RESIDUAL EFFECT OF MODIFIED CHITOSAN POWDER ON THE NITROGEN MANAGEMENT OF BORO RICE

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CERTIFICATE

*This is to certify that thesis entitled, "**RESIDUAL EFFECT OF MODIFIED CHITOSAN POWDER ON THE NITROGEN MANAGEMENT OF BORO RICE**" submitted to the Department of Soil Science Faculty of Agriculture, Sher-e-Bangla Agricultural University Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in SOIL SCIENCE**, embodies the result of a piece of bona fide research work carried out by **Md. Kamruzzaman**, Registration No. **15-06940** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2016
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DEDICATED

TO

MY

BELOVED

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ABSTRACT

The experiments were carried out at the research field of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during the Boro season (November to May, 2016) to investigate residual effect of modified chitosan (CHT) powder on nitrogen management and yield performance of Boro rice. Two individual field experiments were done using two individual rice variety i.e. BRRI dhan28 and BRRI dhan29. The experiments were laid out in randomized complete block design (RCBD) with four replications. The experiments were comprised of five treatments having four levels of modified CHT powder. The treatments were T_1= Modified CHT powder @ 0.5 t/ha (applied in the previous experiment) + 2/3rd N of the recommended dose (RD), T_2 =Modified CHT powder @ 1.0 t/ha (applied in the previous experiment) + 2/3rd N of the RD, T_3 = Modified CHT powder @ 2.0 t/ha (applied in the previous experiment) + 2/3rd N of the RD, T_4 = Modified CHT powder @ 4.0 t/ha(applied in the previous experiment) + 2/3rd N of the RD and T_5 =Modified CHT powder @ 0 t/ha + recommended N (control). Yield and yield contributing characters responded positively with increasing the doses of CHT powder except the following characters i.e. plant height, panicle length, total number of grains/panicle, filled grains/panicle, unfilled grains/panicle. The grain yield significantly decreased in T_1 treatment (5.47 t/ha) compared to T_5 (6.50 t/ha) control treatment due to the lack of nitrogen. But T_4 treatment shows statistically identical grain yield (6.44 t/ha) to the control treatment (6.50 t/ha) in T_5 which indicates the supplementation of N occurs in higher dose of CHT powder in T_4 treatment. Similarly straw yield (7.50 t/ha), number of effective tillers/hill (17.22) as well as biological yield (13.94 t/ha) of T_4 treatment shows statistically identical compared to the T_5 control treatment. The value of pH (7.01), organic carbon content (0.72%), and highest organic matter content (1.23%) in post harvest soil obtained in T_4 treatment were significantly greater than the T_5 control treatment. From these results it can be concluded that yield and yield contributing characters of rice and some chemical properties of soil were improved due to the residual effect of modified CHT powder Taken together, our results suggest that modified CHT powder have some positive residual effect on slow releasing nitrogen supplementation, soil organic carbon and soil pH.

TABLE OF CONTENTS

CONTENTS (Contd.)

CONTENTS (Contd.)

LIST OF TABLES

LIST OF FIGURES

FIGURES (Contd.)

LIST OF APPENDICES

LIST OF ACRONYMS

AEZ	Agro- Ecological Zone
Anon.	Anonymous
AIS	Agricultural Information Service
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BRRI	Bangladesh Rice Research Institute
CHT	Chitosan
Cm	Centimeter
CV	Coefficient of Variance
cv.	Cultivar (s)
DAT	Days After Transplanting
^0C	Degree Centigrade
et al.	And others
FAO	Food and Agriculture Organization
g	Gram (s)
HI	Harvest Index
Hr	Hour(s)
IRRI	International Rice Research Institute
i. e.	That is
K_2O	Potassium Oxide
Kg	Kilogram (s)
LSD	Least Significant Difference
M	Meter
m^2	Meter squares
Mm	Millimeter
MOP	Muriate of Potash
N	Nitrogen
No.	Number
NS	Non significant
%	Percentage
P_2O_5	Phosphorus Penta Oxide
S	Sulphur
SAU SRDI	Sher-e- Bangla Agricultural University Soil Resources Development Institute
t ha^{-1}	Ton per hectare
TSP	Triple Super Phosphate
var.	Variety
Wt.	Weight
Zn	Zinc

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food for the people of Bangladesh and in Asia rice is the staple food for more than two billion people (Hien *et al.*, 2010). Rice is the principle food in most of the countries of Asia and Africa. Rice belongs to the Gramineae family and the genus is *Oryza* which containes about 22 different species (Wopereis *et al.*, 2009). It is also the most important food crop and a dominant food grain for more than one third of the world and the most important source of the food energy for 50% of the Global population (Zhao *et al.*, 2011). Rice has the second largest cereal production after wheat with over 685 million tones recorded in 2009 (Abodolereza and Racionzer, 2009). Rice is grown in 114 countries of the world in about 150 million hectares of land and the annual production of rice is over 525 million tones, nearly 11 per cent of the world's cultivated land is used for rice cultivation (Rai, 2006). According to the Food and Agricultural Organization (FAO) of the UN, 80% of the world rice production comes from 7 countries (UAE-FAO, 2012).

Rice is the staple food for about 156 million people of Bangladesh (Israt *et al.*, 2016). In Bangladesh, rice covers about 28.49 million acres in which 34.5 million M tons of rice is produced while the average yield of rice is around 1.18 tons acre (BBS 2013). According to BBS, 2015, Bangladesh is the 5th largest country of the world based on the rice cultivation. In Bangladesh, per capita rice consumption is about 166 kg per year (BBS, 2015). The contribution of agriculture sector in GDP is 16.33 percent in 2013-14 fiscal years (Bangladesh Economic Review, 2015). In the agriculture sector, the crop sub-sector dominates with 10.74 percent in GDP of which rice alone contributes about 53 percent as well as about one-sixth of the national income comes from the rice sector (Rahman *et al.,* 2015).

The population of Bangladesh is growing rapidly every year and may increase by another 30 million over the next 20 years. Thus, in the year 2020, the population will require about 27.26 million tons of rice (BRRI, 2011). During this time the total area of rice will also shrink to 10.28 million hectares so that, we need to increase rice yield by 53.3% (Mahamud *et al.,* 2013). Again, the increased population will require 70 percent more rice in 2025 than the present consumption (Kim and Krishnan, 2002). As the food requirement is increasing at an alarming rate due to increasing population in Bangladesh, food security has been and will remain a major concern. Rice yield, in general, is comparatively lower than that of other south East Asian countries because of severe insect infestation, drought, salinity etc. Yield loss up to 50% has been recorded in susceptible rice varieties when all the leaf sheaths and leaf blades were infected (Kumar *et al.,* 2012). 474.86 million metric tons of rice was produced throughout the world from 159.64 million hectares of land with an average yield of 4.43 t/ha during the year of 2014-15 (USDA, 2015). USDA estimates Bangladesh has to produce around 34.51 million tons of rice from an estimated 11.7 million hectares of land in the year 2016-17.

In Bangladesh there are three rice seasons. Among the three groups boro rice has highest amount of production. 55% of the total rice production comes from boro rice that covers about 64.11% of the total rice area cultivation (BBS, 2015). But rice production is affected by various biotic and abiotic constraints. Due to high population pressure Bangladesh is facing a chronic shortage of food over the year. It is estimated that, about 220 hectares of agricultural lands are decreased per year due to urbanization, industrialization, housing and road construction purposes. Fifty lac acres of agricultural land decreased during last 20 years (Anon, 2007). Besides this, to meet increasing protein demand of people, some rice growing area is now being used as ponds for raising fishes. Now it is essential to find out sustainable technology for alleviating poverty and ensuring food security for increasing population. So, the researchers have to think how to solve the food problem of the country. Agriculture sector has a significant contribution to Bangladesh economy since it comprises about 15.33% of the country's Gross Domestic Product (GDP) (Bangladesh Economic Review, 2016). Despite such a steady growth in agriculture as well as in food production, Bangladesh has been facing persistent challenges in achieving food security. This is mainly due to natural disasters and fluctuations in food prices from the influence of volatile international market for basic food items (Rahman, 2011). Besides that lack of inputs and socio-economic factor also important. That is why continuous efforts are being taken towards the development of new rice cultivars and their management practices in order to increasing the yield per unit area and meet other requirements. Therefore, we have to think in other ways such as (i) by applying biotechnology, which is also difficult in the present condition in Bangladesh and (ii) by improving plant growth through the application of plant growth regulators like chitosan.

Chitosan is a naturally occurring polymer that became available in the 1980s in industrial quantities enabling it to be tested as an agricultural chemical. This biopolymer stimulates growth and increases yield of plants as well as induces the immune system of plants (Boonlertnirun *et al.*, 2008). Significantly greater number of branches/plant is observed in case of chitosan treated plant than untreated control (Reddy *et al.*, 2000). 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). Chitin/chitosan are well known natural bio-control active ingredients that are found in the shells of crustaceans, such as lobsters, crabs and shrimps and many other organisms, including insects and fungi. It is one of the most abundant biodegradable materials in the world. Degraded molecules of chitin/chitosan exist in soil and water. Chitosan has a wide scope of application on various plants. With high affinity and non-toxicity, it has no harmful effects on human beings and livestock. Chitosan induces the excretion of resistant enzymes and thus it regulates the immune system of plants. 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 assists 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). Chitosan is able to inactivate the replication of viruses and viroids thus limiting their spread (Kulikov *et al.*, 2006). Modified chitosan, the acetylated form of chitosan powder, is the raw material prepared from the shell byproducts of crustaceans such as shrimp, crabs, lobster, cell wall of fungi etc. 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). The residual chitosan can contribute to increase N content of rice soil as well as to increase long term productivity and enhancement of ecological sustainability (Gill and Meelu, 1982). 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).

Therefore, the present study was designed investigate the residual effect of modified chitosan powder on nitrogen management and yield performance of BRRI dhan28 and BRRI dhan29.

The objectives of the study are as follows:

i) To examine growth and yield performance of BRRI dhan28 and BRRI dhan29 as influenced the by the residual effect of modified chitosan powder.

ii) To examine supplementation of the organic N in rice as influenced by the residual value of modified chitosan powder.

CHAPTER II

REVIEW OF LITERATURE

Chitosan is a natural, safe and cheap biopolymer product of chitin deacetylation, widely used because of its interesting features. Chitosan stimulates growth and increases yield of plants as well as induces the immune system of plants. Chitosan has a wide scope of application. 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. Extensive studies of the regulatory effects of chitosan on various crops have been carried out worldwide by different workers and scientists. Some or the related reports are reviewed below.

2.1 Effect of chitosan application on morphological and growth characters

2.1.1. Plant height

Sultana *et al.* (2015) conducted 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. This experiment showed that plant height does not play any statistically significant differences between control and 40 ppm oligo-chitosan sprayed plants. But incase of 80 and 100 ppm oligo-chitosan sprayed rice plants show significant differences with compared to control.

When rice seedlings were treated with oligomeric chitosan with 80% degree of deacetylation at the concentration level of 40 mg/L by seed soaking overnight before sowing, followed by spraying on 2-week and 4-week old seedlings the oligomeric chitosan stimulated plant height, respectively (Supachitra *et al.*, 2011).

Nguyen *et al.* (2011) found that application of oligochitosan increased mineral nutrient uptake of coffee and stimulated the growth of coffee seedlings. Oligo-chitosan with concentration of 60 mg/L was sprayed and the height of the coffee seedlings was increased up to 33.51%.

Guan *et al.* (2009) showed that chitosan under the stress of low temperature enhanced shoot height and root length in maize plants compared to that of the control.

Boonlertnirun *et al.* (2008) observed that chitosan application on rice plants did not influence and stimulate the plant height significantly. Sultana (2007) applied Miyodo on rice and reported that plant height increased in Miyodo application plant than from the control.

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

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

Ouyang and Xu (2003) carried out an experiment with Chinese cabbage (*Brassica campestris*) cv. Dwarf hybrid No.1 and observed that when seed dressed with chitosan at the rate of 0.4-0.6 mg/g seed and leaf sprayed 20-40 micro g/L plant height and leaf area of Chinese cabbage was increased.

Khan *et al.* (2002) was observed that foliar application of oligomeric chitosan did not affect plant height of soybean. Applications with different molecular weights of chitosan did not affect plant height. It was also found that plant height was not significantly different under various methods of application.

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

The growth of nursery-raised seedlings such as cucumber, pepper and tomato among others also increased by the application of chitosan. The root and shoot length, and grain yield was increase by the application of chitosan formulations (Vasudevan *et al.,* 2002).

Chibu and Shibayama (2001) found a positive and stimulating effect of chitosan on the growth of roots, shoots and leaves of several crop plants.

2.1.2. Total number of tillers/hill

Boonlertnirun *et al.* (2008) carried out an experiment and observed that with treatment of seed soaking in chitosan solution before planting maximum tiller number was obtained and then applying in soil but did not significantly differ from the control with no application of chitosan.

Limpanavech *et al.* (2008) carried out an experiment to observed that the effects on Dendrobium 'Eiskul' floral production with six types of chitosan molecules, P-70, O-70, P-80, O-80, P-90, and O-90. Compared to the non-chitosan treated controls, chitosan O-80 induce early flowering at all concentrations tested, 1, 10, 50, and 100 mg/L and during the 68 weeks of the experimental periodic time it increase the accumulative inflorescence number .

Boonlertnirun *et al.* (2006) reported that the application of polymeric chitosan by seed soaking before planting followed by four foliar sprayings of chitosan doses throughout cropping season significantly increased the number of tillers per plant.

Hoque (2002) conducted an experiment on germination of seed and growth of seedling by seed soaking of different wheat cultivars with 0.16 ml/L, 0.33 ml/L and 0.66 ml/L of CI-IAA, GABA and TNZ-303. Compared to the control number of tiller significantly increased at 0.33 ml/L of PGR.

2.2 Effect of chitosan application on yield contributing characters

2.2.1 Effective tillers/hill and length of panicle

Sultana *et al.* (2015) conducted 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 per plant, the number of panicle length of rice show significant differences incase of foliar sprayed chitosan plants and control plants.

Islam (2007) used Miyobi on rice at the rate of 1.0, 2.0, 3.0 and 4.0 mg/L and observed that with increasing hormone concentration panicle length also increased and the highest panicle length was observed in 4.0 mg/L Miyobi application. Sultana (2007) also found same result in rice.

Lu *et al.* (2002) showed 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).

Hoque (2002) carried out a field experiment and showed that the tallest spike (9.00 cm) produced when the wheat cv. Treated with GABA (0.33 ml/L) followed by TNZ303 (8.10 cm) and CL-IAA (7.95 cm) gradually. In GABA treated plant spike length was significantly higher than from the other treatments.

The branch and the node numbers per plant in soybean crop increased with soil application of chitosan (Harada *et al.*,(1995) .

2.2.2 Number of total, filled and unfilled grains/panicle

Sultana *et al.* (2015) conducted 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 total grains per panicle of rice show significant differences in case of foliar sprayed chitosan plants and control plants.

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. From this it was observed that FCW @ 1% the filled grains per panicle significantly differ from 0.5% FCW, 0.25% FCW and the rest of the treatment.

Boonlertnirun *et al.* (2008) carried out an experiment with 4 treatments. The treatments were T_1- control (no chitosan application), T_2- seed soaking with chitosan solution, T_3 - seed soaking and soil application with chitosan solution and T_4 - seed soaking and foliar spraying with chitosan solution. Before planting chitosan application by seed soaking in chitosan solution and then applying in soil tended to produce more filled grains per panicle than the other methods but it was not significantly different from the other treatments and the control.

Boonlertnirun *et al.* (2006) carried out a pot experiment in a greenhouse and observed that polymeric chitosan application by seed soaking before planting followed by four foliar sprayings of chitosan doses throughout cropping season did not affect filled grains per panicle. Polymeric chitosan application show significant resulted in less number of unfilled grains than those of the others. Polymeric chitosan application by seed soaking and four foliar sprayings throughout cropping season reduced unfilled grains of rice.

Boonlertnirun *et al.* (2005) reported that number of seed per panicle of rice plant cv. Suphan Buri-1 were not affected by various chitosan concentrations.

Utsunomiya *et al.* (1998) stuided that when soil treated with oligomeric chitosan under high nitrogen conditions the number of flowers and the harvesting fruits of purple passion fruit increased.

2.2.3 Thousand grain weight

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 revealed that 1000 grain weight (gm) significantly increases FCW @ 0.50% from the rest of the treatment.

Sultana *et al.* (2015) conducted 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. It results revealed that 1000 grain weight (gm) show significant differences between foliar sprayed chitosan plants and control plants.

Ghoname *et al.* (2010) conducted an experimental in the two successive seasons of 2008 and 2009 to investigate and compare the enhancing effects of three different biostimulation compounds on growth and production of sweet pepper plants. Plants were sprayed with any of the individual chitosan (2, 4 and 6 cm/L) after three weeks of transplanting. Data showed that individual fruit weight and number of fruits were also improved.

Boonlertnirun *et al.* (2008) carried out an experiment with 4 treatments. The treatments were T_1- control (no chitosan application), T_2- seed soaking with chitosan solution, T_3 - seed soaking and soil application with chitosan solution and T_4 - seed soaking and foliar spraying with chitosan solution. The results revealed that chitosan application methods did not affect 1,000- grain weight (gm).

Islam (2007) showed that with spraying Myobi on the rice plants @2, 3 and 4 mg/L and GABA at 2, 3 and 4 mg/L as foliar application. The results show highest 1000-seed weight for 2 mg/L GABA followed by 2 mg/L Myobi.

Boonlertnirun *et al.* (2007) conducted a greenhouse experiments to determine the effect of chitosan on drought recovery and grain yield of rice under drought conditions. It observed that before drought treatment the chitosan application gave the highest 1000-grain weight and also showed good recovery on yield.

Boonlertnirun *et al.* (2006) carried out a pot experiment in a greenhouse with chitosan as polymeric chitosan, oligomeric chitosan and monomeric chitosan and application method of chitosan as seed soaking; seed soaking + foliar spraying and foliar spray. The results revealed that the application of chitosan with different molecular weights and different application methods did not affect thousand grain weights.

Krivtsov *et al.* (1996) showed that spike weight and thousand grain weight of wheat plants enhanced with the treatment of low concentrations of polymeric chitosan than the other treatment.

2.2.4 Straw yield

Sultana *et al.* (2015) conducted 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. Finally it is observed that straw yield show significant differences between control plants and foliar sprayed chitosan plants and highest straw yield was observed under 100 ppm oligomeric chitosan and lowest straw yield was observed under 0 ppm oligomeric chitosan.

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 revealed that FCW @ 1% the straw yield differ significantly from 0.5% FCW, 0.25% FCW and the rest of the treatment.

2.2.4 Grain yield

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 revealed that FCW @ 1% the grain yield differ significantly from 0.5% FCW, 0.25% FCW and the rest of the treatment.

Sultana *et al.* (2015) conducted 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. Results found that grain yield show significant differences incase of foliar sprayed chitosan plants and control plants.

Sultana (2010) from BAEC, Bangladesh reported that on growth and productivity of Maize (*Zea mays.* L) plants the oligochitosan was applied for its potential use as plant growth promoter. The application of oligochitosan (molecular weight 7,000 Da) as foliar spraying with the concentration of 25, 50 and 75 mg/L. The results revealed that the application of oligochitosan plays a significant role at the concentration of 75 mg/ L in terms of weight of cob and weight of seeds per Maize and ultimately maize yield

Abdel-Mawgoud *et al.* (2010) showed developmental effects on strawberry production or yield as a result of chitosan application on strawberry plant.

Boonlertnirun *et al.* (2008) carried out an experiment with 4 treatments. The treatments were T_1- control (no chitosan application), T_2- seed soaking with chitosan solution, T_3 - seed soaking and soil application with chitosan solution and T_4 - seed soaking and foliar spraying with chitosan solution. The results revealed that chitosan application by seed soaking and then soil significantly increased yield over the other treatments of rice plants.

Boonlertnirun *et al.* (2007) conducted a greenhouse experiments for determining the effect of chitosan on drought recovery and grain yield of rice under drought conditions. Results showed that the before drought treatment application of chitosan gave the highest yield and yield contributing character and also showed good recovery of rice plants.

Boonlertnirun *et al.* (2006) showed that application of polymeric chitosan at the concentration of 20 ppm rice yield of cultivar SuphanBuri 1 was significantly increased over the control (no chitosan) conditions.

Hong *et al.* (1998) showed that chitin or derivatives chitosan level improves the durability and resistance of the plant, makes it not easily infected by germs, not proliferate even infected, and cures the disease by itself. Application of chitosan in agriculture reduce the use of chemical fertilizer, increases the production of different kinds of plant, by 15-20% .

Krivtsov *et al.* (1996) observed that wheat plants increased grain yield when it was treated with polymeric or oligomeric chitosan. In contrast, the work of Kuznia *et al.* (1993) found that of white lupine seeds did not consistently increase yields when treated with chitosan doses.

2.3 Effect of Chitosan application on chemical properties (pH, organic carbon and organic matter) of soil

Fermented chitin waste (FCW), a by-product obtained from chitinase production using chitin fermentation. 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 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.

FCW application increased organic carbon level in the soil. The organic carbon level differs significantly among the treatments. The results obtained that @ 1% FCW the organic carbon differ significantly from 0.5% FCW, 0.25% FCW and the rest of the treatment.

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. (Khaleel *et al.*, 1981, Metzger and Yaron, 1987, Matsumoto *et al.*, 1999, Farooq and Nawaz, 2014). The organic matter differs significantly among the treatments. 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.

CHAPTER III

MATERIALS AND METHODS

The experiments were carried out during the period from November 2015 to May 2016 at the field of Sher-e-Bangla Agricultural University, Dhaka-1207. 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

3.1.1 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.

3.1.2 Agro-ecological region

The soil of the experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anon., 1988a). 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.

3.1.3 Climate

The climate was subtropical with low temperature and minimum rainfall during November to May that was the main feature of the *rabi* season. The annual precipitation of the site was around 2200 mm and potential evapo-transpiration was 1300 mm. The average maximum temperature was 30.34^0C and average minimum temperature was 21.21^0C. The average mean temperature was 25.17^0C. The experiment was done during the *rab*i season. Temperature during the cropping period ranged between 12.20^0C to 34.5^0C. The humidity varies from 62% to 82% and scattered rainfall during the rest of the year. The monthly total rainfall, average temperature during the study period of the experimental site is shown in Appendix II.

3.1.4 Soil

The general soil type of the experimental field was Shallow Red Brown Terrace soils under Tejgaon Series. Topsoil was clay loam in texture and olive-gray with common fine to medium distinct dark yellowish brown mottles. Before the previous experiment, the initial soil pH was 6.2 and had organic carbon 0.60% and organic matter content was found 1.03%. The experimental site was flat having available irrigation and well drainage system and above flood level. Sufficient sunshine was available during the experimental period. Soil samples were collected 0-15 cm depths from experimental field. The chemical analyses of soil were done in the laboratory of the Department of Soil Science of Sher-e-Bangla Agricultural University, Dhaka-1207. The physicochemical properties of the soil are presented below.

Table 1: Morphological characteristics of the soil of experimental field

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

Table 2: Physical and chemical properties of the initial soil of previous experiment

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
Textural class	Silty-clay
pH	6.2
Organic carbon (%)	0.60
Organic matter (%)	1.03
Total N (%)	0.03
Available P (ppm)	21.00
Exchangeable K (me/100 g soil)	0.12
Available S (ppm)	48

3.2 Experiment details

3.2.1 Crop/Planting material

The experiments were conducted with BRRI dhan28 and BRRI dhan29 individually as test crops. BRRI dhan28 and BRRI dhan29 were developed by Bangladesh Rice Research Institute (BRRI), Joydebpur, Gajipur, Bangladesh for Boro season. . The pedigree line of BRRI dhan28 is Hybridization/ BR 601-3-3-4-2-5. Average height of the plant is 90 cm. The grains are medium, slender and white in color. BRRI dhan28 is moderately resistance to blast. The growth duration of BRRI dhan28 is about 140 day. The pedigree line of BRRI dhan29 is BR 802-118-4-2. Average height of the plant is 95 cm. The grains are medium, slender and white in color. BRRI dhan29 is moderately resistance to leaf blight, sheath blight. The growth duration of BRRI dhan29 is about 160 day

3.2.2 Experimental Treatments

The single factor experiment was compared with five treatments of chitosan.

T_1 = Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N,

T_2 = Modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N,

T_3 = Modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N,

T_4 = Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N and

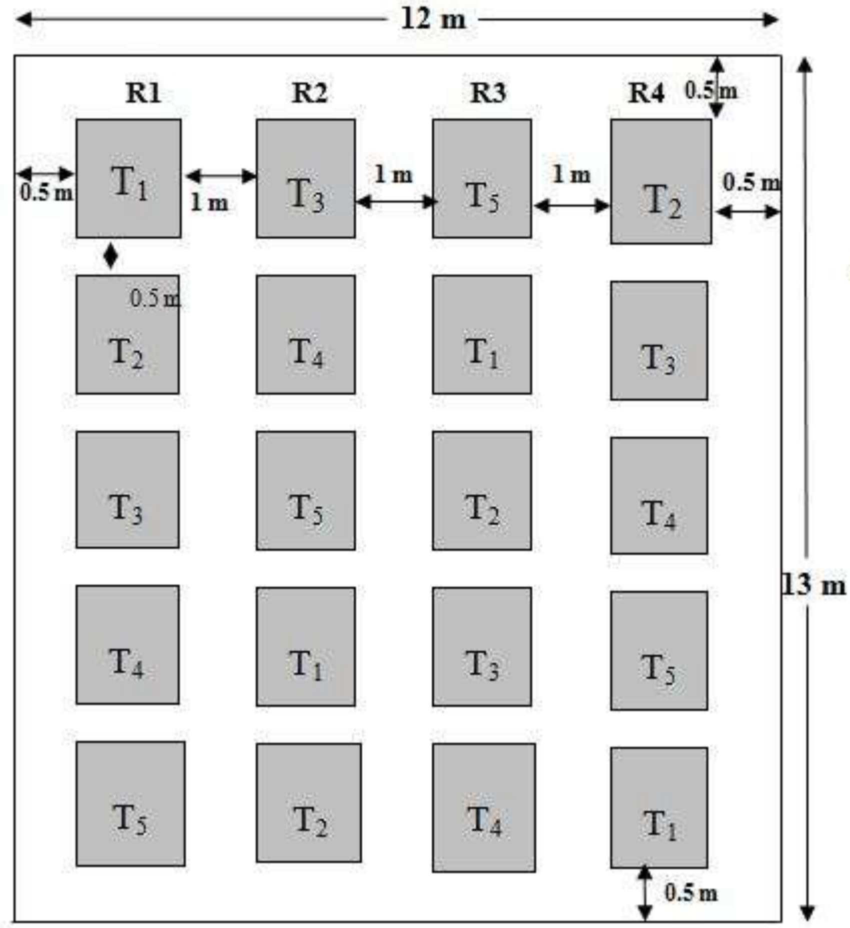
T_5 = Modified CHT powder @ 0 t/ha + Recommended N (control).

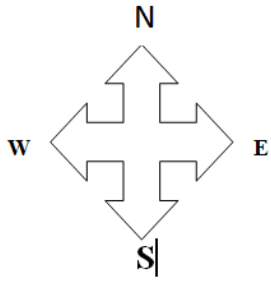
*1/3rd of the total N was reduced during the split applications

All other fertilizers were applied in every treatment @ Recommended dose.

3.2.3 Experimental design

The experiments were done with Randomized Complete Block Design (factorial). Each treatment in the experiment was replicated four times. The total number of unit plots was 40. The size of the unit plot was 2 m × 2 m. 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, respectively. 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 1 and Figure 2.





Distance between replications: 1m

Distance between treatments: 0.5m

Plot size: 2m×2m = 4m^2

Total length of the field: (5×2m) + (6×0.5m) = 13m

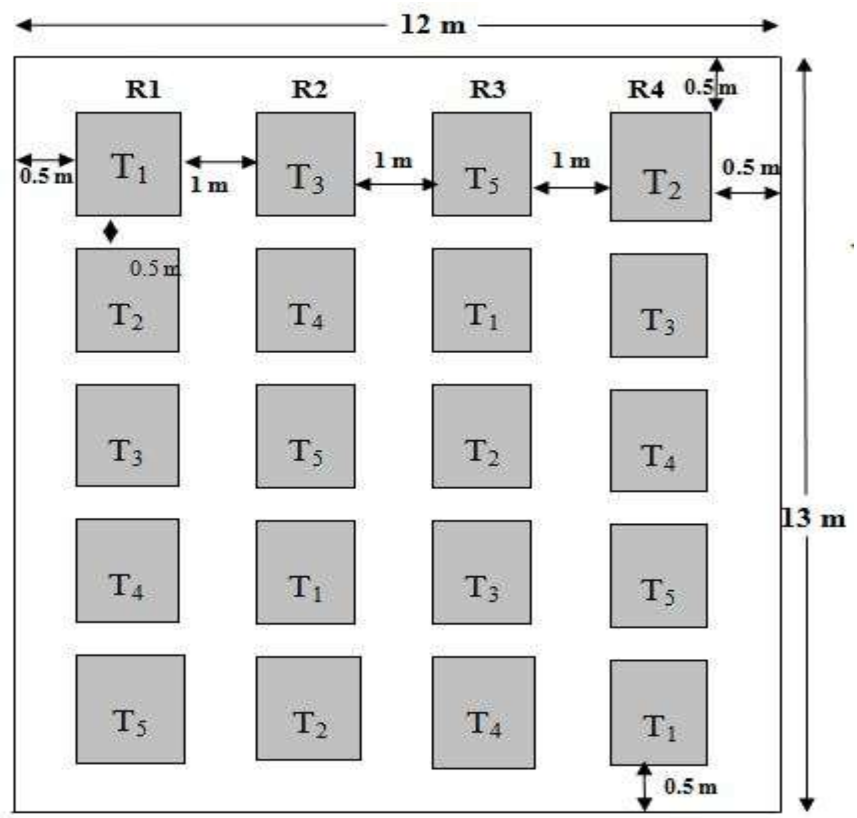
Total width of the field: (4×2m)+(0.5m+1m+1m+1m +0.5m)= 12m

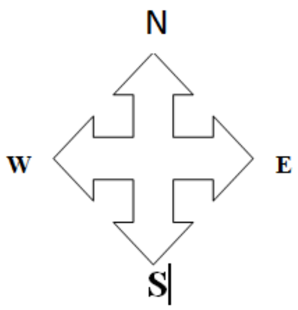
Total area of the field: L×B = 13m × 12m = 156m^2

Replications:	Treatment Combinations:
R_1: Replication 1	T_1 = Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N,
R_2: Replication 2	T_2 = Modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N,
R_3: Replication 3	T_3 = Modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N,
R_4: Replication 4	T_4 = Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N) and
	T_5 = Modified CHT powder @ 0 t/ha + Recommended N (control).

All other fertilizers were applied in each treatment @ Recommended dose.

Figure 1: The layout of the experimental field using BRRI dhan29





Distance between replications: 1m

Distance between treatments: 0.5m

Plot size: 2m×2m = 4m^2

Total length of the field: (5×2m) + (6×0.5m) = 13m

Total width of the field: (4×2m)+(0.5m+1m+1m+1m +0.5m= 12m

Total area of the field: L×B = 13m × 12m = 156m^2

Replications:	Treatment Combinations:
R_1: Replication 1	T_1 = Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N,
R_2: Replication 2	T_2 = Modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N,
R_3: Replication 3	T_3 = Modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N,
R_4: Replication 4	T_4 = Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N) and
	T_5 = Modified CHT powder @ 0 t/ha + Recommended N (control).

*All other fertilizers were applied in each treatment @ Recommended dose.

Figure 2: The layout of the experimental field using BRRI dhan28

3.3 Growing of crops

3.3.1 Seed collection and sprouting

BRRI dhan28 and BRRI dhan29 Seeds were collected from BRRI, Joydebpur, Gazipur, Bangladesh. Healthy seeds were selected by following standard method. Then seeds were immersed in water bucket for 24 hrs. These immersed seeds were taken out from water bucket and tightly kept in gunny bags. The seeds started sprouting after 48 hrs which became suitable for sowing in 72 hrs.

3.3.2 Raising of seedlings

The nursery bed was prepared by puddling with repeated ploughing followed by laddering. Gently irrigation was provided and weeds were removed from the bed as and when required and no fertilizer was used in the nursery bed.

3.3.3 Seed sowing

The seeds were sown on the nursery bed on December 10, 2016 for raising nursery seedlings.

3.3.4 Preparation of experimental land

The soil of the experimental land was first opened on January 9, 2016 with the help of a tractor drawn disc plough; later on January 12, 2016 the land was irrigated and prepared by three successive ploughing and cross ploughing. Each ploughing was followed by laddering to have a good puddled field. After ploughing and laddering, all kinds of uprooted weeds and previous crop residues were removed from the field. After the final land preparation the field layout was made on January 14, 2016 according to experimental plan. Individual plots were cleaned and finally leveled so that no water pocket could remain in the puddle field.

3.3.5 Fertilizer dose and methods of application

The experiment unit plots of were fertilized with urea, triple super phosphate (TSP), muriate of potash (MOP), gypsum and zinc sulphate @ 150, 58, 58, 38 and 10 kg/ha respectively. The entire amounts of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied as basal dose at the time of transplanting of seedlings. No Urea was applied during land preparation. After seedling recovery, two third of urea was splited into two equal parts. At first, half of the two third urea was applied to the soil during vegetative stage and half at 7 days before panicle initiation.

3.3.6 Transplanting of seedlings

The nursery bed was made wet by application of water in one day before uprooting of the seedlings. For transplantation 35 days old seedlings were uprooted carefully from the nursery beds on 16 January, 2016 without causing much mechanical injury to the roots.

3.3.7 Intercultural operations

After transplanting the seedling, different intercultural operations were accomplished for better growth and development, which are as follows.

3.3.7.1 Gap filling

After one week of transplantation, a minor gap filling was done where it was necessary using the seedling from the same source.

3.3.7.2 Weeding

During the early stage of growth establishment the crop was infested with some weeds. Two hand weeding were done for each treatment; first weeding at 20 days after transplanting followed by second weeding at 15 days after first weeding.

3.3.7.3 Application of irrigation water

Irrigation water was added to each plot as and when required. All the plots were kept irrigated maintaining 3-5 cm stagnant water throughout the entire period up to 15 days before harvesting.

3.3.7.4 Plant protection measures

Plants were infested with rice leaf roller (*Cnaphalocrocis medinalis*) and rice bug (*Leptocorisa acuta*) to some extent which were successfully controlled by applying Malathion (57 EC) @ 10 ml/10 liter of water for 5 decimal lands as and when needed. Crop was protected from birds during the grain filling stage. For controlling the birds watching was done properly, especially during morning and afternoon.

3. 4 General observation of the experimental field

Observations were regularly made to detect visual difference among the treatment and any kind of infestation by weeds, insects and diseases so that considerable losses by pest could be minimized. The field looked nice with normal green color plants. Incidence of stem borer, green leaf hopper, leaf roller and rice hispa was observed during tillering stage that controlled properly. No bacterial and fungal diseases were observed in the field.

3.5 Harvesting and post harvest operation

When 90% of the grains became golden yellow in color maturity of crop was determined. BRRI dhan28 was harvested on April 28, 2016 and BRRI dhan29 was harvested on May 03, 2016. Five hills per plot were preselected randomly from which different growth and yield attributes data were collected and $1m^2$ areas from middle portion. Each plot was harvested separately, bundled, properly tagged and then brought to the threshing floor for recording grain and straw yield. Threshing was done by using pedal thresher. The grains were cleaned and sun dried at moisture content of 12 % approximately. Straw was also sun dried properly. Finally grain and straw yields per plot were recorded and converted to ton per ha.

3.6 Recording of data

The followings data were recorded during the experiment.

A. Crop growth characters

i. Plant height (cm) at harvest

ii. Number of tillers/hill

B. Yield and yield components

i. Number of effective tillers/hill

ii. Number of ineffective tillers/hill

iii. Length of panicle (cm)

iv. Number of filled grains/panicle

v. Number of unfilled grains/panicle

vi. Number of total grains/panicle

vii. Weight of 1000 grains (g)

viii. Grain yield (t/ha)

ix. Straw yield (t/ha)

x. Harvest index (%)

3.7 Detailed procedures of recording data

A. Crop growth characters

i. Plant height (cm) at harvest

The height of plant was recorded in centimeter (cm) and measured from the ground level to the top of the tallest panicle. Plants of 5 hills were measured and averaged for each plot.

ii. Number of tillers/hill

The number of tillers/hill were counted at harvest from ten randomly pre-selected hills and averaged as their number/hill. Only those tillers having three or more leaves were considered for counting.

B. Yield and other crop characters

i. Effective tillers/hill (no.)

The total number of effective tillers/hill was counted as the number of panicle which had at least one grain. The number of effective tillers/hill was recorded and finally averaged for counting effective tillers number /hill.

ii. Ineffective tillers/hill (no.)

The total number of ineffective tillers/hill was counted as the tillers which have no panicle on the head. The number of Ineffective tillers/hill was recorded and finally averaged for counting ineffective tillers number/m^2.

iii. Panicle length (cm)

The length of panicle was measured from basal node of the rachis to apex of each panicle. Each observation was an average of 5 panicles.

iv. Filled grains/panicle (no.)

If any kernel was present in grain, the grain was considered to be filled. The total number of filled grains were recorded on five panicles and finally averaged.

vi. Unfilled grains/panicle (no.)

Unfilled grains means the absence of any kernel inside and such grains present on each of five panicles were counted and finally averaged.

vii. Total grains/panicle (no.)

Total number of grains/panicle was calculated by summation of filled and unfilled grains/panicle.

viii. Weight of 1000 grains (g)

One thousand cleaned and dried grains were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained about 12% moisture and the mean weight were expressed in gram.

ix. Grain yield (t/ha)

Grain yield determined from the central $1m^2$ areas of each plot were sun dried, cleaned, weighed carefully and adjusted at 12% moisture level. Weight of grains of each plot was converted into t/ha. Grain moisture content was measured by using a digital moisture tester.

x. Straw yield (t/ha)

Straw yield was determined from the central $1m^2$ areas of each plot. After separating of grains, the sub-samples were oven dried to a constant weight and finally converted to t/ha.

xi. Biological yield (t/ha)

Grain yield together with straw yield was regarded as biological yield and calculated with the following formula:

Biological yield (t/ha) = Grain yield (t/ha) + Straw yield (t/ha)

xii. Harvest Index (%)

Harvest index denotes the ratio of economic yield to biological yield and was calculated with following formula.

$$\text{Harvest index (\%)} = \frac{\text{Economic Yield (Grain weight)}}{\text{Biological Yield (Total weight}} \times 100$$

3.8 Chemical analysis of soil samples

Soil samples were analyzed for both physical and chemical properties in the laboratory of Department of Soil Science of Sher-e-Bangla Agricultural University, Dhaka-1207.The properties studied included texture, pH, organic matter etc. The physical and chemical properties of initial soil have been presented in Table 1 and 2. The soil was analyzed following standard methods:

Particle-size analysis of soil was done by Hydrometer method (Bouyoucos, 1926) and the textural class was determined by plotting the values for % sand, % silt and % clay to the "Marshall's Textural triangular coordinate" following the USDA system.

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

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. To obtain the organic matter content, the amount of organic carbon was multiplied by the Van Bemmelen factor, 1.73. The result was expressed in percentage.

3.9 Statistical Analysis

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

CHAPTER IV

RESULT AND DISCUSSION

This chapter comprises of the presentation and discussion of the results obtained due to residual effect of modified chitosan powder on nitrogen management and yield performance of Boro rice (cv. BRRI Dhan29 and BRRI dhan28) and chemical properties of the soils. The results of the present investigation have been presented, discussed and compared as far as available with the results of the researchers.

4.1 BRRI dhan29

4.1.1 Plant height (cm)

Plant height was found to be statistically insignificant in all of the treatments used in the experiment. The maximum plant height (96.4 cm) was obtained in the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment and minimum plant height (91.33 cm) was obtained in the T_3 {modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment (Table 1). According to the plant height the treatments may be arranged as $T_1>T_5>T_4>T_2>T_3$. These results were supported by Boonlertnirun *et al.* (2008) who found that application of chitosan did not influence and/or stimulate the rice plant height significantly.

Table 1. Residual effect of different doses of modified chitosan powder on yield contributing characters of Boro rice (BRRI dhan29) at harvest, SAU, 2016.

Treatment (dose)	Plant height (cm)	Panicle length (cm)	Total tillers/hill	Ineffective tillers/hill
T_1	96.4	25.91	16.87b	1.07
T_2	92.36	24.10	17.27ab	0.81
T_3	91.33	26.16	17.31ab	0.72
T_4	93.96	25.93	17.66a	0.43
T_5	95.16	26.03	17.74a	0.38
CV (%)	5.61	10.75	0.08	24.72
Level of significance	NS	NS	**	NS

T_1 = Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N,
T_2 = Modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N,
T_3 = Modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N,
T_4 = Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N and
T_5 = Modified CHT powder @ 0 t/ha + Recommended N (control).

All other fertilizers were applied in each treatment @ Recommended dose.

4.1.2 Panicle length (cm)

Panicle length was found to be statistically insignificant in all of the treatments used in the experiment (Table 1). Panicle length was not influenced significantly although there was some apparent difference in panicle length in different treatments. The maximum panicle length (26.16 cm) was obtained in the T_3 {modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment and minimum panicle length (24.1 cm) was obtained in the T_2 {modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment (Table 2). According to the panicle length the treatments may be arranged as $T_3>T_5>T_4>T_1>T_2$.

4. 1.3 Total tillers/hill

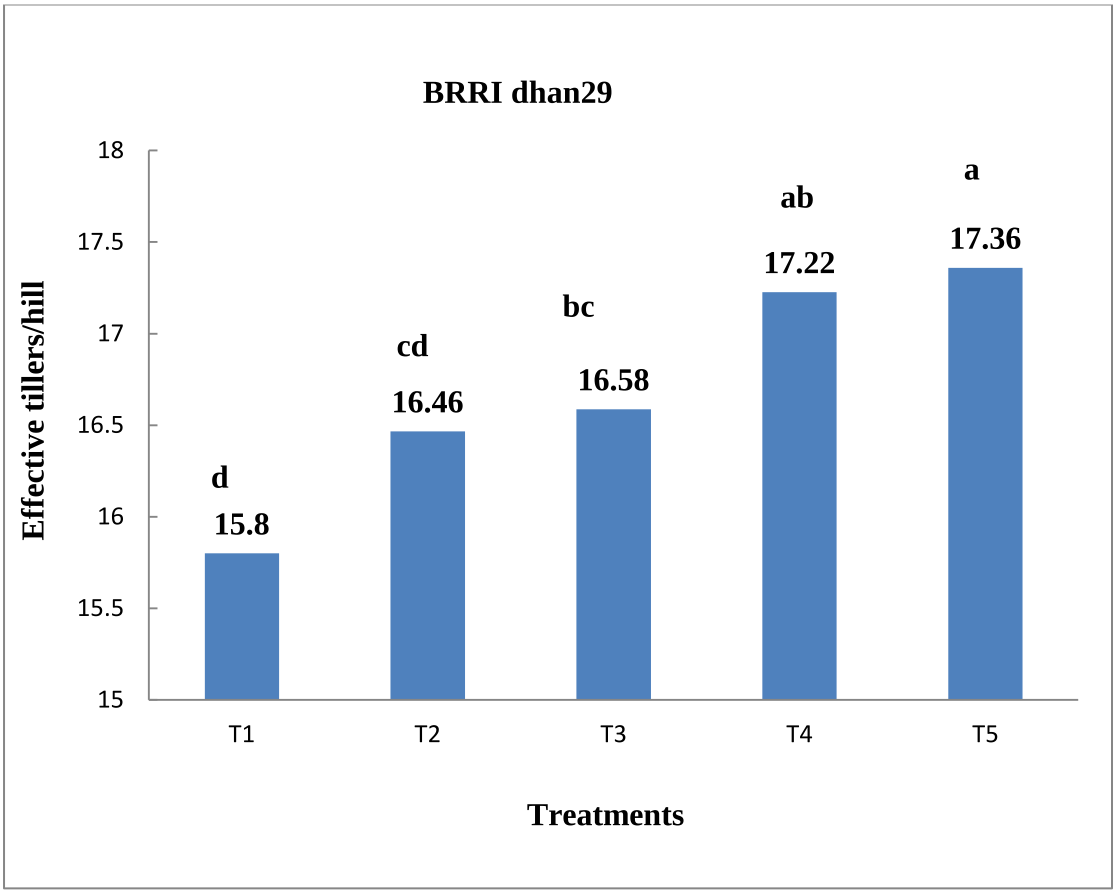
The effect of different treatments on total tillers/hill was statistically significant (Table 1). The maximum number of total tillers/hill (17.74) was obtained in the T_5 {modified CHT powder @ 0 t/ha + Recommended N} (control) treatment which was statistically identical with the treatments obtained in the T_2 {modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N} and T_3 {modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment and T_4 {modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. The minimum number of total tillers/hill (16.87) was obtained in the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. In producing total number of tillers/hill the treatments may be arranged as $T_5>T_4>T_3>T_2>T_1$.

4. 1. 4 Ineffective tillers/hill

The Ineffective tillers/hill varied insignificantly due to the effects of different treatments (Table 1). The highest Ineffective tillers/hill was produced (1.07) by the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment and the lowest ineffective tillers/hill was produced (0.38) by the T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment. In producing non effective number of tillers/hill the treatments may be arranged as $T_1>T_2>T_3>T_4>T_5$.

4.1.5 Effective tillers/hill

Figure 1 shows the effects of different treatments on effective tillers/hill. It was found that effective tillers/hill statistically significant amongst the treatments compared to T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} control treatments. The highest number of effective tillers/hill (17.36) was obtained in the T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment which was statistically identical to the T_4 {modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. The effective tillers/hill significantly decreases in the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} and T_2 treatment {modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N} and T_3 {modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment due to lack of Nitrogen. The lowest number of effective tillers/hill (15.12) was obtained in the T_1 {modified CHT powder @ 0.5 t/ha applied in the previous expt.) + 2/3rd of N} treatment. In producing effective number of tillers/hill the treatments may be arranged as $T_5>T_4>T_3>T_2>T_1$. It was observed that, as the rate of residual modified chitosan application in soil increases the effective tillers/hill also increases. These results were supported by Sultana *et al.* (2015) who conducted a field experiment with Four different concentrations that is 0, 40, 80 and 100 ppm oligomeric chitosan and four times foliar spray after germination were carried out. Finally it was observed that number of effective tillers per plant of rice show significant differences between control plants and foliar sprayed chitosan plants.



T_1 = Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N,

T_2 = Modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N,

T_3 = Modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N,

T_4 = Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N and

T_5 = Modified CHT powder @ 0 t/ha + Recommended N (control).

All other fertilizers were applied in each treatment @ Recommended dose.

Figure 1. Residual effect of different doses of modified chitosan powder on effective tillers/hill of Boro rice (BRRI dhan29). Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT, SAU, 2016.

4.1.6 Number of total grains/panicle

The results (Table 2) indicated that the effects of different treatments on total grains/panicle were found to be statistically insignificant in all of the treatments used in the experiment. Total grains/panicle was not influenced significantly although there was some apparent difference in total grains/panicle in different treatments. The maximum total grains/panicle (121.85) was obtained in the T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment and minimum total grains/panicle (104.90) was obtained in the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. According to the total grains/panicle the treatments may be arranged as $T_5>T_4>T_3>T_2>T_1$. These results were supported by Boonlertnirun *et al.* (2005) indicated that seed numbers per panicle of rice plant cv. Suphan Buri-1 were not affected by various chitosan concentrations.

4.1.7 Number of filled grains/panicle

Table 2 reveals that the effects of different treatments on filled grains/panicle were found to be statistically insignificant in all of the treatments. Filled grains/panicle was not influenced significantly although there was some apparent difference in filled grains/panicle in different treatments. The highest number of filled grains/panicle (115.88) was obtained in the T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment and lowest number of filled grains/panicle (98.09) was obtained in the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. According to the filled grains/panicle the treatments may be arranged as $T_5>T_4>T_3>T_2>T_1$. These results were supported by Boonlertnirun *et al.* (2008) who conducted an experiment with 4 treatments of chitosan and found that application of chitosan by seed soaking in chitosan solution before planting and then applying in soil tended to produce more filled grains/panicle than the other methods but it was not significantly different from the other treatments and the control.

4.1.8 Number of unfilled grains/panicle

Table 2 results showed that the effects of different treatments on unfilled grains/panicle were found to be statistically insignificant in all of the treatments. Unfilled grains/panicle was not influenced significantly although there was some apparent difference in unfilled grains/panicle in different treatments. The highest number of unfilled grains/panicle (6.80) was obtained in the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment and lowest number of unfilled grains/panicle (5.97) was obtained in the T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment. According to the unfilled grains/panicle the treatments may be arranged as $T_1 > T_2 > T_3 > T_4 > T_5$.

Table 2. Residual effect of different doses of modified chitosan powder on other some yield contributing characters of Boro rice (BRRI dhan29) at harvest, SAU, 2016.

Treatment (dose)	Total grains panicle^{-1}	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000-grain weight
T_1	104.90	98.09	6.80	22.26
T_2	108.13	101.73	6.40	23.33
T_3	110.24	104.11	6.12	24.73
T_4	119.42	113.37	6.04	25.73
T_5	121.85	115.88	5.97	25.86
CV (%)	12.69	13.17	11.83	5.67
Level of significance	NS	NS	NS	NS

T_1 = Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N

T_2 = Modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N

T_3 = Modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N

T_4 = Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N and

T_5 = Modified CHT powder @ 0 t/ha + Recommended N (control)

All other fertilizers were applied in each treatment @ Recommended dose.

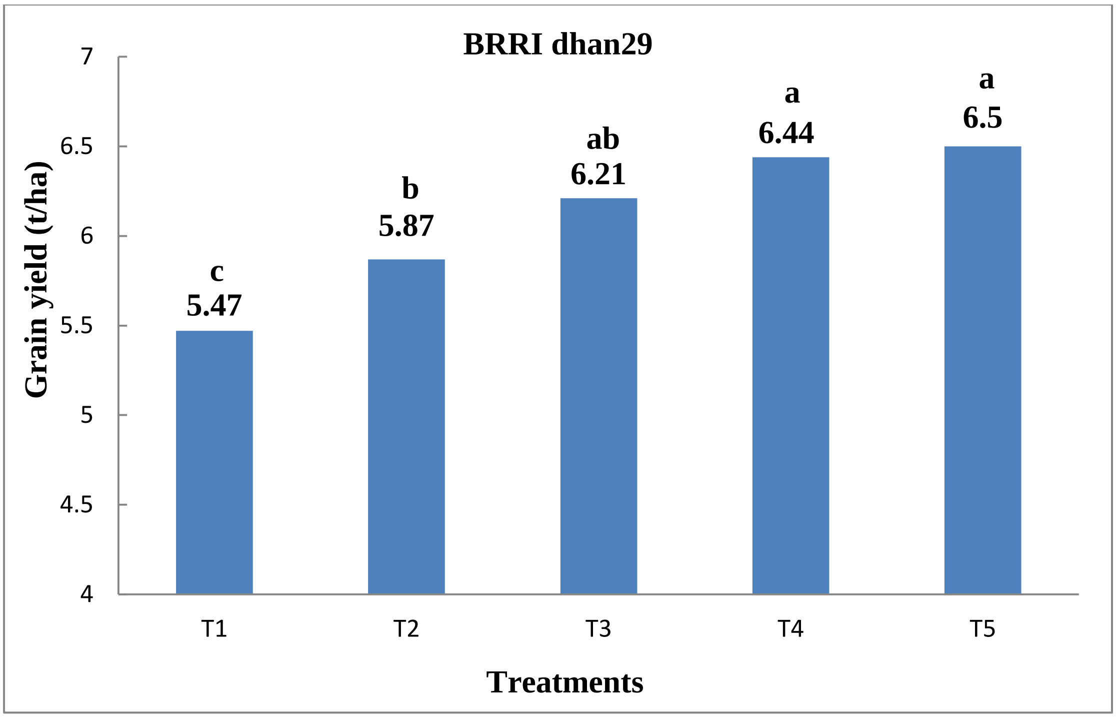
4.1.9 1000-grain weight

Table 2 shows the effects of different treatments on 1000-grain weight. It was found that 1000-grain weight statistically insignificant with compare to the T_5 (modified CHT powder @ 0 t/ha (applied in the previous expt.) + Recommended N} control treatment. The highest 1000-grain weight (25.86g) was obtained in the T_5 {modified CHT powder @ 0 t/ha (applied in the previous expt.) + Recommended N (control)} treatment and the lowest 1000-grain weight (22.26g) was obtained in the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + Recommended N} treatment. However the 1000-grain weight did not differ significantly in T_2, T_3, T_4, witg compared to T_5 control treatments. The lowest 1000-grain weight (22.26g) was obtained in the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + $2/3^{rd}$ of N} treatment. In case of 1000-grain weight the treatments may be arranged as $T_5>T_4>T_3>T_2>T_1$. It was observed that, as the rate of residual modified chitosan application in soil increases the 1000-grain weight increases insignificantly.

4.1.10 Grain yield (t/ha)

Figure 2 shows the effects of different treatments on grain yield was significantly influenced by the residual modified chitosan treatment. Grain yield was relatively decreased in case of the residual effect of modified chitosan treatment though N application was restricted in compare to the control treatment. The highest grain yield (6.49 t/ha) was obtained in the T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment which was significantly greater than that obtained in the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + $2/3^{rd}$ of N} and T_2 {modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + $2/3^{rd}$ of N}treatment and T_3 {modified CHT powder @ 2.0 t/ha (applied in the previous expt.)

+ 2/3rd of N} treatment and statistically identical to T_4 {modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. Here, it shows that, with 2/3rd N give statistically identical yield from T_4 {modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N} in comparison to T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment. However the grain yield did not differ significantly in T_1, T_2 treatments. The lowest grain yield (6.03 t/ha) was obtained in the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment which is statistically identical to T_2 treatment. In terms of grain yield the treatments may be arranged as $T_5>T_4>T_3>2_1>T_1$. It was observed that, as the rate of residual modified chitosan application in soil increases grain yield also increases. These results were supported by Sultana *et al.* (2015) who conducted a field experiment with four different concentrations that is 0, 40, 80 and 100 ppm oligomeric chitosan and four times foliar spray after germination were carried out. Finally it is observed that grain yield of rice show significant differences between control plants and foliar sprayed chitosan plants. Similar results were also found by Boonlertnirun *et al.* (2006), Boonlertnirun *et al.* (2007), Boonlertnirun *et al.* (2008) and Kananont *et al.* (2015).



T_1 = Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N

T_2 = Modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N

T_3 = Modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N

T_4 = Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N) and

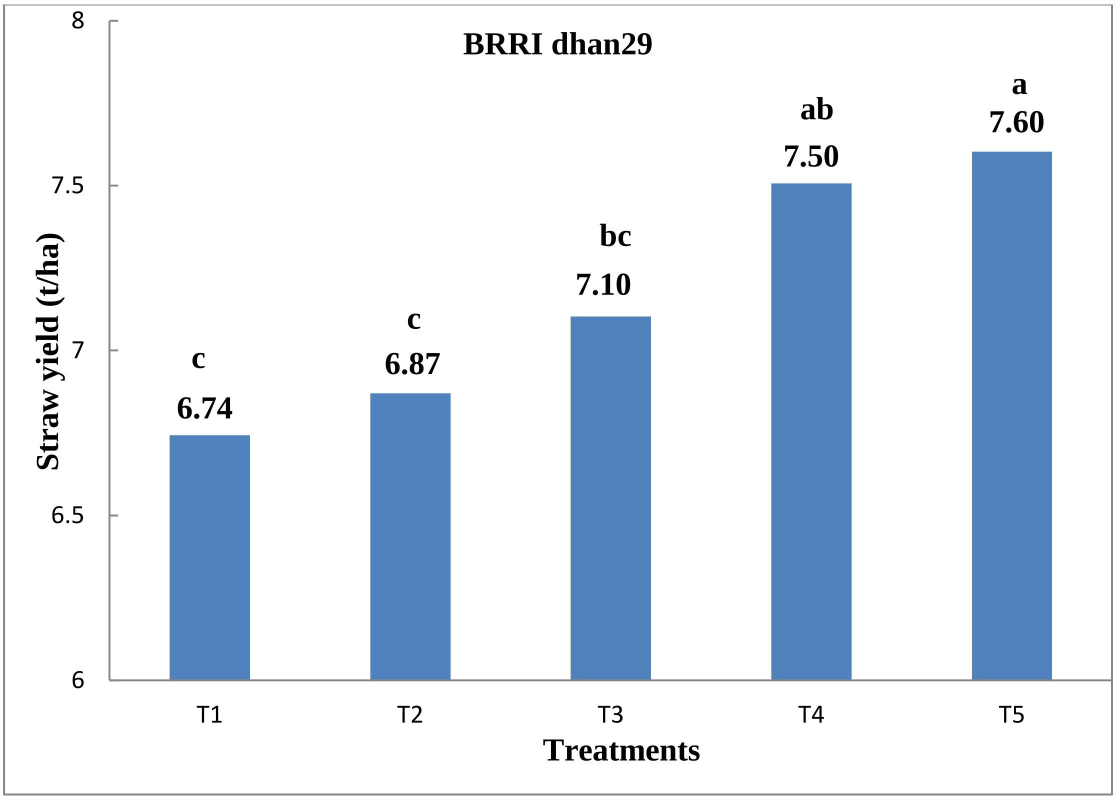
T_5 = Modified CHT powder @ 0 t/ha + Recommended N (control)

All other fertilizers were applied in each treatment @ Recommended dose.

Figure 2. Residual effect of different doses of modified chitosan powder on grain yield of Boro rice (BRRI dhan29). Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at *p* ≤ 0.05 applying DMRT, SAU, 2016.

4.1.11 Straw yield (t/ha)

The effects of different treatments on straw yield were significantly influenced by the residual modified chitosan treatment (Fig 3). The highest straw yield (7.60 t/ha) was obtained in the T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment which was significantly greater than T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N}, T_2 {modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N} and T_3 {modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. However T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment was statistically identical to T_4 {modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. The straw yield did not differ significantly in $T_{1,}$ T_2 treatments. The lowest straw yield (6.74 t/ha) was obtained in the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment which is statistically identical to the T_2 treatment. In terms of straw yield the treatments may be arranged as T_5>T_4>T_3>T_2>T_1. It was observed that, as the rate of residual modified chitosan application in soil statistically increase straw yield. These results were supported by Sultana *et al.* (2015) who conducted a field experiment with Four different concentrations that is 0, 40, 80 and 100 ppm oligomeric chitosan and four times foliar spray after germination were carried out. Finally it is observed that straw yield of rice show significant differences between control plants and foliar sprayed chitosan plants.



T_1 = Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N,

T_2 = Modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N,

T_3 = Modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N,

T_4 = Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N and

T_5 = Modified CHT powder @ 0 t/ha + Recommended N (control).

All other fertilizers were applied in each treatment @ Recommended dose.

Figure 3. Residual effect of different doses of modified chitosan powder on straw yield of Boro rice (BRRI dhan29). Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT, SAU, 2016.

4.1.12 Biological yield (t/ha)

Biological yield were significantly influenced by the modified chitosan treatment (Table 3). The highest biological yield (14.10 t/ha) was obtained in the T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment which was significantly greater than that of obtained in the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N}, T_2 {modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N}, T_3 {modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment and statistically identical to T_4 {modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. The lowest biological yield (12.21 t/ha) was obtained in the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. In terms of biological yield the treatments may be arranged as $T_5>T_4>T_3>T_2>T_1$. It was observed that, as the rate of modified chitosan application in residual soil increases biological yield also increases.

4.1.13 Harvest Index

Harvest index (HI) is the ratio of seed yield to total above ground plant yield. Significant response was not observed in the harvest index due to the effect of different modified chitosan treatments on BRRI dhan29 (Table 3). From the results, it was found that the highest harvest index (46.66%) was obtained from the treatment T_3 {modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment and the lowest harvest index (41.06%) was obtained in the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment.

Table 3. Residual effect of different doses of modified chitosan powder on Biological yield and harvest index of Boro rice (BRRI dhan29) at harvest. SAU, 2016.

Treatments	Biological yield (t/ha)	Harvest index (%)
T_1	12.21	41.06
T_2	12.74	46.13
T_3	13.31	46.66
T_4	13.94	46.18
T_5	14.10	45.41
LSD (0.05)	0.70	5.30
CV (%)	2.84	6.25
Level of significance	**	NS

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD.

** = Significant at 1% level of probability, * = Significant at 5% level of probability

T_1 = Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N,

T_2 = Modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N,

T_3 = Modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N,

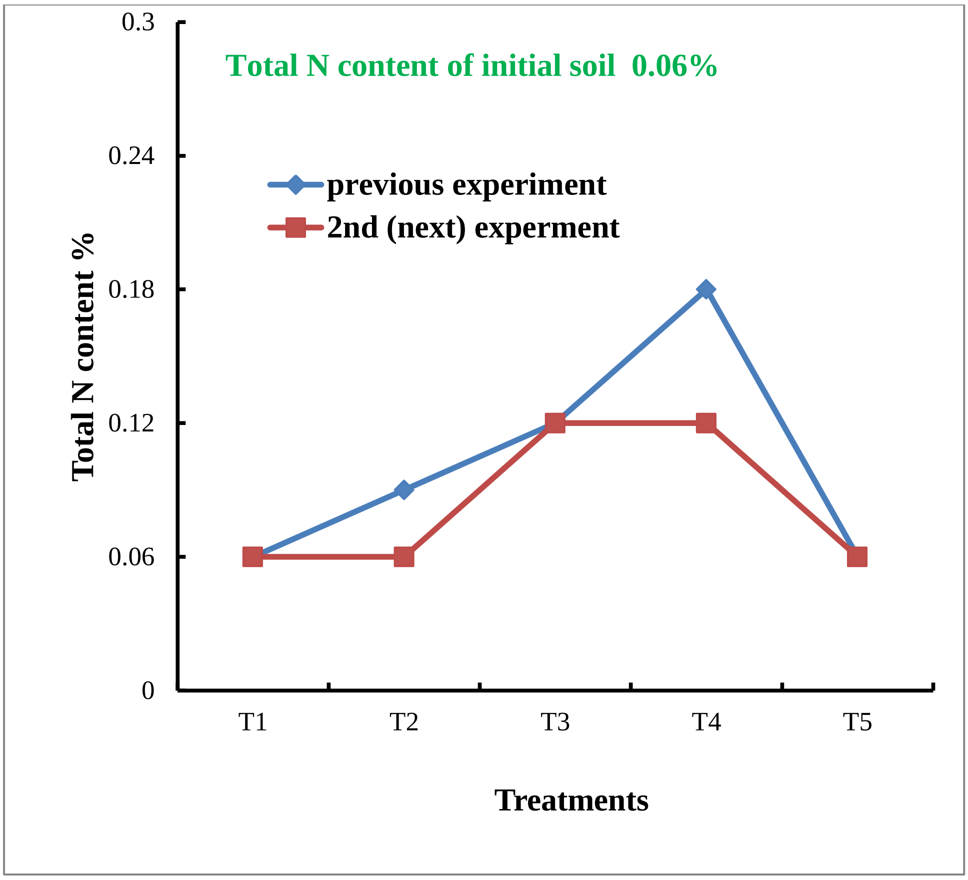
T_4 = Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N and

T_5 = Modified CHT powder @ 0 t/ha + Recommended N (control).

All other fertilizers were applied in each treatment @ Recommended dose.

4.1.14 Residual effect of N in the post harvest soil

Although more than 60% of the added nitrogen is lost from the soil (FRG, BARC, 2012), the residual value of the total N was significantly increased in both the previous and next experiments due to the addition of higher doses of the modified CHT powder under the treatment T3 and T4 compare to the T5 (recommended fertilization, Control). These results indicate that total nitrogen content is high enough in the modified CHT powder and its slow releasing effect significantly increased the organic N supplementation in soils.



T_1 = Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N,

T_2 = Modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N,

T_3 = Modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N,

T_4 = Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N and

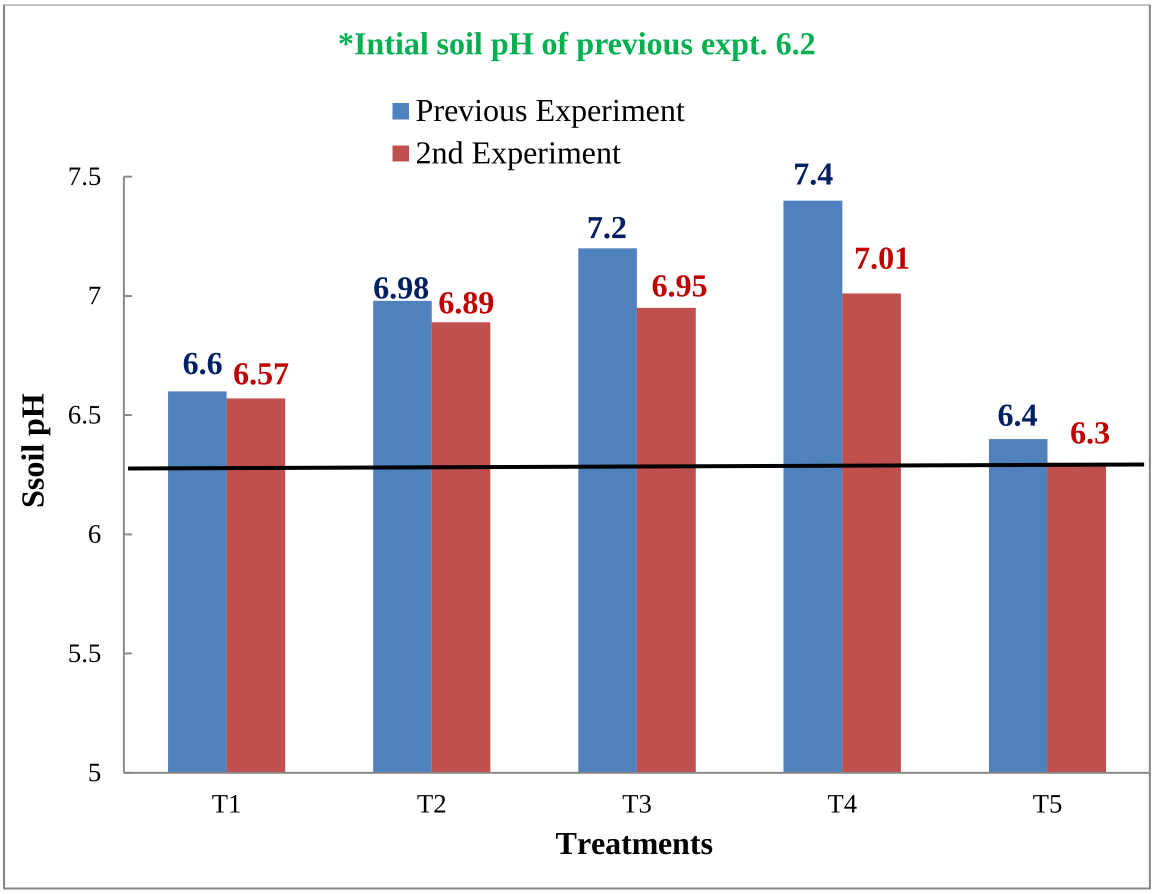
T_5 = Modified CHT powder @ 0 t/ha + Recommended N (control).

All other fertilizers were applied in each treatment @ Recommended dose.

Figure 4. Residual value of total N content as affected by the different doses of modified chitosan powder in the post harvest soils of BRRI dhan29. Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT, SAU, 2016.

4.1.15 pH status of the post-harvest soil

The pH status of the post-harvest soil of running experiment was affected by the different treatments of modified chitosan and ranged from 6.3 to 7.01 (Figure 5). It was found that pH status of soil was statistically significant. The highest pH value (7.01) was recorded in T_4 treatment {modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N} which was significantly greater than from the T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment. The lowest pH value (6.3) was recorded in T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment. According to the pH values treatments may be arranged as $T_4>T_3>T_2>T_1>T_5$. The pH status of post harvest soil in 2nd (running) experiment was decrease with compare to the pH status of post harvest soil in previous experiment. But still in 2nd experiment, the pH status of soil (7.01) was higher than the initial pH (6.2) status of soil before the previous experiment was done. From this study it was observed that, as the residual rate of modified chitosan application in soil increases the pH status of soil also increases. These results were supported by Kananont *et al.* (2015) who conducted an experiment with Fermented chitin waste (FCW) along with CF = soil supplemented with chemical fertilizer and CMF = soil supplemented with chicken manure fertilizer. The results found that FCW @ 1% the ph differ significantly from 0.5% FCW, 0.25% FCW and the rest of the treatment.



T_1 = Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N,

T_2 = Modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N,

T_3 = Modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N,

T_4 = Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N and

T_5 = Modified CHT powder @ 0 t/ha + Recommended N (control).

All other fertilizers were applied in each treatment @ Recommended dose.

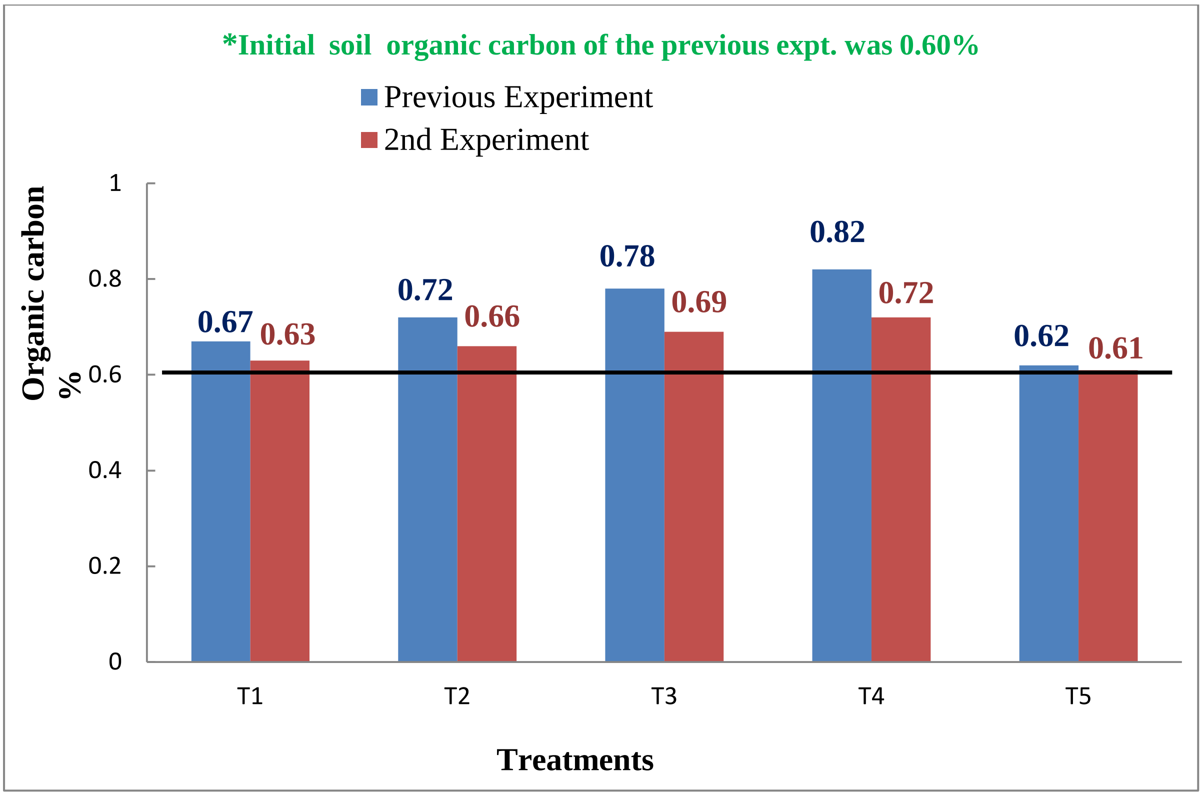
Figure 5. Residual effect of different doses of modified chitosan powder on pH status of soil of Boro rice (BRRI dhan29). Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT, SAU, 2016.

4.1.16 Organic carbon content in the post harvest soil

The organic carbon content in the post harvest soil was affected by different treatments of residual modified chitosan and ranged from 0.61% to 0.72 % (Figure 6). It was found that effects of different residual doses of modified chitosan on organic carbon content of post harvest soil were statistically significant. Maximum organic carbon content (0.72%) was found in T_4 {modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment which was significantly greater than the T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment. However, minimum organic carbon content (0.61%) was found in T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment. According to the organic carbon content of soil the treatments may be arranged as T_4>T_3>T_2>T_1>T_5. The organic carbon content in the post harvest soil of 2nd (running) experiment decrease compared to the previous experiment. But still, the organic carbon content (0.72 %) in the post harvest soil of 2nd experiment was greater than the initial carbon content (0.60%) on initial soil before the previous experiment was done. From this study it was observed that, as the rate of modified chitosan powder application in residual soil increases the organic carbon content of soil also increases. These results were supported by Kananont *et al.* (2015) who conducted an experiment with Fermented chitin waste (FCW) along with CF = soil supplemented with chemical fertilizer and CMF = soil supplemented with chicken manure fertilizer. The results found that FCW @ 1% the organic carbon content in soil differ significantly from 0.5% FCW, 0.25% FCW and the rest of the treatment.

The organic carbon content was increased in a dose dependent manner; it might be due to the use of modified chitosan containing higher level of organic carbon level.

This result suggests that modified chitosan application might be increase the level of organic matter in soils and would be helpful to improve the sustainable soil health.



T_1 = Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N,

T_2 = Modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N,

T_3 = Modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N,

T_4 = Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N and

T_5 = Modified CHT powder @ 0 t/ha + Recommended N (control).

All other fertilizers were applied in each treatment @ Recommended dose.

Figure 6. Residual effect of different doses of modified chitosan powder on organic carbon content of post harvest soil of Boro rice (BRRI dhan29). Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT, SAU, 2016.

4.1.17 Organic matter content in the post harvest soil

Organic matter content in the post harvest soil showed significant differences among treatments with different modified chitosan doses. Organic matter content ranged from 1.05% to 1.23 % (table 6). Maximum organic matter content (1.23%) was found in T_4 {modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment which was significantly greater than from the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} and T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment. However, minimum organic matter content (1.05%) was found in T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment. According to the organic matter content of soil the treatments may be arranged as T_4>T_3>T_2>T_1>T_5. From this study it was observed that, as the rate of modified chitosan powder application in residual soil increases the organic matter content of soil also increases. These results were supported by Kananont *et al.* (2015) who conducted an experiment with Fermented chitin waste (FCW) along with CF = soil supplemented with chemical fertilizer and CMF = soil supplemented with chicken manure fertilizer. The results found that FCW @ 1% the organic matter content in soil differ significantly from 0.5% FCW, 0.25% FCW and the rest of the treatment.

The organic matter content was increased in a dose dependent manner, it might be due to the use of modified chitosan containing high amount of organic matter level. Increasing organic matter content for the sustainable agriculture is a big challenge to the Bangladesh soils; however, the modified chitosan application could play a crucial role to increase the organic matter content in soils.

Table 4. Residual effect of modified chitosan powder on soil organic status

Treatments	Soil organic carbon (%)	Soil organic matter (%)
T_1	0.66b	1.14b
T_2	0.68ab	1.18ab
T_3	0.70ab	1.20ab
T_4	0.72a	1.23a
T_5	0.61c	1.05c
LSD (0.05)	0.04	0.07
CV (%)	4.51	4.40
Level of significance	**	**
Initial soil	**0.60**	**1.03**

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD.

** = Significant at 1% level of probability

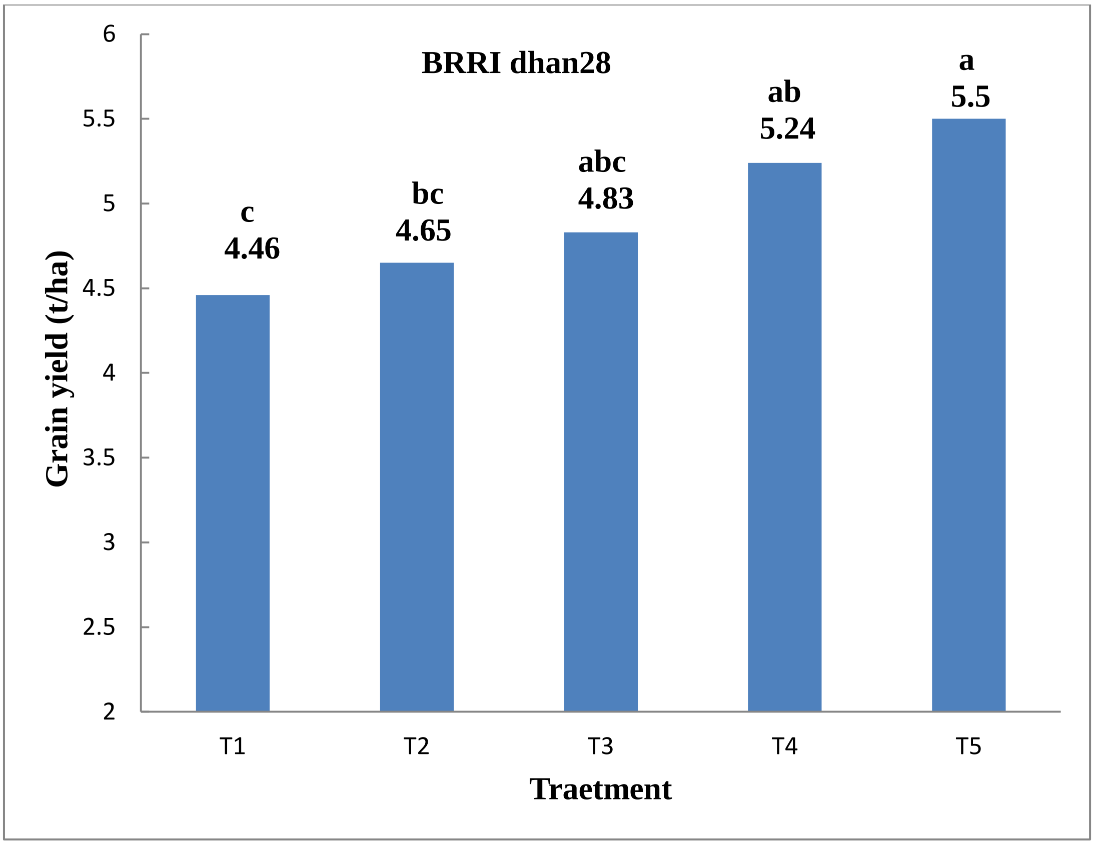
T_1 = Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N,
T_2 = Modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N,
T_3 = Modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N,
T_4 = Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N and
T_5 = Modified CHT powder @ 0 t/ha + Recommended N (control).

All other fertilizers were applied in each treatment @ Recommended dose.

4.2 BRRI dhan28

4.2.1 Grain yield (t/ha)

Figure 7 shows the effects of different treatments on grain yield. Grain yield was significantly influenced by the residual modified chitosan treatment. The highest grain yield (5.50 t/ha) was obtained in the T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment which was significantly greater than that obtained in the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} and T_2 {modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. However, T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment is statistically identical to T_4 {modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. The lowest grain yield (4.46 t/ha) was obtained in the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment which is statistically identical to T_2 treatment. In terms of grain yield the treatments may be arranged as $T_5>T_4>T_3>T_2>T_1$. It was observed that, as the rate of modified chitosan application in residual soil increases grain yield also increases. These results were supported by Sultana *et al.* (2015) who conducted a field experiment with Four different concentrations that is 0, 40, 80 and 100 ppm oligomeric chitosan and four times foliar spray after germination were carried out. Finally it is observed that grain yield of rice show significant differences between control plants and foliar sprayed chitosan plants. Similar results were also found by Boonlertnirun *et al.* (2006), Boonlertnirun *et al.* (2007), Boonlertnirun *et al.* (2008) and Kananont *et al.* (2015).



T_1 = Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N,

T_2 = Modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N,

T_3 = Modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N,

T_4 = Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N and

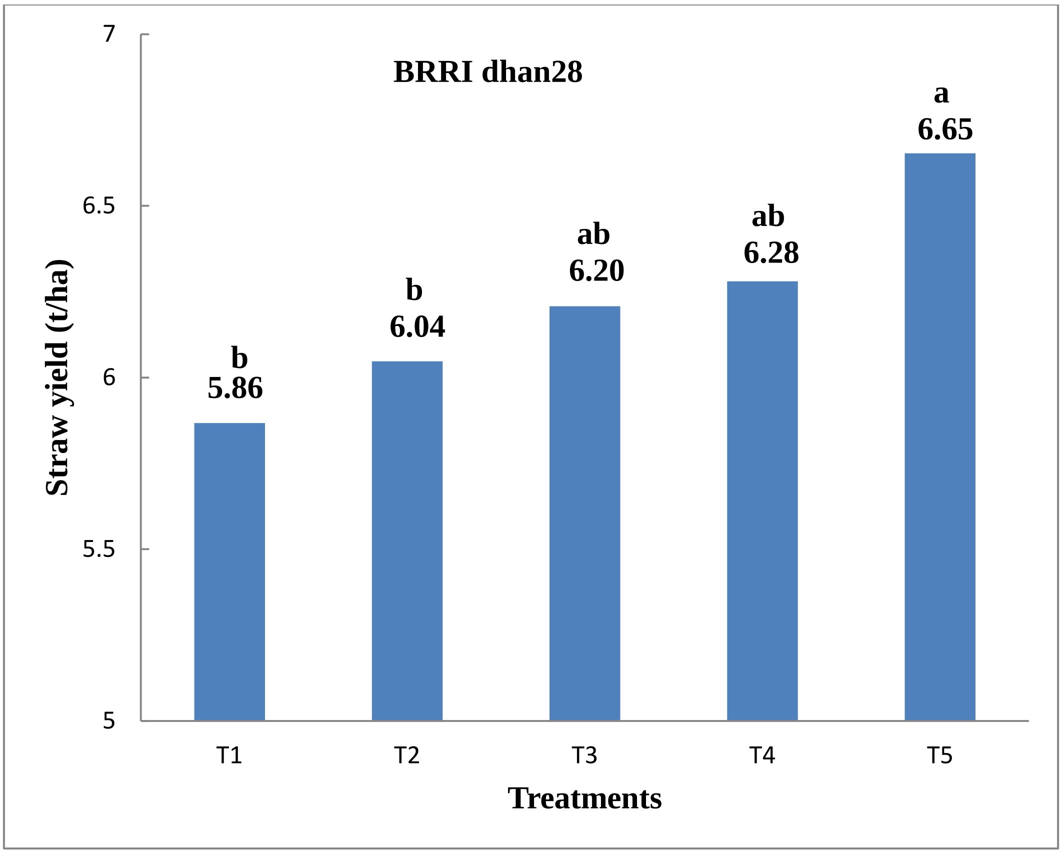
T_5 = Modified CHT powder @ 0 t/ha + Recommended N (control).

All other fertilizers were applied in each treatment @ Recommended dose.

Figure 7. Residual effect of different doses of modified chitosan powder on grain yield of Boro rice (BRRI dhan28). Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT, SAU, 2016.

4.2.2 Straw yield (t/ha)

The effects of different treatments on straw yield were significantly influenced by the residual modified chitosan treatment (Figure 8). The highest straw yield (6.63 t/ha) was obtained in the T_5 {modified CHT powder @ 0 t/ha + Recommended N (control)} treatment which was significantly greater than T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment and T_2 {modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N} and statistically identical to T_4 {modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N} and T_3 {modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N}. The lowest straw yield (5.86 t/ha) was obtained in the T_1 {modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. In terms of straw yield the treatments may be arranged as $T_5>T_4>T_3>T_2>T_1$. It was observed that, as the rate of residual modified chitosan application in soil increases the straw yield was also increase. These results were supported by Sultana *et al.* (2015) who conducted a field experiment with Four different concentrations that is 0, 40, 80 and 100 ppm oligomeric chitosan and four times foliar spray after germination were carried out. Finally it is observed that straw yield of rice show significant differences between control plants and foliar sprayed chitosan plants.



T_1 = Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N,

T_2 = Modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + 2/3rd of N,

T_3 = Modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + 2/3rd of N,

T_4 = Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N) and

T_5 = Modified CHT powder @ 0 t/ha + Recommended N (control).

All other fertilizers were applied in each treatment @ Recommended dose.

Figure 8. Residual effect of different doses of modified chitosan powder on straw yield of Boro rice (BRRI dhan28). Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT. SAU, 2016.

Table 5. Composition of the modified chitosan applied in the previous experiment

Name of the nutrients	Nutrient content
Nitrogen (N)	4.06 %
Phosphorus (P)	0.643 %
Potassium (K)	0.28 %
Sulphur (S)	0.092 %
Calcium (Ca)	2.43 %
Magnesium (Mg)	0.36 %
Zinc (Zn)	92.03 ppm
Boron(B)	152 ppm
Organic Carbon (OC)	7.52 %
Organic Matter (OM)	12.96 %
pH of the Modified Chitosan	8.73

Analytical results (Table 5) revealed that a number of essential (macro and micro elements) were supplied due to the application of the modified chitosan in the rice field soils. With the alkaline behavior of the materials increased the pH level of the rice field soils. Many factors could be involved in the supper growth, development and yield increment of the rice grain. The above mentioned nutritional supplementation and some other growth promoting hormone could be involved in the mechanisms.

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was carried out at the research field of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from November 2015 to May 2016. The study was aimed to determine the residual effect of modified chitosan to the supplementation of nitrogen on the performance of growth, yield contributing characters and yield of rice cv. BRRI dhan28 and BRRI dhan29 at Boro season under the Modhupur Tract (AEZ-28).

The single factor experiment was compared with five treatments of chitosan powder.

T_1 = Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + $2/3^{rd}$ of N,

T_2 = Modified CHT powder @ 1.0 t/ha (applied in the previous expt.) + $2/3^{rd}$ of N,

T_3 = Modified CHT powder @ 2.0 t/ha (applied in the previous expt.) + $2/3^{rd}$ of N,

T_4 = Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + $2/3^{rd}$ of N and

T_5 = Modified CHT powder @ 0 t/ha + Recommended N (control).

All other fertilizers were applied in every treatment @ Recommended dose.

In agriculture, chitosan powder can be used as an alternative source of N which increases efficiency of applied N and can contribute to increase N content of rice soil. Besides that, the residual chitosan powder of previously applied chitosan powder treatment had a profound influence on morphological, reproductive, yield attributes and grain yield of rice. The residual modified chitosan powder also has an effect on improvement and increaser of pH, organic carbon and organic matter content of soil. Among all the treatments T_4 *i.e.* Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + $2/3^{rd}$ of N perform best among the significantly varied parameters compare to control and other concentrations of chitosan powder. But in case of non significant parameters the treatment may differ.

The data on crop growth and yield characters (plant height, total number of tiller, number of effective tiller/hill, number of non effective tiller/hill, panicle length, number of filled and unfilled grains/panicle, number of total grain/panicle, 1000 grains weight, grain and straw yield, biological yield and harvest index) were recorded in the field and analyzed using the software Statistix 10. The mean differences among the treatments were compared by least significant difference test at 5% level of significance. In case of BRRI dhan29, the results revealed that the maximum number of total tillers/hill (17.74) was observed in the T_5 control {Modified CHT powder @ 0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment and minimum number of total tillers/hill (16.87) was observed in the T_1 {Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N}. Similarly highest effective tillers/hill (17.36) was observed in the T_5 control {Modified CHT powder @ 0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment and lowest effective tillers/hill (15.12) was observed in the T_1 {Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. The maximum 1000 grain weight (25.88g) was obtained in the {Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment and minimum 1000 grain weight (23.26g) was obtained in the T_1 {Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. Compared to T_5 {Modified CHT powder @ 0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment, T_4 {Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N} shows statistically identical results in the above mentioned characters.

The highest value of pH (7.01) was recorded in the T_4 {Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N} and the lowest pH value (6.3) was recorded in T_5 {Modified CHT powder @ 0 t/ha (applied in the previous expt.) + 2/3rd

of N} control treatment. Maximum organic carbon content (0.71%) was found in T_4 {Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment and minimum organic carbon content (0.61%) was found in T_5 control {Modified CHT powder @ 0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. Highest organic matter content (1.23%) was found in T_4 {Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment and lowest organic matter content (1.05%) was found in T_5 treatment {Modified CHT powder @ 0 t/ha (applied in the previous expt.) + 2/3rd of N}. Highest grain yield (6.49 t/ha) was obtained in the T_5 control {Modified CHT powder @ 0 t/ha (applied in the previous expt.) + 2/3rd of N}) treatment and lowest grain yield (6.03 t/ha) was obtained in the T_1 {Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. The highest straw yield (7.09 t/ha) was obtained in the T_5 {Modified CHT powder @ 0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment and lowest straw yield (6.74 t/ha) was obtained in the T_1 {Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. T_4 {Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment shows statistically identical grain yield (6.44 t/ha) and straw yield (7.50 t/ha) to the T_5 {Modified CHT powder @ 0 t/ha (applied in the previous expt.) + 2/3rd of N} control treatment though application of N reduced one third in T_4 {Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment.

Highest biological yield (13.59 t/ha) was obtained in the T_5 control {Modified CHT powder @ 0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment and the lowest biological yield (12.77t/ha) was obtained in the T_1 {Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment.

In case of BRRI dhan28, the Highest grain yield (5.50 t/ha) was obtained in the T_5 control {Modified CHT powder @ 0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment and lowest grain yield (4.46 t/ha) was obtained in the T_1 {Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N} treatment. The highest straw yield (6.8 t/ha) was obtained in the T_5 {Modified CHT powder @ 0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment and lowest straw yield (5.86 t/ha) was obtained in the T_1 {Modified CHT powder @ 0.5 t/ha (applied in the previous expt.) + 2/3rd of N}) treatment. T_4 {Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N} treatment shows statistically identical grain yield (5.24 t/ha) and straw yield (6.28 t/ha) to the T_5 {Modified CHT powder @ 0 t/ha (applied in the previous expt.) + 2/3rd of N} control treatment though application of N reduced one third in T_4 {Modified CHT powder @ 4.0 t/ha (applied in the previous expt.) + 2/3rd of N}treatment.

The present study was conducted to improve our understanding of the residual effect of modified chitosan powder to the supplementation of nitrogen on the performance of growth, yield contributing characters and yield of rice cv. BRRI dhan28 and BRRI dhan29. Yield, as well as other yield contributing characters responded positively with the increasing concentration of previously applied chitosan except plant height, total tillers/hill, panicle length, number of total grains/panicle, filled grains/panicle, unfilled grains/panicle, straw yield and harvest index. But the grain yield increased with the increasing doses of modified chitosan among the treatments compare to the control. Besides that, our results indicate that primary tillers become earlier, effective tillers become higher, flowering and maturity time become earlier resulting more yield.

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

i. Booster doses (Treatment T_4) of the modified CHT powder influenced morphological characters, yield attributes and grain & straw yield of rice cv. BRRI dhan28 and BRRI dhan29 compared to the control treatment T_5; and

ii. treatment T_4 showed the statistical similar result to the control T_5 with the application of two third nitrogen of Recommended dose. The treatments T_1, T_2 and T_3 showed statistically similar result.

iii. The modified chitosan improved chemical properties of soil like organic carbon content and soil pH for sustainable agriculture.

Recommendations

From the above experimental findings, it is apparent that the application of modified chitosan @ 4.0 t/ha (T_4) in the previous crop, performed better on yield and yield parameters of rice cv. BRRI dhan28 and BRRI dhan29 in case of residual effect. In order to recommend the practices for the rice growers, the following aspects would be considered in future:

i) Similar experiments need to be conducted in different locations and seasons of Bangladesh to draw a final conclusion regarding the residual effect of modified chitosan applications for the grain yield of rice.

ii) Varietal trials need to be investigated.

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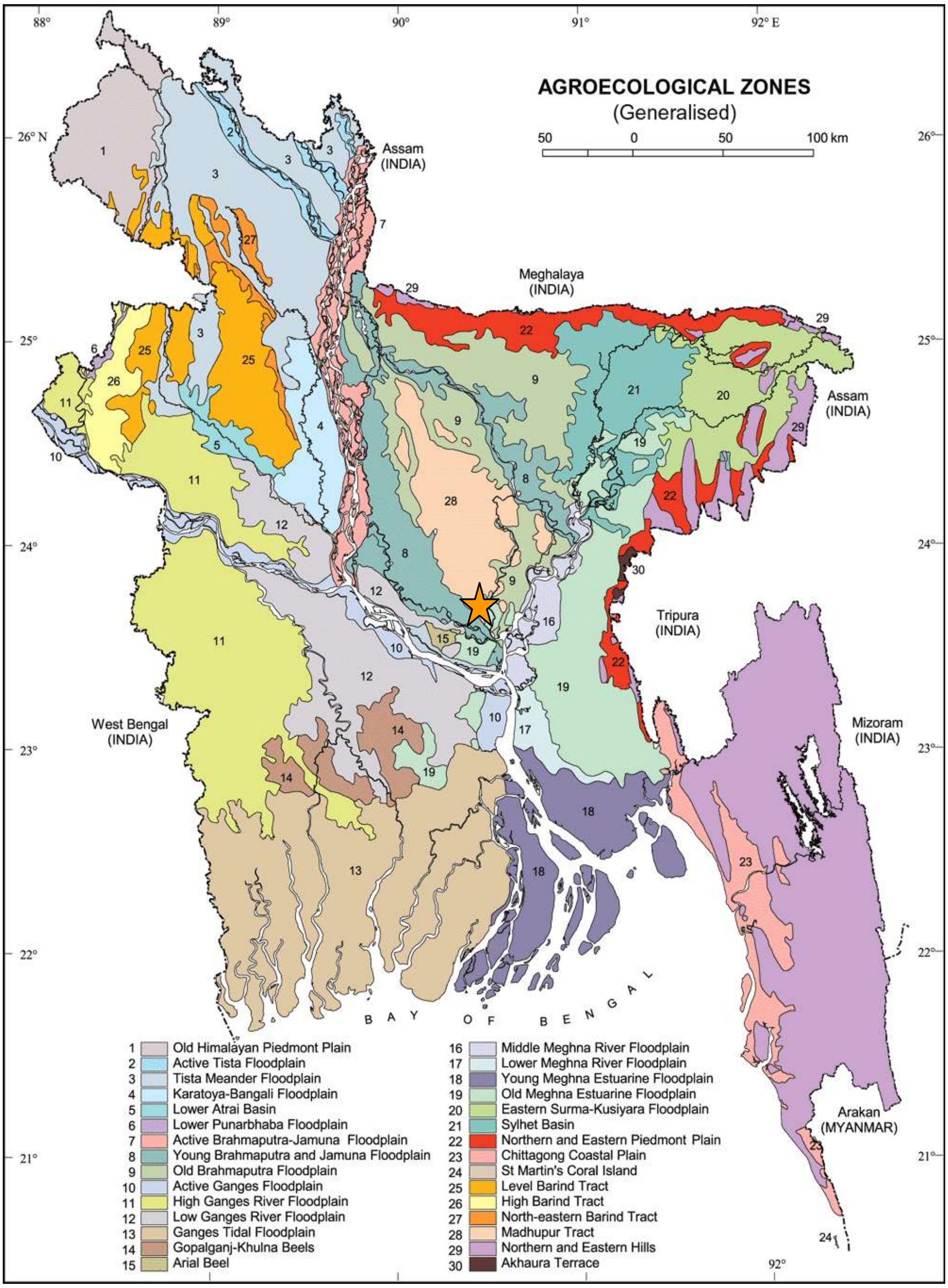
APPENDICES

Appendix I. Map showing the experimental sites under study



Appendix II. Monthly record of air temperature, relative humidity and rainfall (average) of the experimental site during the period from November 2015 to May 2016, SAU.

Month (2016)	Air temperature(^{0}C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
November	26.5	19.4	81	22
December	25.8	16.0	78	00
January	25.8	12.2	72	6
February	28.4	14.7	64	21
March	32.3	19.3	62	57
April	34.5	23.5	66	138
May	33.4	24.8	78	272

Source: Bangladesh Meteorological Department (Climate and weather division) Agargoan, Dhaka-121