EFFECT OF NITROGEN AND CHITOSAN RAW MATERIAL POWDER ON THE PERFORMANCE ON YIELD OF GARLIC (*Allium sativum* L.)

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*This is to certify that thesis entitled, "**EFFECT OF NITROGEN AND CHITOSAN RAW MATERIAL POWDER ON THE PERFORMANCE ON YIELD OF GARLIC (Allium sativum L.)**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN SOIL SCIENCE**, embodies the result of a piece of bona fide research work carried out by **MD. ABDUL JABBER** Registration number **14-05916** 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 truly been acknowledged.

Dated: June, 2021

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Supervisor

DEDICATED

TO

MY BELOVED

PARENTS

AND

TEACHER

LISTS OF ACRONYMS

Abbreviations	Elaboration
%	Percent
@	At the rate
<	Less than
=	Equal
>	Greater than
≤	Less than or equal
^{0}C	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 liter
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	Gibberellic acid
g	Gram

Abbreviations	**Elaboration**
H_2O_2	Hydrogen per oxide
H2SO4	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
LSD	Latin Square Design
$Mg\ L^{-1}$	Milligram per liter
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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ABSTRACT

A field experiment was carried out at the research field of Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from November, 2019 to April, 2020 to study the yield maximization of BARI Garlic-3 by improving growth characters using chitosan raw material powder under silty clay loam soil. The experiment was designed with twenty treatments using different level of chitosan raw material powder in the field. The used treatments were: T_1 (RD of N @ 77 kg/ ha), T_2 (RD of N @ 89 kg/ ha), T_3 (RD of N @ 101 kg/ ha), T_4 (RD of N @ 113 kg/ ha), T_5 (T_1+ 0.1 t CHT Powder/ha), T_6 (T_2+ 0.1 t CHT Powder/ha), T_7 (T_3+ 0.1 t CHT Powder/ha), T_8 (T_4 + 0.1 t CHT Powder/ha), T_9 (T_1 + 0.5 t CHT Powder/ha), T_{10} (T_2+ 0.5 t CHT Powder/ha), T_{11} (T_3 + 0.5 t CHT Powder/ha), T_{12} (T_4 + 0.5 t CHT Powder/ha), T_{13} (T_1 + 1 t CHT Powder/ha), T_{14} (T_2 + 1 t CHT Powder/ha), T_{15} (T_3+ 1 t CHT Powder/ha) T_{16} (T_4 + 1 t CHT Powder/ha), T_{17} (1 t CHT raw material Powder/ha), T_{18} (1.5 t CHT raw material Powder/ha), T_{19} (2 t CHT raw material Powder/ha) and T_{20} (2.5 t CHT raw material Powder/ha). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Result revealed that application of chitosan raw material powder increased plant height, fresh and oven dry weight of tops, bulb diameter, number of cloves/bulb, fresh and dry weight of bulb and yield/ha. With increasing the doses of chitosan raw material powder, most of the morphological, reproductive and yield attributes were increased, whereas control plants showed the lowest value of the above parameters. Most of the morphological, growth and reproductive attributes were recorded maximum in the T_{16}. The experimental results revealed that treatment T_{16} (N 113 kg/ ha + 1 t CHT Powder/ha) produced highest seedling height (64.33 cm), maximum number of leaves (7.77), bulb diameter (14.28 cm) , fresh weight of bulb (24.16 g), number of cloves per bulb (23.52), dry weight of bulb (5.8 g), fresh weight of tops (12.03 g), dry weight of tops (3.01), yield (11.07 ton/ha) and soil properties like N content (0.2%), soil organic carbon (0.55%), soil organic matter (0.95%). Minimum values was found in T_1 treatment. Finally, the study concluded that application of chitosan raw material powder in field, soil has significant effect on growth, yield and yield contributing characters of garlic.

CHAPTER I

INTRODUCTION

Garlic (*Allium sativum* L) is a species of bulbous flowering plant and scented herbaceous plant in the genus *Allium* which belongs to the family of Amaryllidaceae (Kurian, 1995). It is the 2nd most extensively used Allium after onion (Bose and Som, 1990). Its familiar relatives include the onion, shallot, leek, chive, Welsh onion and Chinese onion. It evolved in central Asia (Vvdensky, 1946), especially in Mediterranean region (Thompson and Kelly, 1957) from where it was elaborated to North-East wards to the Pamir- Ali and Tien Shen regions of China. The major garlic producing countries of the world are China, South Korea, Spain, India, USA, Egypt, Thailand, Turkey, Sudan and Mexico, Ukraine, Russian Federation(FAO, 2019). Globally 26,639,081 tons of garlic is produced per year. China is the largest garlic producer in the world with 21,263,237 tones production per year. China produces 76% of the world's supply of garlic (FAO, 2019). India comes second with 1,400,000 tones yearly production.

Garlic is very popular all around the world for its various uses. It is widely used as popular spice to make various dishes. It is highly enriched in carbohydrate, protein and phosphorus (Augusti, 1977). Uses of garlic in Ayurvedic and Unani medicines in the dealing with diseases like chronic infection of the stomach and intestine, dysentery, typhoid, cholera and disease of lungs is very effective (Chopra et al., 1958). Garlic is traditionally used to treat colds and coughs. It's also reported to boost the immune system and help ease asthma symptoms. Arab traditional medicine recommended garlic to help treat heart disease, high blood pressure, arthritis, toothache, constipation, and infections (PubMed Central, 2018). In Bangladesh and other Asian and Middlecast countries, it is commonly used in various food preparations considerably in chutneys, pickles , curry powder, curried vegetables, meat preparation, tomato ketchup and the like (Bose and Som, 1990). In current year's oil, powder, one kind of salt are prepared from it for adding smell to the curries (Pruthi, 1976). Aqueous extracts of garlic cloves (Allicin and related essential oil viz. disulphides) markedly reduce cholesterol level tests on man (Augusti, 1977).

100gm garlic serves 149 calories, 0.5g Fat, 0mg Cholesterol, 17mg Sodium, 401mg Potassium, 33g total Carbohydrates, 6.4g Protein. Garlic is also a good source of vitamins and minerals. Per 100g garlic contains Vit-A 0.2%, Vit-C 52%, Calcium 14%, and Iron 9.4%

Garlic ranks second in world production among the Alliums after onion (Purseglove, 1975). The Average yield of garlic in Bangladesh is only 5.21 ton per hectare (BBS, 2012) which is very low as compared to many countries of the world. In Bangladesh about 485448 metric tons of garlic was produced from approximately 73652 ha of land in 2019-20 (BBS, 2021). The requirement of garlic in Bangladesh is about 0.9-1 million tons (BBS, 2020). The trend of garlic production (2010-2020) in Bangladesh has been presented in Appendix I.

In Bangladesh major garlic contributing districts are Natore, Manikgonj, Faridpur, Jashore, Rajshahi, Dinajpur, Dhaka, Pabna, Rangpur and Cornilla (BBS, 2012). Rajshahi and Natore are top two districts for producing garlic in Bangladesh. In 2018 the highest national yield has been recorded from China (22,273,802 tonnes) and the other countries and their mean production are India (1,721,000 tonnes), South Korea (331,741 tonnes), USA (260,340 tonnes), Egypt (286.213 tonnes), Spain (273,476 tonnes), Uzbekistan (254,857 tonnes), Russia (211,981 tonnes), and Turkey (143,207) as reported by FAO, 2019.

With increasing of population, the demand for garlic in Bangladesh is raising day by day, but due to the limitation of land, it is not possible to extend the crop production area .The use of proper doses of fertilizer and manures and improvement of the traditional production practices may increase per ha yield in the different regions of our country. Moreover, necessary in proper knowledge and information regarding the use of nitrogen and potassium fertilizer in garlic production under Bangladesh condition arc scanty.

Garlic is well known to be thermo photo sensitive crop and grown in Bangladesh in short day condition in winter season (Jones and Mann, 1963; Rahim and Fordham, 1988). Its vegetative growth and bulb development are greatly influenced by growing environment. Soil moisture is an important factor that influences the growth, bulb development and total yield of garlic. Garlic is produced in dry period of the year and soil moisture is dependent on the irrigation and its frequency. 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 aluminium 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 one of the most studied polysaccharides at present. It has a large number of applications because of its biocompatibility, biodegradability and abundance in nature. The chitosan is very active molecule that examined 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 agriculture because it is a good alternatives even in traditional farming. In agriculture, chitosan is used mainly as a natural seed treatment and plant growth enhancer and also as an ecologically friendly bio- pesticidal substance that boosts up the inner ability of plants to protect 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 increases 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 chitosan 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 neo concept to us to boost up 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 Garlic.

The objectives of the study are as follows:

1. To observe the effect of nitrogen and chitosan raw material powder on yield and yield attribute of garlic
2. To examine the effect of chitosan raw material powder on organic nitrogen management

CHAPTER II

REVIEW OF LITERATURE

Plant Growth Regulators (PGRs) are chemicals used to modify plant growth such as increasing branching, suppressing shoot growth, increasing return bloom, removing excess fruit, or altering fruit maturity. Many scientists are now studying the pattern of growth and development of plant treated with different plant growth regulators. Chitosan is an important growth regulator which has many different influences on growth, yield and yield contributing characteristics of different crops. Chitosan is a new plant growth regulator which have a good impact on garlic production. Chitosan has good film forming performance and excellent biocompatibility. It is also safe and non-toxic. It is a natural, safe and cheap biopolymer product of chitin 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, that is easily absorbed by the plant roots. It is alkaline in nature and increases soil pH. It has also a good potential power in agriculture to control various plant diseases. An attempt was made in this section to collect and study relevant information about chitosan raw material powder which is cited below:

2.1 Growth and yield promoter

Issak and Sultana (2017) performed an experiment to observe the role of chitosan powder on the production of quality rice seedlings of BRRI dhan29 and found that Boro rice seedlings production were enhanced by using the chitosan powder in the seedbed.

Rahman *et al.* (2018) carried out 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 per plant 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, anthocyanin, flavonoids and phenolic 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.

Ahmed *et al*., (2013) conducted a field experiment and observed that plant height was significantly influenced due to the effect of different levels of Chitosan throughout the growth period over control. Application of Chitosan as PGR enhanced the plant height. Among the Chitosan concentrations, 50 mg/ L produced the taller plant (32.33, 62.67, 89.00 and 99.67 cm) at 30, 60, 90 and 120 DAT, respectively compare to other concentrations of Chitosan. Chitosan level of 75 mg/L produced the statistically similar taller plant (86.67 cm) at 90 DAS and it was also closely followed by the similar levels of Chitosan (98.00 cm) at 120 DAT.

Islam *et al.* (2018) found that 4 levels of oligochitosan were used with control to optimize the level for obtaining higher yield in tomato and chilli. It was concluded that in case of tomato 50 ppm chitosan level was found optimum in terms of yield (2.48 kg/plant). On the contrary, in case of chilli, 75 ppm chitosan level was found optimum in yield (333.01 g/plant).

Boonlertnirun *et al.* (2008) executed an experiment to find out the impact of chitosan application in rice production and reported that chitosan is an actual biopolymer which stimulates growth and increases yield of plants as well as induces the immune system of plants.

Boonlertnirun *et al*., (2012) found that different application methods significantly affected tiller number per plant, the maximum tiller numbers were obtained from application of chitosan in combination with mixed chemical fertilizer but did not differ from that of mixed chemical fertilizer application while their different treatment combination were T_1 : chitosan at the concentration of 80 mg/L in combination with mixed chemical fertilizer between urea (46-0-0) and 16-20-0 at the rate of 312.5 kg H1, T_2: mixed chemical fertilizer between urea (46-0-0) and (16-20-0) at the rate of 312.5 kg, T_3: chitosan spraying at the concentration of 80 mg/L and T_4: no application of chitosan and mixed chemical fertilizer.

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

Mondal *et al.* (2013) were executed 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 impact of foliar application of chitosan (a growth promoter), on morphological, growth, yield attributes and seed yield of maize plants. The study consists of 5levels of chitosan concentrations viz., 0 (control), 50, 75, 100 and 125 ppm. The chitosan was sprayed 3 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, leaf length and breadth, leaf area/plant), physiological (total dry mass/plant, 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.

Chookhongkha *et al.* (2012) made an experiment on Chilli 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, fruit numbers/plant, seed numbers /fruit, and seed weight/plant was found in the plants grown in the soil mixed with 1.0% high MW of chitosan.

2.2 Plant height

Parvin *et al.,* (2019) carried out an experiment. Results revealed that plant height was higher in chitosan applied tomato (*L. esculentum*) plants than control plants. The longest plant was found in T_4 treatment (74.00 cm) followed by T_9 and T_{10} at 80 DAT. Control plant produced the shortest plant height (62.75 cm) at 80 DAT.

Rahman (2015) conducted a pot experiment at the net-house on BARI tomato-15. The experiment was designed with 5 treatments using 4 levels of modified chitosan in the seedbed soil (10 kg of soils per pot). Treatments were T_1 (control), T_2 (50 g modified chitosan/pot), T_3 (100 g modified chitosan/pot), T_4 (150 g modified chitosan/pot) and T_5 (200 g modified chitosan/pot). Application of modified chitosan increased seedling height, fresh and dry weight of seedlings, soil pH, organic carbon (%), organic matter (%), number of flowers/plant, fruits/plant, fruit size and fruit yield over control. Abdel-Mawgoud *et al.* (2010) found that chitosan application enhanced plant height, number of leaves, fresh and dry weights of the leaves and yield components (number and weight) in strawberry plant.

Salma *et al.*, (2015) showed that soaking of seed in oligo-chitosan before planting tends to stimulate plant height. Plant height does not show any statistically significant differences between control and 40 ppm oligo-chitosan sprayed plants. Plants show significant differences for 80 and 100 ppm oligo-chitosan sprayed with compared to control.

Sekh (2002) carried out an experiment to observe the effect of PGRs on rice and found that GABA @ 0.33 mg/L produced the highest shoot height.

Khan *et al.* (2002) showed that foliar application of oligomeric chitosan did not affect plant height of soybean at all.

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

Minard (1978) carried out a study in New Zealand with garlic cloves of 2 sizes (1.0-l.9 and 2.0-2.9 g) fertilized with N at 0 or 210 kg/ha, P at 263-1250 kg/ha, K at o or 750 kg/ha and lime (as ground lime stone) at 5 or 15 ton I ha. The highest yield was obtained from larger bulb size, receiving N and K at high and low rates respectively, Lazzari et al. (1978) showed that the application of higher nitrogen fertilizer improved the yield and quality of garlic grown in a loam soil in Argentina.

Guandi and Asandhi (1986) studied the influence of fertilization on garlic cv. Lumba Hijau planted at 20 X 80 m2 plots and fertilized with 0, 80, 160 or 240 kg/ha as urea or (NH4)2 S04 + 120 K20/ha as KCL or K2S04 + 120 kg/ha as TSP. They noticed that higher rates of N produced greater plant heights and greater stem diameter.

2.3 Dry matter production

Issak and Sultana (2017) conducted an experiment to observe the effect of chitosan powder on the production of quality rice seedlings of BRRI dhan29 was in the field of Sher-e-Bangla Agricultural University, Dhaka and found that the maximum fresh weight (29.14 g) production of 100 seedlings was found in the treatment T_4 having 400 g CHT powder/m^2 and the lowest fresh weight production (12.6 g) was found in the treatment T_6 (control) which was significantly different from all other treatments. These results say that fresh weight productions of BRRI dhan29 rice seedlings were influenced by the chitosan powder treatments and this might be due its supplementation of plant nutrients and growth regulators.

Rahman (2015) conducted a research and noticed that very strong and significant variation was found in the fresh weight of tomato seedlings at the transplanting time (25 days after sowing). Maximum fresh weight was found in the treatment T_3 (7.93 g) using 100 g modified chitosan in the seedbed soils which was statistically different than any other treatments. The fresh weight production was significantly varied between the treatments T_2 (6.60 g) and T_4 (5.73 g) using 50 g and 150 g of the modified chitosan in the seedbed soils. Here, higher doses of the modified chitosan reduced the fresh weight production of tomato seedlings and these might be due to some toxicity or over stressed by the materials (modified chitosan) used in the seedbed.

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

Zhou *et al.* (2001) reported that pre-soaking seed treatment of grain in various concentration of chitosan showed the optimum results on dry weights.

Chibu and Shibayama (1999) reported that chitosan an 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 impacts on dry weight of tomato.

Krivtsovm *et al.* (1996) carried out a field experiment and observed that thousand grain weights of wheat plants was increased with application of polymeric chitosan at low concentration.

Purcwal and Daragan (1961) carried out experiment fertilization with garlic in India. The application of nitrogen improved the weight of individual bulb significantly over control. The supreme response was found on the weight of individual bulb with 12.27 kg / ha N, P and K did not give any response.

Lazo et al. (1969) in their study on the use of N P K fertilizer in onion @ 50, 100, 150 kg/ha noticed that N used alone or in combination with P and K responded well.

Pimpin (1970) suggested the results of a research made with garlic cv. Blance piacintin where 0, 80 and 160 kg/ ha each of N, P205 and K20 were applied in combinations, N and K increased the number and weight of bulbs, but P showed negative effects on these parameter.

2.4 Residual effect on chemical properties (pH, organic carbon and organic matter) of soil

Sultana *et al.* (2020) made a field study 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 content in the post-harvest-soils were improved due to the residual effect of the powder in rice growing soils. The highest 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) carried out 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 showed 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) reported 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 increased 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) reported that the mixed application of organic manure and chemical fertilizers improved organic matter content in soil.

Hu *et al.* (2006) revealed 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) concluded that its addition increases both prokaryote and eukaryote microbial populations and their activities, since they are altogether engaged 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.

2.5 Others reviews on chitosan application in sustainable Agriculture

Shahrajabian *et al.* (2021) showed that Chitin and chitosan used in plant defence systems against biological and environmental stress conditions and as a plant growth promoter it can improve stomata conductance and decline 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) reported that chitosan has great versatility of modifications and formulations for industrial applications, such as controlled release, surface modification, and preparation of nanoparticles. This chapter shows 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) suggested that the treatment with chitosan causes reduction in stomata 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) carried out a greenhouse experiment on one-year old sour orange seedlings. Results revealed 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 putrescence application resulted in enhancement gradually of the previous parameters by increasing concentrations applied. Rosul (2014) revealed 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 higher rice grain protein and which was 19.8% higher comparing to CK.

Berger *et al*. (2013) made an experiment which revealed the potential of rock bio fertilizer mixed with earthworm compound inoculated with free living diastrophic bacteria and *C. elegans* (Fungi chitosan) for plant production and nutrient uptake. The bio fertilizer, such as may be an alternative for NPK fertilization that slows the release of nutrients, favouring long term soil productivity.

Farouk and Amany (2012) reported 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 non-stressed conditions as compared to untreated plants. Treatment with chitosan, in particular, 250 mg/L 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) carried out a pot test on Indian spinach. The study consists of 5 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) conducted an experiment to determine the impact of chitosan on drought recovery and grain yield of rice under drought conditions. Results showed that the chitosan applied before drought treatment gave the highest 1000-seed yield and also showed good recovery on yield.

CHAPTER III

MATERIALS AND METHODS

The experiment was undertaken at the research field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November 2019 to April 2020. This chapter deals with a brief description on experimental site, characteristics of soil, climate, land preparation, layout and design of the experiment, preparation of chitosan raw material powder, intercultural operations, data recording and statistical analysis.

3.1 Experimental period

The research was conducted during the period from November-2019 to April 2020 in Boro season.

3.2 Geographical location

The location of the experimental site is situated between $23^{\circ}77'$N latitude and $90^{\circ}33'$E longitude at an altitude of 8.2 meter from the mean sea level (Anon., 1989)

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 II.

3.4 Climate and Weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from

March to April and the monsoon period from May to October (Edris *et al.*, 1979). The climate of the experimental site is subtropical that is characterized by high temperature and heavy rainfall during Kharif season (April-September) and scanty rainfall during Rabi season (October-March) associated with moderately low temperature. The experiment was carried out in the month of November, 2019 to April, 2020 (Rabi season). The monthly average minimum and maximum temperature during the crop period was 13^{o}C to 27.9^{o}C. The monthly average minimum and maximum relative humidity during the crop period was 57% to 76%. The monthly average minimum and maximum rainfall was 1 mm and 127 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, and Dhaka 1207. The monthly temperature, relative humidity, rainfall and sunshine hour during the study period Appendix III.

3.5 Soil

The soil belongs to the general soil type, Shallow Red Brown Terrace under Tejgaon soil Series. Top soils were clay loam in texture, olive-grey with common fine to medium distinct dark yellowish brown mottles Appendix IV. Initial Soil pH was 6.05 and had organic carbon 0.60% and organic matter content is 1.03%. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples were collected from 0-15 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. The characteristics of the experimental soil are presented in Appendix V.

3.6 Experimental details

3.6.1 Planting material

BARI Garlic-3 was used in the experiment. It was certified in 2004 by National Seed Board, Bangladesh. Plant height is 60-62 cm. Cloves are 2-2.5 cm long. Each bulb produces 20-22 cloves. The lifespan of this crop is about 140-150 days.

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 chitosan raw material powder following a new traditional method. The prepared chitosan raw material powder was used in the crop on 4th November, 2019 during the final land preparation.

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

The composition of chitosan raw material powder is given below

Table 1. 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	18.39%	Wet Oxidation Method (Walkley and Black, 1934)
Organic Matter	31.70%	Organic carbon x 1.724 (Van Bemmelen factor)
Total Nitrogen (N)	7.56-7.7%	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 Seed collection

BARI Garlic-3 bulbs were collected from BARI, Joydebpur, Gazipur , Bangladesh. Healthy and disease free seeds were collected for seed sowing.

3.6.4 Experimental treatment

T_1 (RD of N @ 77 kg/ha)

T_2 (RD of N @ 89 kg/ha)

T_3 (RD of N @ 101 kg/ha)

T_4 (RD of N @ 113 kg/ha)

T_5 (T_1 + 0.1 t CHT Powder/ha)

T_6 (T_2 + 0.1 t CHT Powder/ha)

T_7 (T_3 + 0.1 t CHT Powder/ha)

T_8 (T_4 + 0.1 t CHT Powder/ha)

T_9 (T_1 + 0.5 t CHT Powder/ha)

T_{10} (T_2 + 0.5 t CHT Powder/ha)

T_{11} (T_3 + 0.5 t CHT Powder/ha)

T_{12} (T_4 + 0.5 t CHT Powder/ha)

T_{13} (T_1 + 1 t CHT Powder/ha)

T_{14} (T_2 + 1 t CHT Powder/ha)

T_{15} (T_3 + 1 t CHT Powder/ha)

T_{16} (T_4 + 1 t CHT Powder/ha)

T_{17} (1 t CHT raw material Powder/ha)

T_{18} (1.5 t CHT raw material Powder/ha)

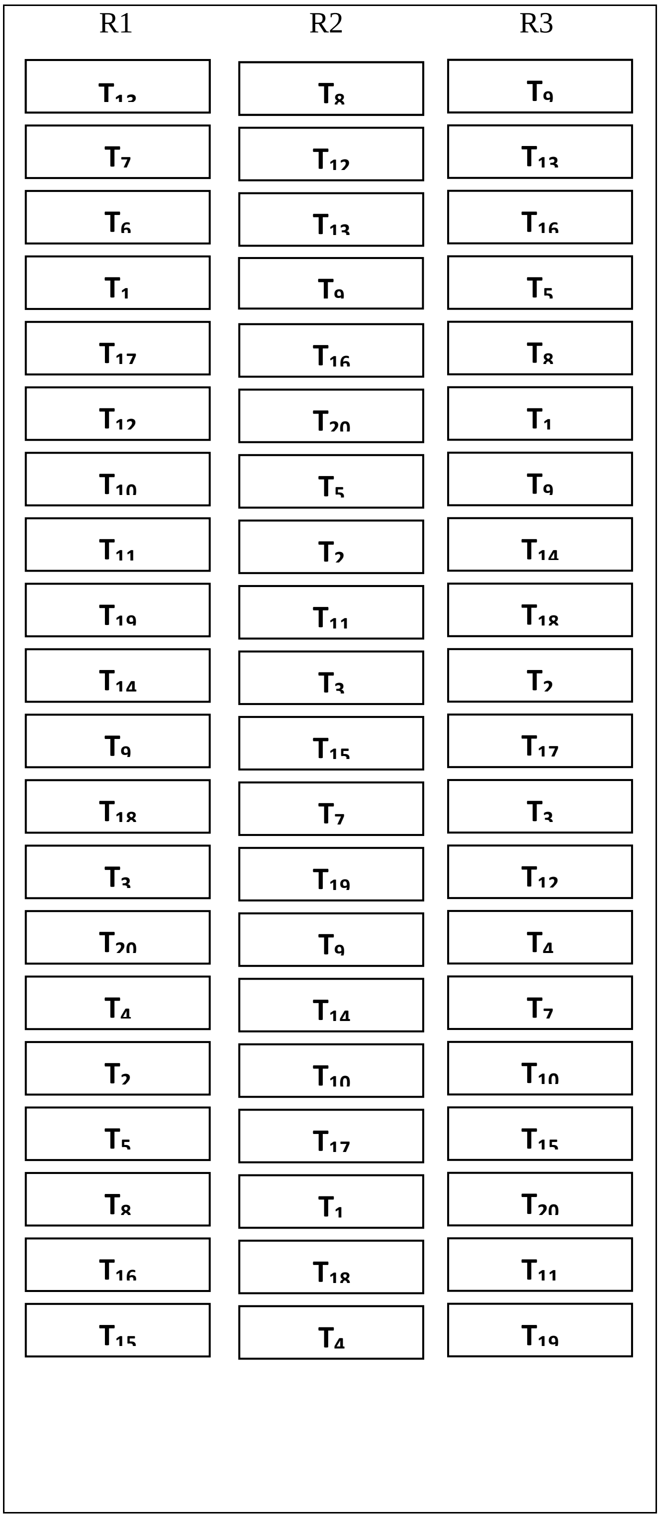
T_{19} (2 t CHT raw material Powder/ha)

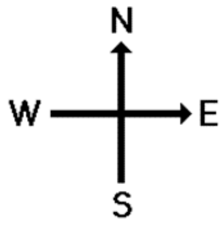
T_{20} (2.5 t CHT raw material Powder/ha)

All other fertilizers were applied @ Recommended dose.

3.6.5 Experimental design

The experiment was embodied in a Randomized Complete Block Design. Number of treatment was 20 and number of replication was 3. The size of the plot was 1.2 m^2 (0.6m × 2m). Total plots in the experimental field were 60. 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 layout of the experiments has been shown in Figure 1.





Distance between replications: 0.75m

Distance between treatments: 0.5m

Plot size: 0.6m×2m = 1.2m^2

Total area of the field: 200m^2

Figure 1. Layout of the experiment

3.6.6 Preparation of experimental land

The research field was prepared on November 01, 2019 with the help of spade; aftermath on November 03, 2019 the land was irrigated and levelled 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 November 05, 2019 according to experimental plan. By using wooden plank all plots were cleaned and finally levelled for seed sowing.

3.6.7 Fertilizer application

The following doses of fertilizer were applied in the experimental field (FRG, 2012).

Fertilizers	Quantity (kg/ha)	Fertilizer given plot^{-1} (g)
TSP	50	29
MoP	125	22
Gypsum	25	30
Boric acid	3	3
Zinc	3	1

3.6.8 Cloves sowing

Cloves were separated from the mother bulb for sowing in the plot and 55 cloves were sown in each plot on 6th November, 2019. In every plot there were 5 rows. 10cm*10cm spacing were maintained. Sowing depth was around 2.5cm from the soil surface. Cloves were also sown around the field area for gap filling.

3.7 Intercultural operations

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

3.7.1 Gap filing

The whole experimental area were kept by netting. No gap filing was needed cause of germinating of all cloves in the all plots.

3.7.2 Weeding and hoeing

Every plot was covered with some weeds after the germination of seedlings. Hand weeding and hoeing was done by labours in every individuals plot. Weeding and hoeing was done at 20 days after sowing of cloves and second weeding at 25 days after first weeding and final weeding was done at 27 days after second weeding.

3.7.3 Irrigation

A light irrigation was done just after sowing the cloves with the help of cane. Then a week later flow irrigation was given in right proportion. Whenever the plants of the plot had sown the symptoms of wilting the plots were irrigated properly until the wet.

3.7.4 Plant protection measures

In the experimental plot the disease leaf blotch was found after 45 days of germinating. Necessary steps was taken with spraying Dithan M-45 at an interval of 10 days @ 60g in 10 litres of water.

3.8 Harvesting

The crop was harvested when the plants come at maturing showing the sign of dying out most of its leaves on 17th March, 2020. Harvesting was done with hoe very carefully so that no bulb injured during lifting from the soil.

3.9 Data collection

Ten (10) plants were randomly selected for the collection of data from each plot. The plants in the outer rows and at the terminal end of the middle rows were excluded from the random selection to avoid the border effect. During the course of experiment. The following data were recorded which are cited below these are given below:

3.9.1 Plant height (cm)

Height of plant was measured in centimetre (cm) by a meter scale from the point of attachment of the leaves to the ground level up to the tip of the longest leaf and the mean value was recorded. Plant height recorded at final harvest.

3.9.2 Fresh weight of tops/plant (g)

It was taken in gram from 10 randomly plants from each plot after 2 days later of sun drying. Tops weight were taken by an electric balance

3.9.3 Dry weight of tops/plant (g)

After harvest, tops of ten selected plants were weighed and kept in an oven at 80° c for drying. It took 72 hours to reach the constant weight and then the average dry weight per plant was calculated in gram.

3.9.4 Leaves number per plant

Randomly10 plants were taken for counting the leaves number from each plot. All the leaves of each plant were counted separately except the smallest young leaf at the growing point of the plant. The average number of leaves of ten plants gave number of leaves per plant.

3.9.5 Fresh weight of bulb/plant (g)

After removing the top portion and roots, the bulb weight of ten plants randomly selected was taken and their average was calculated by the total weight of bulb (g) by dividing its single bulb weight.

3.9.6 Dry weight of bulb/plant (g)

After lifting and sun drying for two days the bulb samples were dried for 72 hours at 80° c in an oven After doing it, the weight of the bulb were recorded in gram.

3.9.7 Bulb diameter (cm)

The diameter was measured with a slide callipers at the middle part of the bulb after harvesting and their average was recorded in centimetre.

3.9.8 Number of cloves/plant

After harvesting the crop the number of cloves of ten randomly selected bulbs was counted thoroughly. The mean number of cloves per bulb was recorded by dividing the total number of cloves counted from ten bulb by ten.

3.9.9 Yield of bulb (kg/plot)

Yield of bulb per plot was recorded by harvesting all the bulbs in each plot and taking their weight after removing roots. Yield per plot was converted in kilogram.

3.9.10 Yield of bulb (t /ha)

Yield of bulb per plot was converted to yield/ha and was presented as metric ton.

3.10 Chemical analysis of soil samples

Soil samples were collected from 0-15cm of soil layer from the experimental field on 19 November, 2019 (one year after of application of chitosan raw material powder). Chemical properties of soil samples were analysed in the laboratory of Department of Soil Science of Sher-e-Bangla Agricultural University, Dhaka-1207.

3.10.1 Soil pH

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

3.10.2 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:

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

Therefore, % Organic matter = % Organic carbon x 1.724

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

3.10.3 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:

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

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

3.11. Statistical Analysis

All the data were analysed 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, Statistix10.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter expounds the presentation and explication of the results attained due to Yield performance of garlic influenced by the effect of chitosan raw material powder. The results of this experiment have been illustrated, explained and compared as far as available with the results of the researchers.

4.1 Height of plant (cm)

In all of the treatments used in the experiment, plant height of garlic showed significant variation with the application nitrogen and chitosan raw material powder. The T_{16} treatment showed the highest plant height 64.33 cm, and second highest height was T_{15} (62 cm) which was statistically similar to the T_{17} (61.67 cm) and T_{13} (60.50 cm) treatments. T_1 treatment showed the lowest plant height 57.80 cm and second lowest height was found in T_2 (58.10 cm) which was statistically similar to T_3 (58.20 cm), T_7 (58.20 cm) and T_4 (58.27 cm) treatments (Table-2). The height of the plant was increased in a dose-dependent manner.

These results were supported by Mondal *et al*., (2012) who executed pot and field experiments with the five levels of chitosan concentrations viz., 0 (control), 50, 75, 100 and 125 ppm. Results showed that most of the morphological character (plant height) were improved with increasing concentration of chitosan. Similar findings were found by Rahman et al., (2015), Ahmed et al., (2020), and Sultana et al., (2020).

4.2 Number of leaves/plant

It was found that treatment means in terms of number of leaves/plant was highly significant. The maximum number of leaves/plant (7.77) was found in T_{16} treatment which is statistically significant with T_{14} (7.57), T_{15} (7.11), T_{17} (6.77), T_{18} (6.84), T_{19} (6.83), T_{11} (6.73), T_{12} (6.53) treatment and T_{10} (6.30) treatment. The lowest number of leaves/plant (5.41) was found in treatment T_{20} which is similar to treatment T_7 (5.57) and T_4 (5.71) treatment (Table-2). It was found that, the impact of chitosan raw material powder application in soil shows the positive effect on number of number/plant among the different treatment doses.

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 CRD with 4 replications and 12 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 showed that there were significant variations among the treatments on number of leaves/plant.

Table 2. Effect of different doses of chitosan raw material powder on plant height (cm) and number of leaves/plant (BARI Garlic-3) at harvest

Treatments	Height of plant (cm)	Number leaves/plant
T_1 (RD of N @ 77 kg/ha)	57.80h	5.97bcd
T_2 (RD of N @ 89 kg/ha)	58.10gh	6.11bcd
T_3 (RD of N @ 101 kg/ha)	58.20gh	6.75abcd
T_4 (RD of N @ 113 kg/ha)	58.27gh	5.71cd
T_5 (T_1 + 0.1 t CHT Powder/ha)	58.43fgh	6.44abcd
T_6 (T_2 + 0.1 t CHT Powder/ha)	58.50fgh	6.10bcd
T_7 (T_3 + 0.1 t CHT Powder/ha)	58.20gh	5.57cd
T_8 (T_4 + 0.1 t CHT Powder/ha)	59.07defgh	6.23abcd
T_9 (T_1 + 0.5 t CHT Powder/ha)	58.67efgh	6.17abcd
T_{10} (T_2 + 0.5 t CHT Powder/ha)	59.33defgh	6.30abcd
T_{11} (T_3 + 0.5 t CHT Powder/ha)	59.00defgh	6.73abcd
T_{12} (T_4 + 0.5 t CHT Powder/ha)	59.17defgh	6.53abcd
T_{13} (T_1 + 1 t CHT Powder/ha)	60.50bcd	6.20abcd
T_{14} (T_2 + 1 t CHT Powder/ha)	60.17cde	7.57ab
T_{15} (T_3 + 1 t CHT Powder/ha)	62.00b	7.11abc
T_{16} (T_4 + 1 t CHT Powder/ha)	64.33a	7.77a
T_{17} (1 t CHT raw material powder/ha)	61.67bc	6.77abcd
T_{18} (1.5 t CHT raw material powder/ha)	60.17cde	6.84abcd
T_{19} (2 t CHT raw material powder/ha)	60.00def	6.83abcd
T_{20} (2.5 t CHT raw material powder/ha)	59.5defg	5.41d
CV%	1.61	15.3
LSD (0.05%)	1.5895	1.6329

4.3 Fresh weight of tops (g)

Remarkable significant variations in respect of fresh weight of straw were recorded due to the impact of N and chitosan raw material powder. The highest straw weight was found in treatment T_{16} (12.03 g) which was statistically similar to treatments T_{17} (11.91 g) and T_{15} (11.78 g). The minimum fresh weight of straw (10.19 g) was obtained from T_1 (Table-3). Hossain (2003), Adetunji (1994) and Bhuiya (l999) found similar result in garlic experiment.

4.4 Dry weight of tops (g)

The maximum oven dry weight of tops (3.01 g) was recorded in T_{16} treatment, which was statistically similar to T_{17} (2.98 g) and T_{15} (2.94 g) treatment. In T_1 treatment, the minimum oven dry weight 2.55 g was recorded, which was statistically similar to the T_2 (2.63 g) treatment (Table-3). This findings was familiar with the reports of Talukder (1998). And similar trend of results were reported by Halim (2000) and Hossain (1996), who found in garlic.

Table 3. Effect of different doses of chitosan raw material powder on sundry weight and dry weight of tops (g) (BARI Garlic-3) at harvest

Treatments	Sundry weight of tops (g)	Dry weight of tops (g)
T_1 (RD of N @ 77 kg/ha)	10.19g	2.55l
T_2 (RD of N @ 89 kg/ha)	10.50f	2.63kl
T_3 (RD of N @ 101 kg/ha)	10.63f	2.66jk
T_4 (RD of N @ 113 kg/ha)	10.66f	2.66jk
T_5 (T_1 + 0.1 t CHT Powder/ha)	10.72f	2.68ijk
T_6 (T_2 + 0.1 t CHT Powder/ha)	11.22de	2.72hij
T_7 (T_3 + 0.1 t CHT Powder/ha)	11.36cde	2.75ghi
T_8 (T_4 + 0.1 t CHT Powder/ha)	11.25de	2.81defgh
T_9 (T_1 + 0.5 t CHT Powder/ha)	11.16e	2.79fgh
T_{10} (T_2 + 0.5 t CHT Powder/ha)	11.24de	2.81defgh
T_{11} (T_3 + 0.5 t CHT Powder/ha)	11.22de	2.81efgh
T_{12} (T_4 + 0.5 t CHT Powder/ha)	11.35cde	2.84defg
T_{13} (T_1 + 1 t CHT Powder/ha)	11.36cde	2.84defg
T_{14} (T_2 + 1 t CHT Powder/ha)	11.60bc	2.90bcd
T_{15} (T_3 + 1 t CHT Powder/ha)	11.78ab	2.94abc
T_{16} (T_4 + 1 t CHT Powder/ha)	12.03a	3.01a
T_{17} (1 t CHT raw material powder/ha)	11.91a	2.98ab
T_{18} (1.5 t CHT raw material powder/ha)	11.47cd	2.86cdef
T_{19} (2 t CHT raw material powder/ha)	11.55bc	2.89bcde
T_{20} (2.5 t CHT raw material powder/ha)	11.20e	2.80efgh
CV%	1.47	1.95
LSD (0.05%)	0.2717	0.0903

4.5 Bulb diameter (cm)

The diameter of bulb was also influenced significantly by the impact of different levels of chitosan raw materials. The maximum (14.28 cm) bulb diameter was recorded from T_{16} treatment (Table 4) which was identical to treatment T_{15} (13.95 cm). On the other hand lowest (11.48 cm) bulb diameter was found from T_1 treatment. This results agree with Hossain (2003), Uddin (1997) and Iroc et al. (1991).

4.6 Number of cloves/bulb

Significant variation was found due to use of different levels of CHT powder on number of cloves per bulb (Table 4). The maximum cloves bulb^{-1} (23.52) was found in T_{16} treatment which is statistically significant from T_2 (23.38) treatment and T_{17} (22.81) & T_{12} (22.81) treatment. On the contrary the minimum cloves bulb^{-1} (20.04) was found in T_1 treatment. Halim (2000), Rekowaska, (1997) and Asandhi (1989) stated the similar results for garlic.

These results were also supported by Kamruzzaman (2016) who carried out 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 5 treatments having 4 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.

Table 4. Effect of different doses of chitosan raw material powder on bulb diameter (cm) and number of cloves/bulb (BARI Garlic-3) at harvest

Treatments	Bulb diameter (cm)	Number of cloves/bulb
T_1 (RD of N @ 77 kg/ha)	11.48i	20.04f
T_2 (RD of N @ 89 kg/ha)	11.78hi	23.38ab
T_3 (RD of N @ 101 kg/ha)	11.86hi	20.42ef
T_4 (RD of N @ 113 kg/ha)	12.03ghi	20.55def
T_5 (T_1 + 0.1 t CHT Powder/ha)	12.17efghi	21.18bcdef
T_6 (T_2 + 0.1 t CHT Powder/ha)	11.99ghi	21.17bcdef
T_7 (T_3 + 0.1 t CHT Powder/ha)	12.46defgh	20.93cdef
T_8 (T_4 + 0.1 t CHT Powder/ha)	12.08fghi	21.57abcdef
T_9 (T_1 + 0.5 t CHT Powder/ha)	12.28defghi	21.81abcdef
T_{10} (T_2 + 0.5 t CHT Powder/ha)	12.66cdefgh	22.04abcdef
T_{11} (T_3 + 0.5 t CHT Powder/ha)	12.89cdefg	22.54abcde
T_{12} (T_4 + 0.5 t CHT Powder/ha)	13.21bcd	22.81abcd
T_{13} (T_1 + 1 t CHT Powder/ha)	12.85cdefg	22.54abcde
T_{14} (T_2 + 1 t CHT Powder/ha)	13.55abc	22.64abcde
T_{15} (T_3 + 1 t CHT Powder/ha)	13.95ab	23.12abc
T_{16} (T_4 + 1 t CHT Powder/ha)	14.28a	23.52a
T_{17} (1 t CHT raw material powder/ha)	13.10bcde	22.81abcd
T_{18} (1.5 t CHT raw material powder/ha)	12.95cdefg	22.78abcd
T_{19} (2 t CHT raw material powder/ha)	13.00bcdef	22.38abcde
T_{20} (2.5 t CHT raw material powder/ha)	12.94cdefg	21.57abcdef
CV%	4.62	6.36
LSD (0.05%)	0.9682	2.3104

4.7 Fresh weight of bulb (g)

The variation in term of fresh weight of bulb per plant among different treatments were found to be highly significant. It was found that, the maximum (24.16 g) individual fresh bulb weight was obtained from T_{16} which was identical to T_{17} and T_{18} and the lowest (20.60 g) fresh weight of bulb was obtained from T_1 that is similar to T_2 (Table 5) These results agree with the results of Hossain (2003), Halim (2000) and Bhuiya (1999).

These results were supported by Rahman (2015) who executed a pot experiment with tomato cv. BARI tomato-15. The used treatments were T_1 (control), T_2 (50 g modified chitosan/pot), T_3 (100 g modified chitosan/pot), T_4 (150 g modified chitosan/pot) and T_5 (200 g modified chitosan/pot).

4.8 Dry weight of bulb (g)

Dry weight of individual bulb was measured and observed, there were significant variations due to influence of CHT powder. The highest dry weight was found in T_{16} (5.84 g) which was identical to T_{17}. And the lowest weight was found in T_7 (5.03 g) treatment (Table 5). This result is identical to the results of Rekwaska (1997), Hasan (1999) and Uddin (1997).

Table 5. Effect of different doses of chitosan raw material powder on fresh and dry weight of bulb (g) (BARI Garlic-3) at harvest

Treatments	Fresh weight of bulb (g)	Dry weight of bulb (g)
T_1 (RD of N @ 77 kg/ha)	20.60j	5.21bcde
T_2 (RD of N @ 89 kg/ha)	20.86ij	5.21bcde
T_3 (RD of N @ 101 kg/ha)	21.26hij	5.06e
T_4 (RD of N @ 113 kg/ha)	21.46ghij	5.11de
T_5 (T_1 + 0.1 t CHT Powder/ha)	21.75fghi	5.32bcde
T_6 (T_2 + 0.1 t CHT Powder/ha)	22.07efgh	5.35bcde
T_7 (T_3 + 0.1 t CHT Powder/ha)	21.59ghi	5.03e
T_8 (T_4 + 0.1 t CHT Powder/ha)	22.14defgh	5.43abcde
T_9 (T_1 + 0.5 t CHT Powder/ha)	22.06efgh	5.45abcde
T_{10} (T_2 + 0.5 t CHT Powder/ha)	22.13defgh	5.40abcde
T_{11} (T_3 + 0.5 t CHT Powder/ha)	22.35cdefg	5.58abc
T_{12} (T_4 + 0.5 t CHT Powder/ha)	22.62bcdef	5.60abc
T_{13} (T_1 + 1 t CHT Powder/ha)	23.00bcd	5.59abc
T_{14} (T_2 + 1 t CHT Powder/ha)	23.09bc	5.34bcde
T_{15} (T_3 + 1 t CHT Powder/ha)	22.97bcde	5.55abcd
T_{16} (T_4 + 1 t CHT Powder/ha)	24.16a	5.84a
T_{17} (1 t CHT raw material powder/ha)	23.52ab	5.66ab
T_{18} (1.5 t CHT raw material powder/ha)	23.20bc	5.35bcde
T_{19} (2 t CHT raw material powder/ha)	23.20bc	5.34bcde
T_{20} (2.5 t CHT raw material powder/ha)	23.04bcd	5.19cde
CV%	2.5	5.1
LSD (0.05%)	0.9252	0.454

4.9 Yield of bulb/plot (kg)

Yield of garlic/plot was recorded to be statistically significant due to different treatments. The highest yield/plot was achieved from T_{16} (1.33 kg/plot). T_{17} (1.29 kg/plot) showed statistically identical reading with T_{16} and the lowest yield/plot was obtained from T_1 (1.13 kg/plot) (Table 6).

4.10 Yield of bulb (t ha^{-1})

The effects of different treatments on bulb yield was significantly enhanced by the effect of chitosan raw material powder treatment (Table 6). The maximum yield (11.07 t ha^{-1}) was accomplished in the T_{16} treatment (17.27% yield increased over T_1) which was significantly greater than that accomplished in the T_{17} treatment. The minimum yield (9.44 t ha^{-1}) was accomplished in the T_1 treatment. It was found that, as the rate of chitosan raw material powder application in soil increases yield of garlic.

These results were supported by Mondal *et al*., (2012) who conducted 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/plan were increased with increasing concentration of chitosan until 25 ppm and the highest yield (27.9% yield increased over the control).

Table 6. Effect of different doses of chitosan raw material powder on yield/plot (kg) and yield (t/ha) (BARI Garlic-3) at harvest

Treatments	Yield/ plot (kg)	Yield (t/ha)
T_1 (RD of N @ 77 kg/ha)	1.13j	9.44j
T_2 (RD of N @ 89 kg/ha)	1.15ij	9.56ij
T_3 (RD of N @ 101 kg/ha)	1.17hij	9.74hij
T_4 (RD of N @ 113 kg/ha)	1.18ghij	9.83ghij
T_5 (T_1 + 0.1 t CHT Powder/ha)	1.20fghi	9.97fghi
T_6 (T_2 + 0.1 t CHT Powder/ha)	1.21efgh	10.11efgh
T_7 (T_3 + 0.1 t CHT Powder/ha)	1.19ghi	9.89ghi
T_8 (T_4 + 0.1 t CHT Powder/ha)	1.22defgh	10.14defgh
T_9 (T_1 + 0.5 t CHT Powder/ha)	1.21efgh	10.11efgh
T_{10} (T_2 + 0.5 t CHT Powder/ha)	1.22defgh	10.14defgh
T_{11} (T_3 + 0.5 t CHT Powder/ha)	1.23cdefg	10.24cdefg
T_{12} (T_4 + 0.5 t CHT Powder/ha)	1.24bcdef	10.36bcdef
T_{13} (T_1 + 1 t CHT Powder/ha)	1.27bcd	10.54bcd
T_{14} (T_2 + 1 t CHT Powder/ha)	1.27bc	10.58bc
T_{15} (T_3 + 1 t CHT Powder/ha)	1.26bcde	10.52bcde
T_{16} (T_4 + 1 t CHT Powder/ha)	1.33a	11.07a
T_{17} (1 t CHT raw material powder/ha)	1.29ab	10.78ab
T_{18} (1.5 t CHT raw material powder/ha)	1.28bc	10.63bc
T_{19} (2 t CHT raw material powder/ha)	1.28bc	10.63bc
T_{20} (2.5 t CHT raw material powder/ha)	1.27bcd	10.55bcd
CV%	2.5	2.5
LSD (0.05%)	0.0509	0.4239

4.11 Effect of chitosan raw material powder on total N content (%) at Post-harvest soil

The total N content of the post-harvest soil of experiment that was affected by the different treatments of chitosan raw material powder and ranged from 0.08% to 0.20% (Table 7). It was found that N status of soil was statistically different among the treatments. The highest N value (0.20%) was found in T_{16} and the lowest N value (0.08%) was recorded in T_1 treatment.

These results were supported by Sultana *et al*., (2020) who conducted 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, T_2 = 1.0 t/ha, T_3 = 2.0 t/ha, T_4 = 4.0 t/ha and T_5 = 0 V t/ha. 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 (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 (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 (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 (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 + recommended N (control). The results concluded that the total nitrogen content in the post-harvest-soils were increased due to the residual effect of the powder in rice growing soils.

4.12 Soil organic carbon content (%) in the post-harvest soil

The organic carbon content in the post-harvest soil (0-15 cm) was affected by different treatments of residual effect of chitosan raw material powder (Table 7). In case of 0-15 cm of soil layer all treatments were found which ranged from 0.47% to 0.55 %. Maximum organic carbon content (0.65%) was found in T_{16} treatment which was greater than T_{15} treatment. The minimum organic carbon content (0.47%) was found in T_1 treatment.

These results were supported by Sultana *et al*., (2020) who conducted an experiment with the raw material of CHT powder with one control. There were 4 replications using 4 different doses of the raw material of CHT powder. The treatments were as follows: T_1= 0.5 t/ha, T_2 = 1.0 t/ha, T_3 = 2.0 t/ha, T_4 = 4.0 t/ha and T_5 = 0 t/ha. The 2nd 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 (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 (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 (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 (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 + recommended N (control). The results revealed that soil organic carbon status in the post-harvest-soils were increased.

4.13 Soil organic matter content (%) in the post-harvest soil

Soil organic carbon content in the post-harvest soil (0-15 cm) was affected by residual effect of chitosan raw material powder among all the treatments (Table 7). In case of 0-15 cm of soil layer all treatments were found statistically similar and ranged from (0.80% to 0.95%). Maximum organic matter content (0.95%) was found in T_{16}

treatment which was greater than T_{15} treatment. The minimum organic matter content (0.80%) was found in T_1 treatment.

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, T_2 = 1.0 t/ha, T_3 = 2.0 t/ha, T_4 = 4.0 t/ha and T_5 = 0 t/ha. 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 (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 (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 (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 (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 + 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 use of chitosan raw material powder contains higher level of organic carbon. It might be increased the level of organic matter content of the post-harvest 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.

Table 7. Effect of different doses of chitosan raw material powder on total N content (%), Soil organic carbon (%) and Soil organic matter (%) (BARI Garlic-3) at harvest

Treatments	Total N content (%)	Soil organic carbon (%)	Soil organic matter (%)
T_1 (RD of N @ 77 kg/ha)	0.08e	0.46h	0.80h
T_2 (RD of N @ 89 kg/ha)	0.08e	0.46h	0.80h
T_3 (RD of N @ 101 kg/ha)	0.08e	0.46h	0.80h
T_4 (RD of N @ 113 kg/ha)	0.09de	0.47gh	0.81gh
T_5 (T_1 + 0.1 t CHT Powder/ha)	0.12d	0.49ef	0.85ef
T_6 (T_2 + 0.1 t CHT Powder/ha)	0.13cd	0.50def	0.87def
T_7 (T_3 + 0.1 t CHT Powder/ha)	0.13cd	0.49fg	0.84fg
T_8 (T_4 + 0.1 t CHT Powder/ha)	0.13cd	0.49fg	0.85fg
T_9 (T_1 + 0.5 t CHT Powder/ha)	0.13cd	0.50def	0.87def
T_{10} (T_2 + 0.5 t CHT Powder/ha)	0.13cd	0.52bcd	0.90bcd
T_{11} (T_3 + 0.5 t CHT Powder/ha)	0.13cd	0.50def	0.87def
T_{12} (T_4 + 0.5 t CHT Powder/ha)	0.14cd	0.50def	0.87def
T_{13} (T_1 + 1 t CHT Powder/ha)	0.14cd	0.61cde	0.89cde
T_{14} (T_2 + 1 t CHT Powder/ha)	0.15bc	0.62bcd	0.90bcd
T_{15} (T_3 + 1 t CHT Powder/ha)	0.17b	0.64ab	0.93ab
T_{16} (T_4 + 1 t CHT Powder/ha)	0.20a	0.65a	0.95a
T_{17} (1 t CHT raw material powder/ha)	0.15bc	0.63abc	0.91abc
T_{18} (1.5 t CHT raw material powder/ha)	0.14cd	0.61cde	0.89cde
T_{19} (2 t CHT raw material powder/ha)	0.13cd	0.61cde	0.89cde
T_{20} (2.5 t CHT raw material powder/ha)	0.14cd	0.61cde	0.89cde
CV%	13.04	2.66	2.66
LSD (0.05%)	0.0295	0.0221	0.0381

CHAPTER V
SUMMARY AND CONCLUSION

An experiment was conducted at the research field of Sher-e-Bangla Agricultural University (SAU), Dhaka, at the time of November 2019 to April 2020 to determine the yield performance of garlic influenced by the effect nitrogen and chitosan raw material powder under in Rabi season and under the Madhupur Tract (AEZ-28). During the time of garlic experiment there were composed of twenty treatments of chitosan raw material powder and three replications.

Percentage of N, Soil pH, soil organic carbon and soil organic matter is an important constituent of soils. Most of the soil in Bangladesh is deficient in N, organic-matter content and low in soil pH . For improvement of soil chitosan raw material powder can be used as an another source of N which improves efficiency of applied N and can contribute to enhance N content, maintain the organic matter and soil pH of garlic growing soil. The impact of chitosan raw material powder has a positive effect on changes of total N, pH, organic carbon and organic matter content of soil. Among the significantly different parameters T_{16} treatment performed best compare to other concentrations of chitosan raw material powder. The data on crop growth and yield contributing characters (Plant height (cm) at harvest, average number of leaves plant^{-1}, cloves bulb^{-1}, total bulb plot^{-1}, average single bulb fresh weight (g), average single bulb fresh weight (g plot^{-1}), average bulb oven dry weight (g), average single bulb oven dry weight (g plot^{-1}), Yield (t ha^{-1}). Data were recorded in the field and analysed using the software Statistix10. The mean differences were compared by least significant difference test at 5% level of significance among all the treatments. In case of garlic, the results revealed that the maximum plant height (64.33 cm) was found in the T_{16} (1 ton/ha CHT raw material powder) treatment and the minimum plant height (57.80 cm) was found in the T_1 (0 ton/ha CHT raw material powder) treatment. The maximum no. of leaves plant^{-1} (7.77) was found in T_{16} (1 ton/ha CHT raw material powder) treatment. On the other hand the minimum no. of leaves/plant (5.97) was found in T_1 (0 ton/ha CHT raw material powder) treatment. . The maximum bulb diameter (14.28 cm) was found in T_{16} (1 ton/ha CHT raw material powder) treatment and the minimum bulb diameter (11.48 cm) was found in T_1 (0 ton CHT raw material powder) treatment. The maximum bulb fresh weight (24.16 g) was found in T_{16} (1 ton/ha CHT raw material powder) treatment and the minimum bulb fresh weight (20.60 g) was found in T_1 {0 ton CHT raw material powder) treatment. On the contrary the maximum dry bulb weight (5.84 g) was found in T_{16} (1 ton/ha CHT raw material powder) treatment and the minimum dry bulb weight (5.03 g) was found in T_7 (0.1 ton/ha CHT raw material powder) treatment. Highest number of cloves per bulb was found in T_{16} (1 ton/ha CHT raw material powder) treatment and lowest number of cloves was in T_1 (0 ton/ha CHT raw material powder) treatment. The maximum tops fresh weight (12.03 g) were found in T_{16} (1 t/ha CHT raw material powder) treatment and the minimum tops fresh weight (10.19 g) were found in T_1 {0 ton CHT raw material powder) treatment. The maximum straw dry weight (3.01 g) was found in T_{16} (1 t/ha CHT raw material powder) treatment and the minimum straw dry weight (2.55 g) was found in T_1 {0 ton CHT raw material powder) treatment. The maximum yield (11.07 ton/ha) was found in T_{16} (1 t/ha CHT raw material powder) treatment and the minimum straw dry weight (9.44 t/ha) was found in T_1 {0 ton CHT raw material powder) treatment. In case of soil chemical properties the highest N value (0.2 %) was recorded in T_{16} treatments (1 t/ha CHT raw material powder) which was significantly greater than the T_1 (0 t/ha CHT raw material powder) treatment and the lowest N value (0.12%) was recorded in $T_{1,}$ $T_{2,}$ $T_{3,}$ (0 t/ha CHT raw material powder) treatment. The highest organic carbon (0.55 %) was recorded in T_{16} treatments (1 t/ha CHT raw material powder) which was significantly greater than the T_1 (0 t/ha CHT raw material powder) treatment and the lowest organic carbon (0.46%) was recorded in $T_{1,}$ $T_{2,}$ $T_{3,}$ (0 ton/ha CHT raw material powder) treatment. The highest organic matter (0.95 %) was recorded in T_{16} treatments (1 ton/ha CHT raw material powder) which was significantly greater than the T_1 (0 t/ha CHT raw material powder) treatment and the lowest organic matter (0.80%) was recorded in $T_{1,}$ $T_{2,}$ $T_{3,}$ (0 t/ha CHT raw material powder) treatment.

The stated experiment was conducted to improve our understanding of the yield maximization effect of chitosan raw material powder on the performance of growth, yield contributing characters and yield of garlic. Yield, as well as other yield contributing characters responded positively with the increasing concentration of applied chitosan raw material powder.

From the above experimental results, it can be concluded that,

I. Treatment T_{16} of the CHT raw material powder influenced morphological characters, yield attributes and bulb yield of garlic compared to the control treatment T_1; and

II. The chitosan raw material powder increased chemical properties of soil like total N%, soil organic carbon and soil organic matter content in T_{16} treatment compare to control treatment T_1; that obviously helpful for sustainable agriculture.

Recommendations

From the stated experimental outcomes, it is concluded that the application of 1t/ha chitosan raw material powder (T_{16}) in garlic performed better on yield and yield parameters. In order to recommend the practices for the spices growers, the following aspects would be considered in future:

i) Similar experiments need to be executed in different parts of the country and seasons of Bangladesh to draw a final conclusion regarding the proper effect of chitosan raw material powder applications for the yield of this crop.

ii) Performance on different varieties to be needed for the better investigation.

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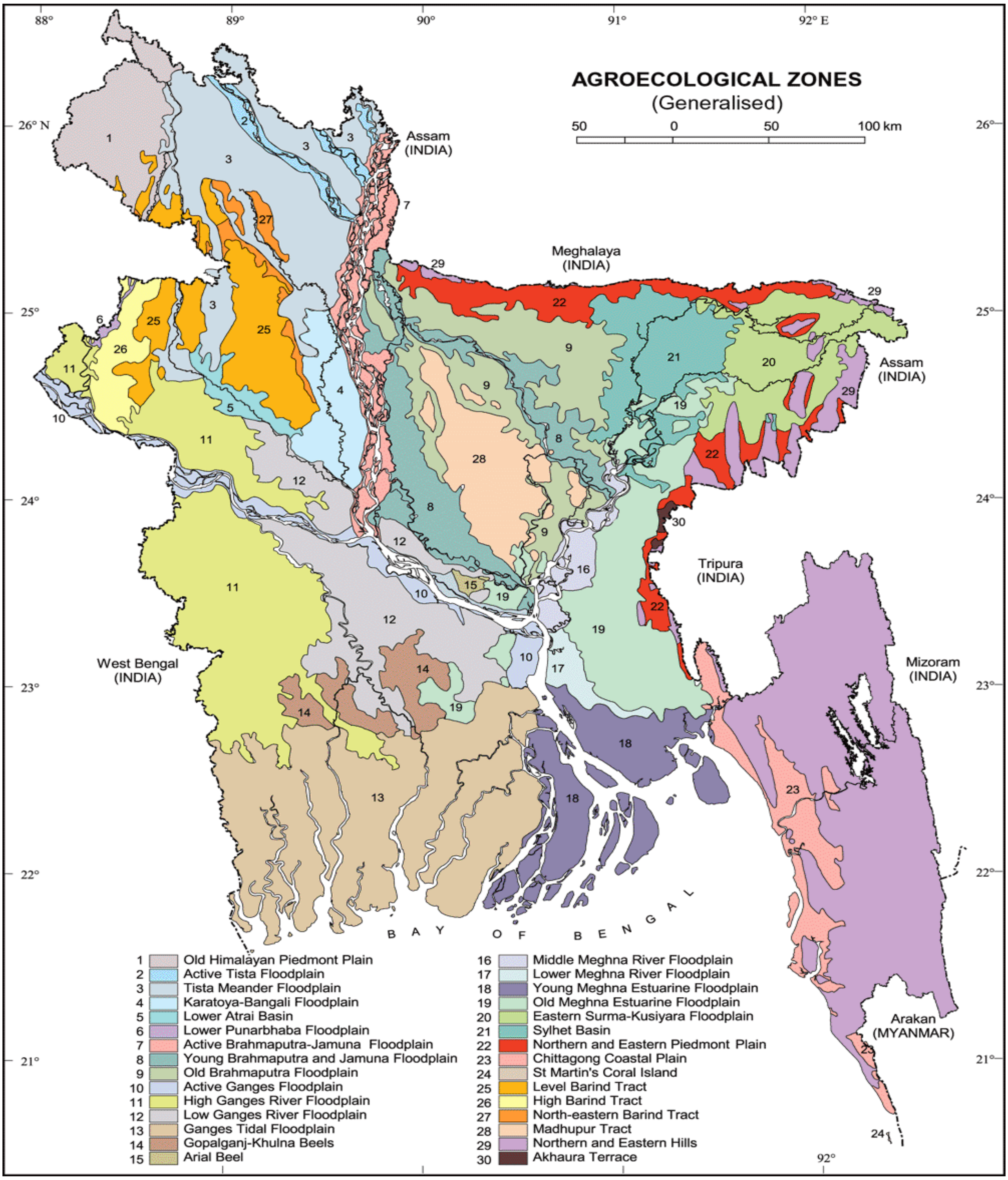
APPENDICES

Appendix I. Map showing the experimental location under study



Appendix II. Trend of garlic production in Bangladesh from 2010 to 2020

Year	Cultivated land (Acres)	Production (M ton)
2010-2011	194	209
2011-2012	109	234
2012-2013	105	224
2013-2014	131	312
2014-2015	141	346
2015-2016	150	382
2016-2017	164	425
2017-2018	176	462
2018-2019	177	466
2019-2020	182	485

(Source : (BBS (2021). Yearbook of Agricultural Statistics-2020)

Appendix III. Monthly meteorological information during the period from November, 2019 to April2020

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

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

Appendix IV. Morphological characteristics of the experimental area

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

Appendix V. The initial physical and chemical characteristics of soil used in this experiment

Physical characteristics	
Constituents	Percent (%)
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Soil characteristics	Value
pH	5.8
Organic carbon (%)	0.5
Organic matter (%)	0.87
Total nitrogen (%)	0.08
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10