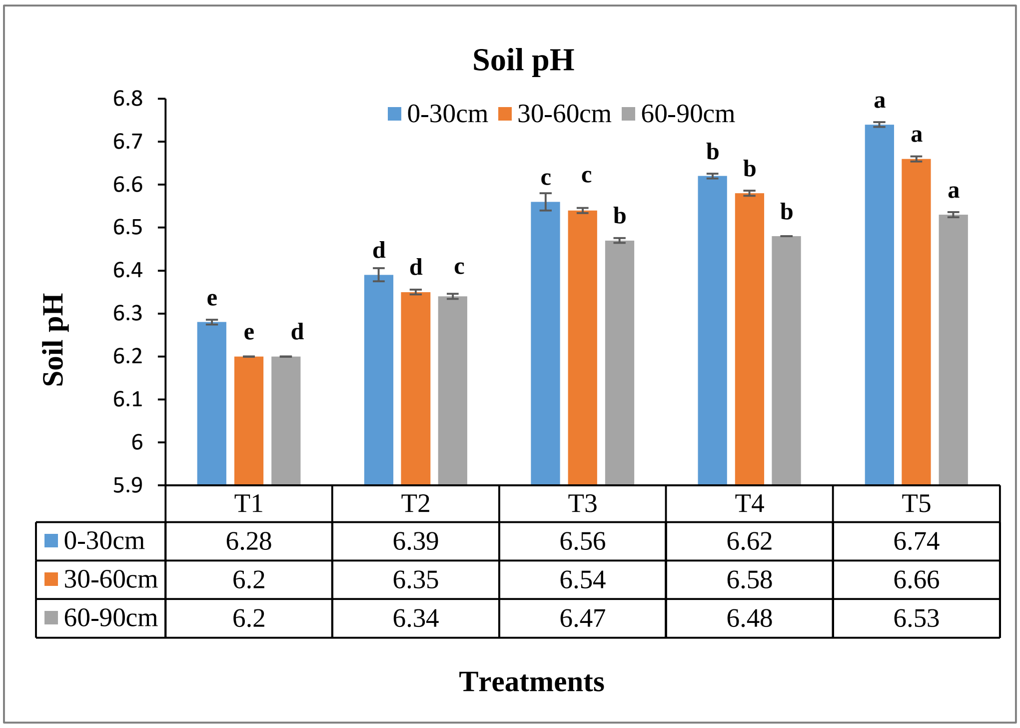
Note: 1st CHT raw material powder application date (26 November 2018); Residual soil sample collection date (19 October 2019, after one cropping season).

4.12.2 Soil pH status of the post-harvest soil

Residual effect of chitosan raw material powder has positive effect on soil pH status of post-harvest soil (0-30 cm, 30-60 cm and 60-90 cm) among all the treatments (Figure 10). In case of 0-30 cm of soil layer all treatments were found statistically different and ranged from (6.28 to 6.74). It was revealed that the highest pH value (6.74) was found in T_5 treatment which was significantly greater than T_1 treatment. The lowest pH (6.28) was found in T_1 treatment. According to the soil pH status of this soil layer all treatments may be organized as $T_5>T_4>T_3>T_2>T_1$. 30-60 cm of soil layer showed statistically different in all the treatments and ranged from (6.20 to 6.66). In this soil layer highest pH value (6.66) was found in T_5 treatment which was significantly greater than T_1 treatment. The lowest pH value (6.20) was found in T_1 treatment. Following to the soil pH of this soil layer all treatments may be organized as $T_5>T_4>T_3>T_2>T_1$. On the other hand 60-90 cm of soil layer was found significantly different among the all treatments and ranged from (6.20 to 6.53). The highest soil pH value (6.53) was found in T_5 treatment which was significantly greater than T_1 treatment. Moreover T_4 treatment was statistically identical to T_3 treatment. The lowest soil pH value (6.20) was found in T_1 treatment. Following to the pH of this soil layer all treatments may be arranged as $T_5>T_4>T_3>T_2>T_1$.

From the three layer of soil it was found that the highest soil pH was value found in T_5 treatment which was greater than the T_1 treatment. From this study it was examined that, the residual effect of chitosan raw material powder application in soil increases the pH status of soil.

These results were supported by Sultana *et al*., (2020) who carried out an experiment with the raw material of CHT powder with one control. There were four replications using four different doses of the raw material of CHT powder. The treatments were as follows: T_1= 0.5 t ha^{-1}, T_2 = 1.0 t ha^{-1}, T_3 = 2.0 t ha^{-1}, T_4 = 4.0 t ha^{-1} and T_5 = 0 t ha^{-1}. The second experiment was conducted in the same plot using the following treatments were T_1= Residual effect of the raw material of CHT powder @ 0.5 t ha^{-1} (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T_2 = Residual effect of the raw material of CHT powder @ 1.0 t ha^{-1} (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T_3 = Residual effect of the raw material of CHT powder @ 2.0 t ha^{-1} (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T_4 = Residual effect of the raw material of CHT powder @ 4.0 t ha^{-1} (applied in the previous experiment) + 2/3rd of recommended N fertilizer and T_5 = Residual effect of the raw material of CHT powder @ 0 t ha^{-1} + recommended N (control). The results revealed that soil pH status in the post-harvest-soils were increased due to the residual effect of the chitosan powder in rice growing soils.



T_1 = {0% CHT raw material powder (control)}

T_2 = {0.1% CHT raw material powder (applied in the previous expt.)}

T_3 = {0.2% CHT raw material powder (applied in the previous expt.)}

T_4 = {0.3% CHT raw material powder (applied in the previous expt.)} and

T_5 = {0.4% CHT raw material powder (applied in the previous expt.)}

Figure 10. Residual effect of different doses of chitosan raw material powder on soil pH of three layer of post-harvest soil of okra (BARI Dheros-1). Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD

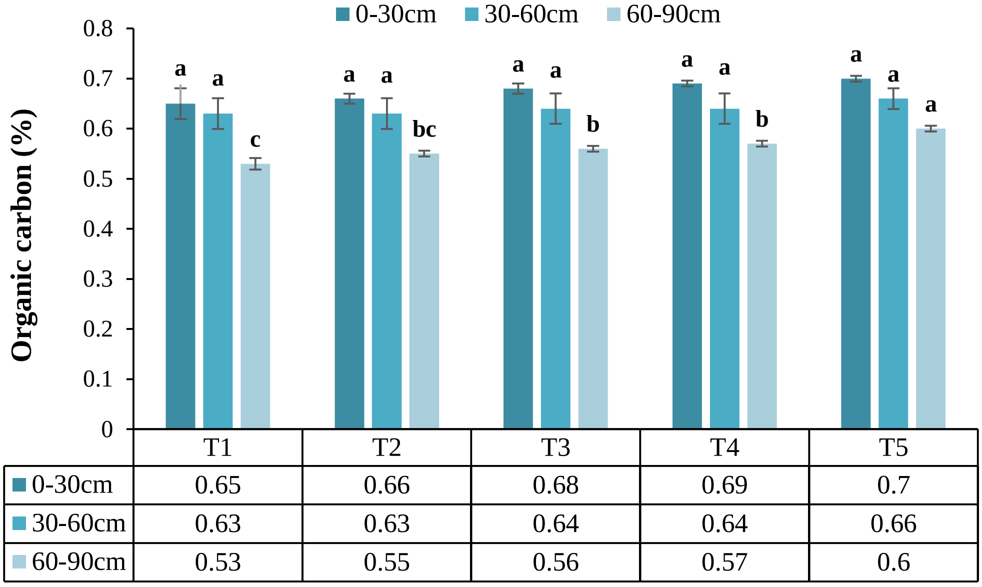
4.12.3 Organic carbon content in the post-harvest soil

The organic carbon content in the post-harvest soil (0-30 cm, 30-60 cm and 60-90 cm) was affected by different treatments of residual effect of chitosan raw material powder (Figure 11). In case of 0-30 cm of soil layer all treatments were found statistically similar and ranged from 0.65% to 0.70 %. Maximum organic carbon content (0.70%) was found in T_5 treatment which was greater than T_1 treatment. The minimum organic carbon content (0.65%) was found in T_1 treatment. Following to the organic carbon content of this soil layer all treatments may be organized as $T_5>T_4>T_3>T_2>T_1$. 30-60 cm of soil layer showed statistically similar in all the treatments and ranged from (0.63% to 0.66%). In this soil layer maximum organic carbon content was found (0.66%) was found in T_5 treatment which was greater than T_1 treatment. The minimum organic carbon content (0.63%) was found in T_1 treatment. Following to the organic carbon content of this soil layer all treatments may be organized as $T_5>T_4>T_3>T_2>T_1$. On the other hand 60-90 cm of soil layer was found significantly different among the all treatments and ranged from (0.53% to 0.60%). Maximum organic carbon content was found (0.60%) was found in T_5 treatment which was significantly greater than T_1 treatment. Moreover T_4 treatment was statistically identical to T_3 treatment and T_2 treatment was statistically similar to T_1 treatment. The minimum organic carbon content (0.53%) was found in T_1 treatment. Following to the organic carbon content of this soil layer all treatments may be arranged as $T_5>T_4>T_3>T_2>T_1$.

From the three layer of soil it was found that maximum organic carbon content was found in T_5 treatment which was greater than the T_1 treatment. From this study it was examined that, application of different dose of chitosan raw material powder in soil and the residual effect of chitosan raw material powder increases the organic carbon content of soil.

These results were supported by Sultana *et al*., (2020) who carried out an experiment with the raw material of CHT powder with one control. There were four replications using four different doses of the raw material of CHT powder. The treatments were as follows: T_1= 0.5 t ha^{-1}, T_2 = 1.0 t ha^{-1}, T_3 = 2.0 t ha^{-1}, T_4 = 4.0 t ha^{-1} and T_5 = 0 t ha^{-1}. The second experiment was conducted in the same plot using the following treatments were T_1= Residual effect of the raw material of CHT powder @ 0.5 t ha^{-1} (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T_2 = Residual effect of the raw material of CHT powder @ 1.0 t ha^{-1} (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T_3 = Residual effect of the raw material of CHT powder @ 2.0 t ha^{-1} (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T_4 = Residual effect of the raw material of CHT powder @ 4.0 t ha^{-1} (applied in the previous experiment) + 2/3rd of recommended N fertilizer and T_5 = Residual effect of the raw material of CHT powder @ 0 t ha^{-1} + recommended N (control). The results revealed that soil organic carbon status in the post-harvest-soils were increased due to the residual effect of the powder in rice growing soils.

The use of chitosan raw material powder (in the previous experiment) containing higher level of organic carbon. It might be increased the level of organic matter content of the post-harvest of okra growing soil. Considering the sustainable soil health application of chitosan raw material powder might be increased the level of organic matter in soils.



	T1	T2	T3	T4	T5
0-30cm	0.65	0.66	0.68	0.69	0.7
30-60cm	0.63	0.63	0.64	0.64	0.66
60-90cm	0.53	0.55	0.56	0.57	0.6

T_1 = {0% CHT raw material powder (control)}

T_2 = {0.1% CHT raw material powder (applied in the previous expt.)}

T_3 = {0.2% CHT raw material powder (applied in the previous expt.)}

T_4 = {0.3% CHT raw material powder (applied in the previous expt.)} and

T_5 = {0.4% CHT raw material powder (applied in the previous expt.)}

Figure 11. Residual effect of different doses of chitosan raw material powder on organic carbon content of three layer of post-harvest soil of okra (BARI Dheros-1). Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD

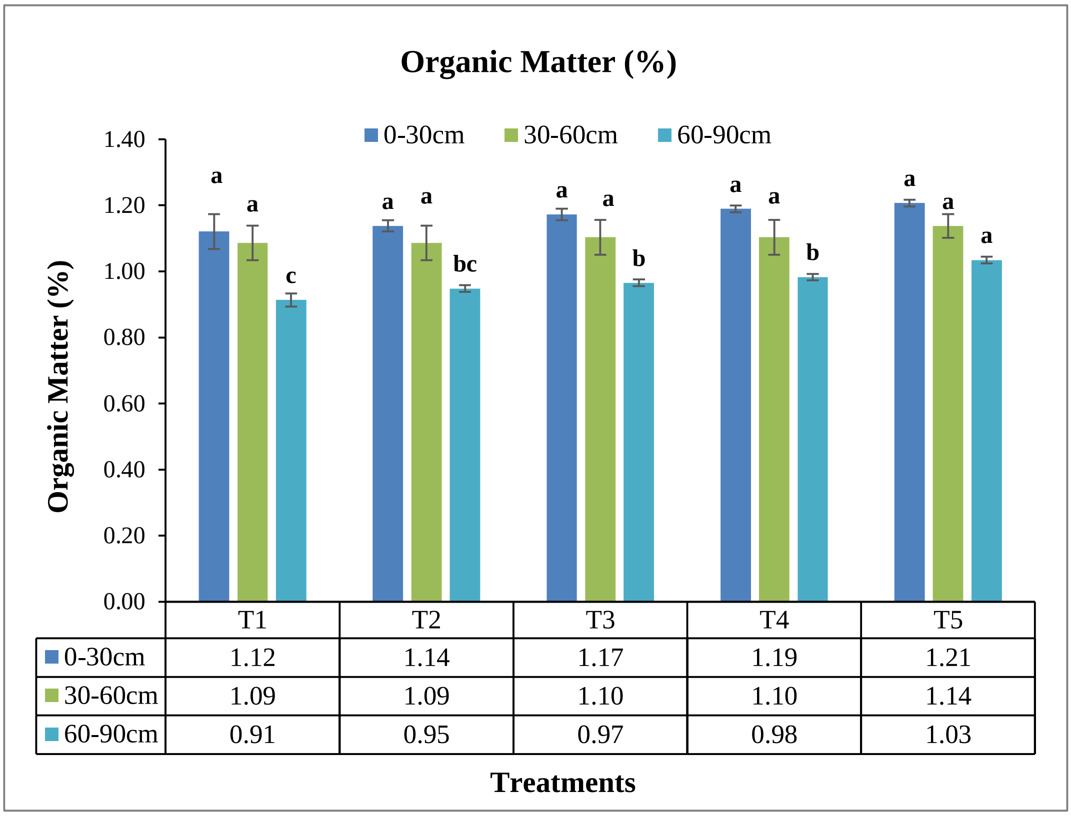
4.12.4 Organic matter content in the post-harvest soil

Organic carbon content in the post-harvest soil (0-30 cm, 30-60 cm and 60-90 cm) was affected by residual effect of chitosan raw material powder among all the treatments (Figure 12). In case of 0-30 cm of soil layer all treatments were found statistically similar and ranged from (1.12% to 1.21%). Maximum organic matter content (1.21%) was found in T_5 treatment which was greater than T_1 treatment. The minimum organic matter content (1.12%) was found in T_1 treatment. Following to the organic matter content of this soil layer all treatments may be organized as $T_5>T_4>T_3>T_2>T_1$. 30-60 cm of soil layer showed statistically similar in all the treatments and ranged from (1.09% to 1.14%). In this soil layer maximum organic matter content was found (1.14%) was found in T_5 treatment which was greater than T_1 treatment. The minimum organic matter content (1.09%) was found in T_1 treatment. Following to the organic matter content of this soil layer all treatments may be arranged as $T_5>T_4>T_3>T_2>T_1$. On the other hand 60-90 cm of soil layer was found significantly different among the all treatments and ranged from (0.91% to 1.03%). Maximum organic matter content was found (1.03%) was found in T_5 treatment which was significantly greater than T_1 treatment. Moreover T_4 treatment was statistically identical to T_3 treatment and T_2 treatment was statistically similar to T_1 treatment. The minimum organic matter content (0.91%) was found in T_1 treatment. Following to the organic carbon matter content of this soil layer all treatments may be arranged as $T_5>T_4>T_3>T_2>T_1$.

From the three layer of soil it was found that maximum organic matter content was found in T_5 {0.4% CHT raw material powder (applied in the previous expt.)} treatment which was greater than the T_1 {0% CHT raw material powder (control)} treatment. From this experiment it was found that, in residual soil the organic matter content was increased by the application of different doses of chitosan raw material powder in the previous experiment.

These results were supported by Sultana *et al*., (2020) who carried out an experiment with the raw material of CHT powder with one control. There were four replications using four different doses of the raw material of CHT powder. The treatments were as follows: T_1= 0.5 t ha^{-1}, T_2 = 1.0 t ha^{-1}, T_3 = 2.0 t ha^{-1}, T_4 = 4.0 t ha^{-1} and T_5 = 0 t ha^{-1}. The second experiment was conducted in the same plot using the following treatments were T_1= Residual effect of the raw material of CHT powder @ 0.5 t ha^{-1} (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T_2 = Residual effect of the raw material of CHT powder @ 1.0 t ha^{-1} (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T_3 = Residual effect of the raw material of CHT powder @ 2.0 t ha^{-1} (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T_4 = Residual effect of the raw material of CHT powder @ 4.0 t ha^{-1} (applied in the previous experiment) + 2/3rd of recommended N fertilizer and T_5 = Residual effect of the raw material of CHT powder @ 0 t ha^{-1} + recommended N (control). The results revealed that organic matter status in the post-harvest-soils were increased due to the residual effect of the chitosan powder in rice growing soils.

The results revealed that soil organic matter status in the post-harvest soils were increased due to the residual effect of the powder in okra growing soils. The use of chitosan raw material powder (in the previous experiment) containing higher level of organic carbon. It might be increased the level of organic matter content of the post-harvest of okra growing soil. It’s a big challenge to increasing the organic matter content of Bangladesh soils for the sustainable agriculture. After all the chitosan raw material powder application could play a vital role to increase the organic matter content in soils.



T_1 = {0% CHT raw material powder (control)}

T_2 = {0.1% CHT raw material powder (applied in the previous expt.)}

T_3 = {0.2% CHT raw material powder (applied in the previous expt.)}

T_4 = {0.3% CHT raw material powder (applied in the previous expt.)} and

T_5 = {0.4% CHT raw material powder (applied in the previous expt.)}

Figure 12. Residual effect of different doses of chitosan raw material powder on organic matter content of three layer of post-harvest soil of okra (BARI Dheros-1). Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD

CHAPTER V
SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

A net house experiment was supervised at the research field of Sher-e-Bangla Agricultural University (SAU), Dhaka, at the time of May 2019 to September 2019 to examine the Residual effect of chitosan raw material powder on yield performance of okra under tomato-okra cropping system.

During the time of tomato experiment there were composed of five treatments of chitosan raw material powder

T_1 = 0% CHT raw material powder (control)

T_2 = 0.1% CHT raw material powder applied in the previous expt.

T_3 = 0.2% CHT raw material powder (applied in the previous expt.

T_4 = 0.3% CHT raw material powder (applied in the previous expt. and

T_5 = 0.4% CHT raw material powder (applied in the previous expt.

Percentage of N, Soil pH, organic carbon and organic matter is an important constituent of soils. Most of the soil in Bangladesh is deficient in nitrogen, organic-matter content and low in soil pH. For improvement of soil chitosan raw material powder can be used as an alternative source of N which increases efficiency of applied N and can contribute to increase N content, maintain the organic matter and soil pH of okra growing soil. Besides that, the residual effect of chitosan raw material powder of previously applied treatment had a profound influence on plant growth character, yield contributing characters and fruit yield of okra.

The residual effect of chitosan raw material powder has a positive effect on changes of total N, pH, organic carbon and organic matter content of soil. Significant effect was observed with T_4 i.e. {0.3% CHT raw material powder (applied in the previous expt.)}

treatment performed best compare to T_1 (0% CHT raw material powder) control treatment and other concentrations of chitosan raw material powder. The data on crop growth and yield contributing characters plant height (cm) at harvest, number of flower plant^{-1}, Number of flower dropping plot^{-1}, fruits plant^{-1}, total fruits plot^{-1}, fruit length (cm plant^{-1}), fresh weight of single fruit (g), fresh weight of fruit (g plot^{-1}), oven dry weight of single fruit (g), single fruit oven dry weight plot^{-1} (g), Yield (t ha^{-1}). Data were recorded in the field and analyzed using the software Statistix 10. The mean differences were compared by least significant difference (LSD) test at 5% level of significance among all the treatments. In case of BARI Dheros-1, the results indicated that the maximum plant height (124.75 cm) was found with the T_4 (0.3% CHT raw material powder applied in the previous expt.) treatment and the minimum plant height (113.67 cm) was found in the T_1 (0% CHT raw material powder). The maximum no. of flower plant^{-1} (30.50) was found with T_4 (0.3% CHT raw material powder applied in the previous expt.). On the other hand the minimum no. of flower plant^{-1} (22.25) was found in T_1 and T_5 (0.4% CHT raw material powder). The maximum fruits plant^{-1} (28.25) was found in T_4 {0.3% CHT raw material powder (applied in the previous expt.)} treatment which is statistically significant from T_1 treatment and the minimum fruits plant^{-1} (20.75) was found in T_1 treatment. The maximum fruit length plant^{-1} (12.50 cm) was obtained in the T_4 (0.3% CHT raw material powder applied in the previous expt.) treatment which was significantly different from T_1 and the minimum fruit length (7.75 cm) was found in the T_1 (0% CHT raw material powder control) treatment. The maximum fruit yield (7.31 t ha^{-1}) was accomplished with the T_4 (0.3% CHT raw material powder applied in the previous expt.) treatment and 45.08% yield increased over the control. Which was significantly greater than that accomplished in the T_1 (0% CHT raw material powder) treatment. On the other hand T_5 (0.4% CHT raw material powder applied in the previous expt.) treatment and 18.65% yield increased over the control and was statistically similar to T_1 (0% CHT raw material powder control) treatment. The minimum fruit yield (5.04 t ha^{-1}) was accomplished in the T_1 (0% CHT raw material powder). In case of soil chemical properties the highest N value (0.112 %) was recorded in T_5 treatments (0.4% CHT raw material powder) which was significantly greater than the T_1 (0% CHT raw material powder) treatment and the lowest N value (0.091%) was recorded in T_1 {0% CHT raw material powder (control)} treatment. From the three layer of soil it was found that the highest soil pH value 6.74, 6.66 and 6.53 of 0-30 cm, 30-60 cm and 60-90 respectively and was found in T_5 (0.4% CHT raw material powder applied in the previous expt.) treatment which was significantly greater than the T_1 (0% CHT raw material powder). The lowest soil pH value 6.28, 6.20 and 6.20 of 0-30 cm, 30-60 cm and 60-90 respectively and was found in T_1 control treatment. From the three layer of soil it was disclosed that organic carbon content of soil was statistically similar and the maximum value 0.70% and 0.66% of 0-30cm and 30-60 cm respectively was found in T_5 (0.4% CHT raw material powder applied in the previous expt.) treatment which was greater than the T_1 (0% CHT raw material powder (control)} treatment and the minimum organic carbon content 0.65% and 0.63% of 0-30 cm and 30-60 cm respectively was found in T_1 {0% CHT raw material powder (control)} treatment. In case of 60-90 cm of soil layer it was found statistically different among all the treatments and the maximum value (0.60%) was found in T_5 (0.4% CHT raw material powder applied in the previous expt.) treatment which was significantly greater than the T_1 control treatment and the minimum organic carbon content (0.53%) was found in T_1 (0% CHT raw material powder) treatment.

In case of organic matter content of soil was found statistically similar and the maximum value 1.21% and 1.14% of 0-30cm and 30-60 cm respectively was found in

T_5 (0.4% CHT raw material powder) treatment which was greater than the T_1 (0% CHT raw material powder) treatment and the minimum organic carbon content 1.12% and 1.09% of 0-30 cm and 30-60 cm respectively was found in T_1 {0% CHT raw material powder (control)} treatment. In case of 60-90 cm of soil layer it was found statistically different among all the treatments. The maximum value (1.03%) was found in T_5 (0.4% CHT raw material powder applied in the previous expt.) treatment which was significantly greater than the T_1 {0% CHT raw material powder (control)} treatment and the minimum organic carbon content (0.91%) was found in T_1 {0% CHT raw material powder (control)} treatment.

The present experiment was carried out the residual effect of chitosan raw material powder on the performance of growth, yield contributing characters and yield of vegetable crop. Yield, as well as other yield contributing characters responded positively with the increasing concentration of previously applied chitosan raw material powder.

From the above experiment, it might be revealed that,

I. 0.3% CHT treatment (T_4) influenced morphological characters and yield attributes of okra cv. BARI Dheros-1 compared to the control treatment T_1; and

II. The chitosan raw material powder improved chemical properties of soil like total N%, soil pH, organic carbon and organic matter content. That might be helpful for sustainable agriculture.

III. Economical point of view, T_3 (0.2% CHT raw material powder) can be superior than other treatments considering yield data and soil chemical properties of soil.

Recommendations

From the study, it can be concluded that the application of 0.3% chitosan raw material powder in the previous crop performed better on yield and yield parameters. This has residual effect in order to recommend the practices, the following aspects would be considered.

i) Similar experiments need to be carried out in different locations of Bangladesh to draw a final conclusion regarding the residual effect of chitosan raw material powder.

ii) Varietal trials to be set up in different locations to give recommendation.

CHAPTER VI

REFERENCES

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REFERENCES

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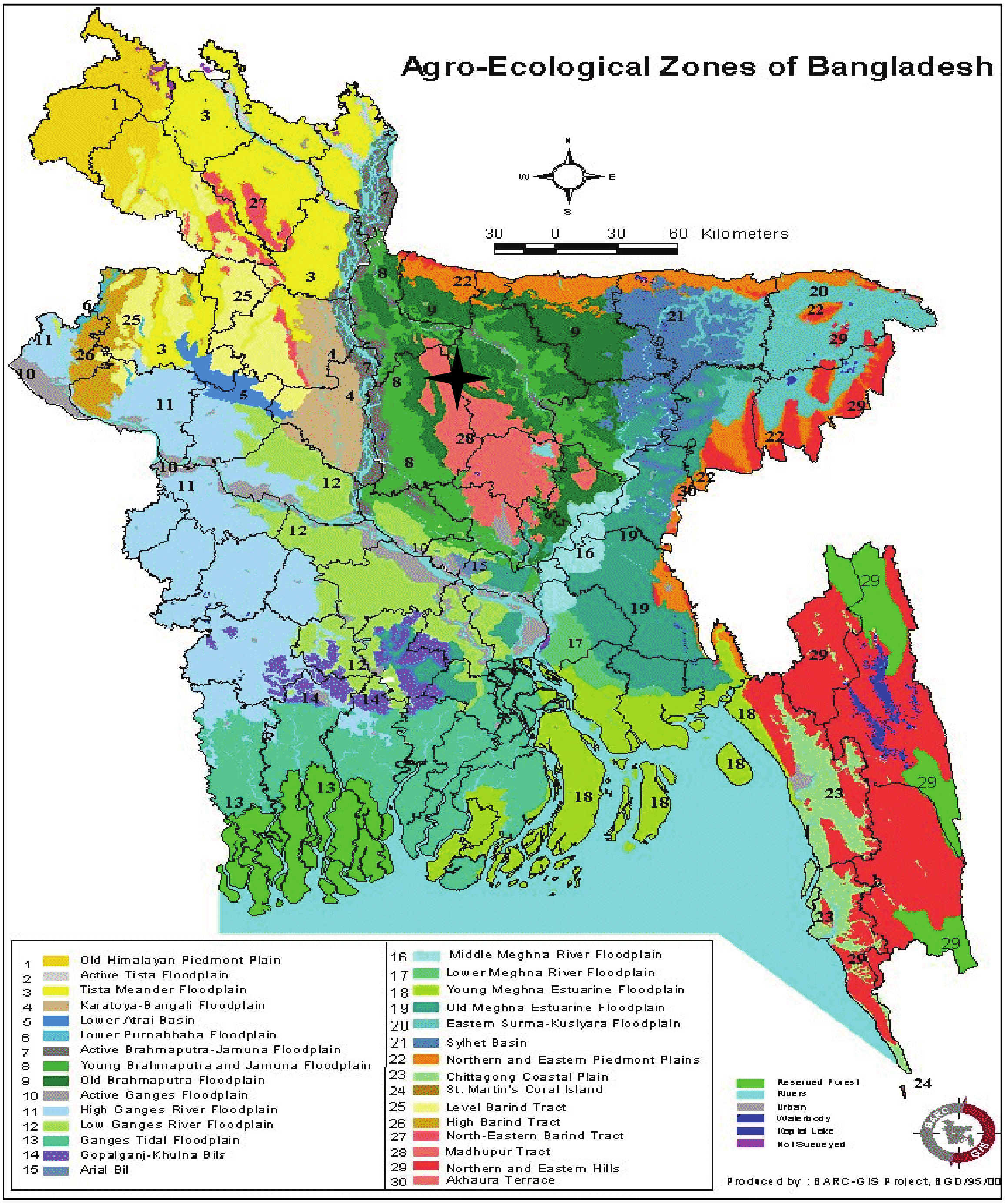
APPENDICES

Appendix I. Map showing the experimental sites (Madhupur Tract, 28) under the study



Experimental area under the study

Appendix II. Monthly record of temperature, relative humidity and rainfall (average) of the experimental site during the period from May 2019 to September 2019, SAU

Month (2019)	Air temperature(^{0}C)			Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum	Mean		
May	29.8	20.8	25.3	73%	231
June	29.9	19.9	24.9	78%	242
July	29.3	19.1	24.2	82%	383
August	29.9	18.2	24.05	79%	223
September	29.1	19.3	24.2	80%	161

Source: Bangladesh Meteorological Department (Climate and weather division) Agargoan, Dhaka-1212.

Appendix III. ANOVA Table

Source of variance	DF	MS										
		Plant height (cm)	Average number of flower plant^{-1}	Fruits plant^{-1}	Number of flower dropping plot^{-1}	Total fruits plot^{-1}	Average fruit length (cm)	Fresh weight of single fruit (g)	Oven dry weight of single fruit (g)	Fresh weight (g) of fruit plot^{-1}	Fruit oven dry weight plot^{-1}(g)	Yield (t ha^{-1})
Replication	3	0.795	144.45	2.583	0.0667	165.33	5.933	1.251	0.075	80.085	4.829	0.971
Treatment	4	72.378**	45.43*	36.425**	0.925*	2331.20**	11.575**	4.75**	0.408*	304**	26.142*	2.655**
Error	12	0.289	11.325	0.792	0.192	50	0.808	0.375	0.094	23.979	5.999	0.445

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD. ** = Significant at 1% & LSD * = 5% level of probability.

Appendix III. ANOVA Table (Contd.)

Source of variance	**DF**	**MS**									
		Soil pH			**Organic carbon**			**Organic matter**			**Total Nitrogen**
		0-30 cm	30-60 cm	60-90 cm	0-30 cm	30-60 cm	60-90 cm	0-30 cm	30-60 cm	60-90 cm	
Replication	2	0.001	0.000	0.000	3.800	2.340	1.4	1.220	7.220	3.267	6.020
Treatment	4	0.100**	0.105**	0.054**	1.293NS	4.5NS	2.010**	3.723NS	1.423NS	5.857**	1.911**
Error	8	0.001	0.000	0.000	8.050	2.540	1.65	2.328	7.40	5.017	1.370

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD. ** = Significant at 1% & LSD * = 5% level of probability & NS = Non-Significant

Plate 2. Pictorial view of experimental field and lab