Role of chitosan powder on the production of quality seedlings of BRRI dhan29 and its effect on yield

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*This is to certify that thesis entitled, "**Role of chitosan powder on the production of quality seedlings of BRRI dhan29 and its effect on yield**"submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in SOIL SCIENCE, embodies the result of a piece of bona fide research work carried out by **MD. SAIFUL ISLAM**, Registration No. **15-06948** 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.

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DEDICATED

TO

MY BELOVED

PARENTS

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ABSTRACT

Role of chitosan powder on the production of quality Boro rice seedlings and its effect on yield was examined. The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Dhaka. There were six treatments and three replications in the experiment. The treatments were as follows: T_1 = 100 g powder/m^2, T_2 = 200 g powder/m^2, T_3 = 300 g powder/m^2, T_4 = 400 g powder/m^2, T_5 = 500 g powder/m^2, T_6 = 0 g powder/m^2. A significant variation was observed in the seedlings height, biomass production and chemical properties of the seedbed soils due to the application of chitosan powder in the seedbed. The maximum seedlings height, fresh weight, oven dry weight were observed in the treatment T_4 and the minimum seedlings height, fresh weight and oven dry weight were recorded in the treatment T_6, control. Whereas, the maximum level of organic carbon, organic matter and soil pH were recorded in the treatment T_5 and the minimum level of organic carbon, organic matter and soil pH were recorded in the treatment T_6, control. Chitosan powder increased the level of organic matter in a dose dependent manner. Quality of the rice seedlings were improved due to the application of the chitosan powder in a dose dependent manner and the treatment T_4 (400 g powder/m^2) was the more effective than other treatments. All the treatments were produced good rice seedlings having more chlorophyll level than control treatments. Application of chitosan increased plant height, effective tillers hill^{-1}, number of panicle/m^2, panicle length, grain yield and straw yield over control. Most of the morphological, yield attributes and grain yield were increased with increasing the dose of chitosan in the seedbed. Maximum grain yield was observed in T_4 treatment followed by T_3, T_5, T_2 ,T_1 and T_6 (control). Results indicate that primary tiller production become earlier, effective tiller become higher, flowering and maturity time become earlier resulting higher yield. These results might be due some growth promoting hormones (especially GA3, Auxin etc.), soil alkalization nature and other some macro-micro nutritional supplementation which might be induced some early flowering genes (*ELF1, ELF2, ELF3*).

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ABBREVIATIONS

Abbreviations	Full word
%	Percent
@	At the rate
AEZ	Agro-Ecological Zone
ANOVA	Analysis of variance
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
cm	Centi-meter
CV%	Percentage of Coefficient of Variation
CHT	Chitosan
et al.	And others
etc	et cetera
FAO	Food and Agricultural Organization
g	Gram
j.	Journal
MSE	Mean Square of Error
RCBD	Randomized Complete Block Design
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sc.	Science
Univ.	University
Var.	Variety

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Rice belongs to the Gramminae family with the scientific name *Oryza sativa* L. Rice is the staple food of more than half of the world's population more than 3.5 billion people depend on rice for more than 20% of their daily calories. Rice provided 19% of global human per capita energy and 13% of per capita protein (FAO, 2004**).** In Asia**,** r ice consumption is very high, exceeding 100 kg per capita annually in many countries. For about 520 million people in Asia Rice is the most important source of the food energy for more than half of the human population. Rice is the agricultural GDP and one-sixth of the national income in Bangladesh (Rai, 2006). According to the Food and Agriculture Organization (FAO) of the U.N., 80% of the world rice production comes from staple food of about 135 million people of Bangladesh. Rice sector contributes one-half of the 7 countries (UAE-FAO, 2012). In worldwide, 474.86 million metric tons of rice was produced 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.

Boro rice is more popular in Bangladesh. Among different groups of rice, transplant Boro rice covers about 49.11% of total rice area and it contributes to 38.11% of the total rice production in the country (BBS, 2013). The population of Bangladesh is still growing by two million every year and may increase by another 30 million over the next 20 years. Thus, Bangladesh will require about 27.26 million tons of rice for the year 2020 (FAO, 2009). During this time total rice area will also shrink to 10.28 million hectares. Rice yield therefore, needs to be increased from the present 2.74 to 3.74 t/ha. So, the researchers have to think how to solve the food problem of the country. Beside, agriculture is the single largest producing sector of Bangladesh economy since it comprises about 14.79% of the country's Gross Domestic Product (GDP) (AIS, 2006) where employs around 45% of the total labor force. 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 socio-economic factor and lack of inputs also important. That is why continuous efforts are being taken towards the development of new rice cultivars and their management practices to increase the yield per unit area and meet other requirements. So, 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 Chitosan.

Chitosan (CHT) is a natural biopolymer modified from chitin, which is the main structural component of squid pens, cell walls of some fungi and shrimp and crab shells. Chitin and chitosan are copolymers found together in nature. They are inherent to have specific properties of being environmentally friendly and easily degradable. Thailand is a world-leading exporter of frozen shrimps. Therefore, there are abundant raw materials for chitosan production. Chitosan has a wide scope of application. With high affinity and non-toxicity, it does no harm human beings and livestock (Harmed*et al.,* 2016).

Chitosan regulates the immune system of plants and induces the excretion of resistant enzymes. Moreover, chitosan not only activates the cells, but also improves its disease and insect resistant ability.Chitosan has strong effects on agriculture such as acting as the carbon source for microbes in the soil, accelerating of transformation the process of organic matter into inorganic matter and assisting the root system of plants to absorb more nutrient from the soil. Chitosan is absorbed to the root after being decomposed by bacteria in the soil. 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 (Choi, 2016).

The organic manures viz. sludge and spray of CHT may be used as an alternative source of N which increases efficiency of applied N (Saravanan*et al.*, 1987). Integrated use of organic manures with the combination of inorganic fertilizers 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).

Combined application of sludge and spray of CHT along with chemical nitrogen fertilizer improves 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. When sludge and spray of CHT are applied along with chemical fertilizers 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).

The objectives of the study are as follows:

1. To determine the effect of chitosan powder on quality seedling production of BRRI dhan29.
2. To examine yield performance of the chitosan powder treated rice seedlings.

Chapter II

Review of literature

CHAPTER II

REVIEW OF LITERATURE

A number of research works relating to the application of chitosan and chemical fertilizers to rice crop have been carried out in different rice growing countries of the world including Bangladesh. A better understanding of the effects of the nutrients supplied from manures and fertilizers on rice will obviously facilitate the development of some agronomic practices for production of other crops. Since review of literature forms a bridge between the past and present research works related to problem, which helps an investigator to draw a satisfactory conclusion, an effort was thus made to present some research works related to the present study in this section. This chapter includes the available information regarding the effect of chitosan along with chemical nitrogenous fertilizers on Boro rice.

2.1 Effect of chitosan on growth, yield parameter and yield

2.1.1. Plant height

Arif et al. (2015) revealed that application of modified chitosan increased tomato seedling height, fresh and dry weight of the seedlings, seedbed soil pH, seedbed organic carbon (%) & organic matter (%), number of flowers/ plant, fruits/plant, fruit size and fruit yield over control.

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

Kobayashi *et al. (*1989); conducted different experiment which revealed that the increasing of plant height obtain through the application of chitosan along with N, P, K and S was also reported by many other scientists.

Ma *et al*. (2013) studied to treat wheat seeds with oligochitosan by soaking seeds in 0.0625% oligochitosan solution for 5h. The results showed that chlorophyll content increased by treating seeds with oligochitosan. It suggested that seeds treatment with oligochitosan had a beneficial effect on photosynthesis. They also confirmed the positive effect of oligochitosan in improving the plant growth and plant's capacity of tolerance to salt stress.

Sekh (2002) carried out an experiment to find out the effect of PGRs on rice and found that GABA @ 0.33 mgL^{-1} produced the highest shoot height.

Supachitra *et al*. (2011) conducted an experiment to determine the plant growth stimulating effects of chitosan on Thai indica rice (*Oryza sativa* L.) cv. Leung PraTew 123. Rice seedlings were applied with oligomericchitosan with 80% degree of deacetylation at the concentration of 40 mgL^{-1} by seed soaking overnight before sowing, followed by spraying on 2-week and 4-week old seedlings, respectively. The oligomericchitosan stimulated plant height.

Hoque (2002) conducted field experiment on a high yielding variety (Shatabdi) of wheat to evaluate the effect of CI-IAA, GABA and TNZ-303 by soaking seeds in 0.16 mlL^{-1}, 0.33 mlL^{-1} and 0.66 mlL^{-1} aqueous solutions and revealed that the GABA at 0.33 mlL^{-1} produced the tallest shoot at 60 and 90 DAS. Shoot height was significantly higher over that produced in control.

.1.2. Number of tillers hill-1

Boonlertnirun *et al.* (2012) showed different application methods significantly affected tiller number per plant, the maximum tiller numbers were obtained from application of chitosan in combination with mixed chemical fertilizer but did not differ from that of mixed chemical fertilizer application while their different treatment combination were Trl : chitosan at the concentration of 80 mgL^{-1} in combination with mixed chemical fertilizer between urea (46-0-0) and 16-20-0 at the rate of 312.5 kg H^{-1}, Tr2: mixed chemical fertilizer between urea (46-0-0) and (16-20-0) at the rate of 312.5 kg Tr3: chitosan spraying at the concentration of 80 mgL^{-1} and Tr4: no application of chitosan and mixed chemical fertilizer. Boonlertnirun *et al*. (2005) showed that the application of chitosan via seed soaking and spraying 4 times created variation in number of tillers $plant^{-1}$ and dry matter accumulation, but did not affect plant height, 1000-grain weight and number of seeds $head^{-1}$ of rice.

Bhuvaneswari and Chandrasekharan *et al.* (2008) showed varying chitosan application methods did not affect tiller numbers per plant. The maximum tiller numbers obtained from treatment of seed soaking in chitosan solution before planting and soil application, however did not significantly differ from the control.Their treatment combination were Tr 1- no chitosan application (control), Tr2- seed soaking with chitosan solution Tr 3 - seed soaking and soil application with chitosan solution and Tr 4 - seed soaking and foliar spraying with chitosan solution.

2.1.3 Number of leaves $hill^{-1}$

Jia'an*et al*. (2001) reported that application of 75 mg L^{-1} of Chotsan on rice increased root length, root number, leaf length, leaf width, seedling height and stem diameter of seedlings. SuchadaBoonlertnirun, RaweewunSuvannasara, PrapurtPromsomboon and Kitti Boonlertnirun (2012) conducted an experiment in a greenhouse of AGRIL.

Technology and Agro-Industry Faculty, Rajamangala University of Technology Suvarnnaphunmi, during April to August, 2011. The results revealed that application of chitosan in combination with mixed chemical fertilizer showed positive effect on leaf number per plant, dry weight, yield and yield components of rice plants, however did not significantly differ from those of application of mixed chemical fertilizer alone.

2.1.4. Leaf area hill^{-1} and Leaf area index (LAI)

Nguyen *et al*. (2011) were investigating on the effects of chitosan and chitosan oligomer solutions on growth and development of coffee have been investigated. Spraying of oligo chitosan @600 mgL^{-1} increase stem diameter up to 30.77% and the leaf in area by up to 60.53%.In addition application of oligo chitosan reduced by 9.5–25.1% transpiration of the leaves at 60 and 120 min.

2.1.5 Total dry matter (TDM)

Boonlertnirun *et al*. (2006) indicated that application of polymeric chitosan by seed soaking before planting followed by four foliar sprayings throughout cropping season significantly increased ($P<0.05$) the dry matter accumulation in the rice grain.

Lu Chang-min *et al*. (2009) reported that the tomato seed were soaked in different concentration of chitosan solution which were impact on tomato seed germination and the growth of seedlings. The results showed that the tomato main root length and root activity were higher than the control that applied with water. chitosan under low temperature increased shoot and root dry weight in maize plants compared to that of the control.

Afzal *et al* (2005) sprayed Myobi @1, 2 and 3 mg L^{-1} on boro rice. Myobi increased total dry matter production with the increased concentration of Myobi. In general, that the best response was obtained when seeds were applied with 1 mgL^{-1} chitosan during four hours, as this concentration stimulated significantly plant dry weight, although the other indicators were not modified (Martinez et al., 2007).

Afzal *et al.* (2007) were investigated that the effects of seed soaking with plant growth regulators (IAA, GA3, kinetin or prostart) on wheat (*Triticumaestivum* cv. Auqab-2000). Results revealed that the root and shoot length, fresh and dry weight of seedlings were significantly increased by 25 mgL^{-1} kinetin followed by 1% prostart for 2 h treatments under both normal and saline conditions.

Boonlertnirun *et al*. (2006) indicated that application of polymeric chitosan by seed soaking before planting followed by four foliar sprayings throughout cropping season significantly increased ($P<0.05$) the dry matter accumulation in the rice grain.

2.2.2 Number of filled and unfilled grains panicle^{-1}

Jing Peng (2010) of Peking University in China, showed that the radiation produced PGP oligo chitosan has been used for maize, cucumber and so on. A field test indicated that the foliar spray of radiation produced oligo-chitosan and its derivatives could improve per weight, length, and diameter.

Wang *et al*. (2011) showed that the application of chitosan solution with recommended chemical fertilizer significantly increased the number of filled grain panicle^{-1} and the highest the number of filled grain panicle^{-1}.

Sarkar and Singh *et al.* (2002) who found increased the number of filled grains per panicle and decreased the number of unfilled grains per panicle significant increased with the application of N, P, K with chitosan.

2.2.3 Panicle length (cm)

Hoque (2002) conducted a field experiment and observed that the wheat applied with chitosan (0.33 mlL^{-1}) produced the tallest spike (9.00 cm) followed by TNZ303 (8.10 cm) and CL-IAA (7.95 cm). The length of spike in chitosan applied plant was significantly higher than the other treatments.

Guan *et al*. (2009) showed that application of oligo-chitosan also increased mineral uptake of maize and stimulated the growth of maize seedlings. Spraying oligo chitosan with concentration of 60 mgL^{-1}. A positive effect of chitosan was observed on the growth of roots, shoots and leaves of several crop plants (Chibu and Shibayama, 2001). chitosan under low temperature increased shoot height and root length in maize plants compared to that of the control.

ChaweewanBoonreung and SuchadaBoonlertnirun (2013) conducted a pot experiment in an open greenhouse during March to June 2012. The results were revealed that all studied traits of inoculated and non-inoculated rice plants applied with various application methods were not significantly different. Application of chemical fertilizer in combination with chitosan did not significantly differ from application of chemical fertilizer alone on leaf greenness, plant height, dry matter, grain yield and panicle length but significantly differed from those unapplied both chemical fertilizer and chitosan.

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

2.2.4 Thousand grain weight

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

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

Krivtsovm *et al.* (1996) reported that chitosan spray recorded significantly higher rice seed length (8.05 cm) and breadth (2.49 cm) as well as 1000 seed weight (16.55 g) as compared to without chitosan spray (7.98 cm, 2.45 cm and 15.59 g, respectively).

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

Boonlertnirun *et al*. (2007) greenhouse experiments were conducted to determine the effect of chitosan on drought recovery and grain yield of rice under drought conditions. Results revealed that the chitosan applied before drought treatment gave the highest 1000-seed yield and also showed good recovery on yield.

2.2.5 Grain yield

Nguyen Toah and Tran Hanh (2013) conducted an experiment where the field data of their studies showed that the yields of rice significantly increased (~31%) after applying chitosan solution. In general, applying chitosan increased rice production and reduced cost of production significantly.

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

Abdel-Mawgoud *et al*. (2010) conducted a pot experiment and they reported that application of chitosan at 2 mgL^{-1} improve yield components (number and weight) of strawberry plants.

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

SuchadaBoonlertnirun *et al.* (2008) conducted an experiment in which the results showed that application of chitosan by seed soaking and soil application four times throughout cropping season significantly increased rice yield over the other treatments whereas application by seed soaking and spraying the foliar four times tended to show an ability on disease control. However, it did not show statistically significant differences when compared with the control.

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

Uddin *et al*. (2009) studied the effect of four different plant growth regulators viz. Control (No application of PGR), NAA (30 mg L^{-1}), GA (30 mg L^{-1}) and 2, 4-D (30 mg L^{-1}) on tomato. The maximum fruits $plant^{-1}$ (42.66), average weight of individual fruit (92.06 g), yield $plant^{-1}$ (2.49 kg) and yield ha^{-1} (93.23 t ha^{-1}) were found in PGR and the minimum for all parameters were found in control (PGR) treatment.

2.2.6 Harvest index

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

Akter *et al*. (2007) concluded that the highest harvest index (38.50%) was observed from 50 mg L^{-1} GA3 which was statistically identical with 25 mgL^{-1} and the lowest harvest index (32.96%) was obtained in control.

Baruah (1990) observed Wheat cv. Sonalika grown with 100 mgL^{-1} GA3 or 10 mgL^{-1} IAA + $ZnSO_4$ enhanced the harvest index which was the highest over unapplied control and other treatments.

2.2.7 Desease Control

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

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

Li *et al.* (2013) conducted an experiment which showed that the two kinds of chitosan solution possess a strong antibacterial activity against both rice bacterial pathogens and significantly reduced disease incidence and severity by comparison with the control under greenhouse conditions. However, the interaction between chitosan and rice pathogens was affected by the type and concentration of chitosan, the bacterial species and the contact time between chitosan and bacteria. The direct antibacterial activity of chitosan may be attributed to both membrane lysis and the destruction of biofilm. In addition, both chitosan solutions significantly increased the activities of phenylalanine ammonia lyase, peroxidase and polyphenol oxidase in rice seedlings following inoculation of two rice pathogens by comparison with the control.

2.2.8 Others reviews about chitosan on growth, yield parameter and yield

John Berber *et al.* (2012) conducted a pot experiment in an open greenhouse during March to June 2012. The results were revealed that all studied traits of inoculated and non inoculated rice plants applied with various application methods were not significantly different. Application of chemical fertilizer in combination with chitosan did not significantly differ from application of chemical fertilizer alone on leaf greenness, plant height, dry matter, grain yield and panicle numbers but significantly differed from those unapplied both chemical fertilizer and chitosan. However, seeds of dirty panicle disease were significantly affected by various application methods, the lowest numbers were obtained from application of chemical fertilizer in combination with chitosan whereas no application of both chemical fertilizer and chitosan showed negative effect on controlling dirty panicle disease in both inoculated and non-inoculated rice plant.

Van *et al.* (2013) conducted that the increase of the chlorophyll content as a result of application of chitosan may be caused by plants enhanced uptake of nutrients, which occurred in the studies by Nguyen on coffee seedlings.

Mondal*et al*. (2012) showed that, when chitosan used in *Boro rice,* chitosan can increase the yield.

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

Dzung *et al*. (2011) conducted that to reduce transpiration and to induce a range of metabolic changes as a result of which, plants become more resistant to viral, bacterial and fungal infections.

Hasegawa *et al* (2005) reported that corms with an increased diameter and height are obtained as a result of *Arisaemater natipartitum* cultivation in a substrate with an addition of chitosan.

Ohta *et al.* (2004) conducted that earlier flowering resulting from chitosan application was also found in the following species: *Exacum affine, Lobelia erinus, Mimulus×hybridus*, *Sinningia speciosa* and*Torenia fournieri.*

According to Win *et al*. (2005), spraying *Dendrobium*'Missteen' plants with chitosan significantly increased the length of the inflorescence but did not affect the size of flowers.

Ohta *et al.* (1999) conducted that a stimulating effect of chitosan on the number of flowers was observed in plants such as *lisianthus*..

Al-Hetar*et al*. (2011) conducted that chitosan is harmless to crops, animals and humans, and is biodegradable and friendly to the environment.

Wanichpongpan *et al*. (2006) conducted that to introduced as a material to improve grain yield under unfavorable conditions due to their bioactivities to plants such as inducing the plants resistance against a wide range of diseases through antifungal, antibacterial, antivirus activities, stimulating the growth of plants and seed germination, improving soil fertility and enhancing the mineral nutrient uptake of plant, increasing the content of chlorophylls, photosynthesis and chloroplast enlargement.

Bartkowiak *et al*. (2003) reported that seeds of no heading Chinese cabbage dressed with chitosan atthe rate 0.4-0.6 mg g^{-1} seed and leaf spraying with 20-40 micro g ml^{-1} increased fresh weight.

Limpanavech*et al*. (2006) reported that tillers per plant significantly increased($P<0.05$) with the increase in molecular weights of chitosan spray.

Hong *et al*. (1998) Using chitosan in agriculture with less use of chemical fertilizer increases the production, in different kinds of plant, by 15-20%.

Hirano (1996) reported that chitin and chitosan have various biological functions, for instance, antimicrobial activity, growth inhibitor of some pathogens, elicitor of phytoalexins, inducer of chitinase including accelerator of lignification in plants. Compared with chitin, chitosan has high degrees of deacetylation.

A experiment by Rosul *et al.* (2014) showed that applying carboxymethyl chitosan could strongly improve the abilities of transportation of N in functional leaves and stem-sheaths of rice and key enzyme activities of nitrogen metabolism and contents of total N and protein N in brown of rice comparing to CK. Applying 0.5% concentration of carboxymethyl chitosan resulted in the highest rice grain protein and which was 19.8% higher comparing to CK. Therefore, 0.5% carboxymethyl chitosan was recommended for rice production.

Bartnicki-Garcia (1968) showed that chitosan (b-1,4-linked glucosamine) is a deacetylated derivative of chitin found in the composition of cell walls of many fungi. From data in previous reports, two biological roles can be ascribed to this compound. First, at defined concentrations, it presents antifungal properties as shown by its inhibitory action on the mycelial growth of a number of pathogenic fungi, including root pathogens, such as *Fusarium oxysporum* and *Pithium phanidermatum*.

El Ghaouth *et al*. (1994) conducted an experiment at which chitosan is an effective inducer of phytoalexin synthesis in various plant cells (Hadwiger and Beckman, 1980; Ko'hle *et al*., 1984), and triggers callose formation (Ko'hle*et al*., 1985; Conrath*et al*., 1989), lignification responses in wounded wheat leaves (Pearce and Ride, 1982), and the production of proteinase inhibitors (Walker-Simmons *et al*., 1984; Pena-Cortes *et al*., 1988).

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the soil science field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from December 2015 to May 2016. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout of the experimental design, intercultural operations, data recording and their analyses.

3.1 Experimental details

3.2 Site description

The research work was carried out at the experimental field of Sher-e-Bangla Agricultural University, Dhaka. The soil of the experimental plots belonged to the Agro Ecological Zone Madhupur Tract (AEZ-28).

3.3 Geographical location

The experimental area was situated at 23°77′N latitude and 90°33′E longitude at an altitude of 8.6 meter above sea level.

3.4 Agro-ecological region

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.

3.5 Climate

The experimental area is under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the Rabi season (October-March). The weather data during the study period of the experimental site is shown in Appendix II.

3.6 Soil

The farm belongs to the general soil type, Shallow Red Brown Terrace soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Initial Soil pH was 7.2 and had organic carbon 0.63% and organic matter content is 1.09%. The experimental area was flat having available irrigation and drainage system. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The chemical analyses were done in the laboratory of the Department of Soil Science of Sher-e-Bangla Agricultural University, Dhaka-1207.

3.7 Crop/Planting material

BRRI dhan29 were used as the test crop. The variety BRRI dhan29 was developed by Bangladesh Rice Research Institute (BRRI), Joydebpur, Gajipur, Bangladesh for Boro season. The pedigree line of BRRI dhan29is BR 802-118-4-2. Average height of the plant is 95 cm. The grains are medium in size, medium slender and white in color. The growth duration is about 160 days.

3.8 Experimental Treatments

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

Variety: BRRI dhan29

T_1: seedbed applied CHT powder at 100 g/m^2

T_2: seedbed applied CHT powder at 200g/m^2

T_3: seedbed applied CHT powder at 300g/m^2

T_4: seedbed applied CHT powder at 400g/m^2

T_5: seedbed applied CHT powder at 500g/m^2

T_6: seedbed applied CHT powder at 0g/m^2

Every treatment received N, P and K as basal doses.

Table 1: Name of the element, rate (kg ha^{-1}) and name of the fertilizer used for the experiment:

Name of the element	**Rate (kg ha^{-1})**	**Name of the fertilizer**
N	195	Urea
P	72	Triple Super Phosphate(TSP)
K	120	Muriate of Potash (MOP)
S	68	Gypsum
Zn	5	Zinc sulphate

Ref. According to Fertilizer Recommendation Guide, 2012.

3.9 Preparation of modified chitosan

Chitosan was prepared using shrimp shell byproducts collecting from the Khulna region of Bangladesh following a new traditional method. The prepared chitosan was used in the experiment during the final land preparation.

3.10 Experimental design

The experiment was laid out in a Randomized Complete Block Design (factorial). Each treatment was replicated three times. The size of a unit plot was 4 m × 1.5 m. Total plots in the experimental field were 54. The treatments were randomly distributed to each block. The distance between two adjacent replications (block) was 1m and row-to-row distance was 0.5 m. The inter block and inter row spaces were used as footpath and irrigation or drainage channel.

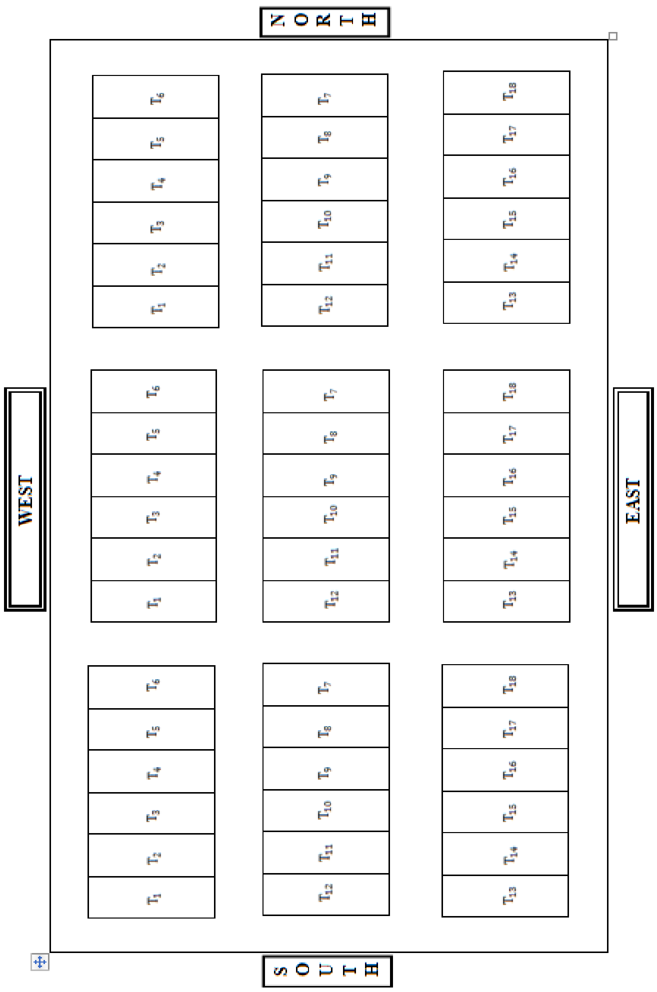

Fig: The layout of the experimental field

Distance between replications: 1m
Distance between treatments: 0.5m
Total length of the field:(6×3m) + (7×0.5m) = 21.5m
Total width of the field:(3×3m)+(0.5m+1m+1m+0.5m= 12m
Total area of the field:L×B = 21.5m × 12m = 258m2

Treatment Combinations:
T1: seedbed applied with CHT powder @ 100 g/m2
T2: seedbed applied with CHT powder @ 200 g/m2
T3: seedbed applied with CHT powder @ 300g/m2
T4: seedbed applied with CHT powder @ 400g/m2
T5: seedbed applied with CHT powder @ 500g/m2
T6: seedbed applied with CHT powder @ 0g/m2

3.11 Growing of crops

3.12 Seed collection and sprouting

Seeds BRRI dhan29 were collected from BRRI, Joydebpur, Gazipur, Bangladesh. Healthy seeds were selected following standard method. Seeds were immersed in water in a bucket for 24 hrs. These were then taken out of water and tightly kept in gunny bags. The seeds started to sprout after 48 hrs which became ready for sowing in 72 hrs.

3.13 Raising of seedlings

A common procedure was followed in rising of seedlings in the nursery bed. The nursery bed was prepared by puddling with repeated ploughing followed by laddering. Weeds were removed and irrigation was gently provided to the bed as and when needed. No fertilizer was used in the nursery bed.

3.14 Seed sowing

Seeds were sown on the nursery bed on December 09, 2015 for raising nursery seedlings.

3.15 Preparation of experimental land

The experimental field was first opened on January 09, 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 with a tractor plough and subsequently leveled by laddering. All kinds of weeds and residues of previous crop 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 with the help of wooden plank so that no water pocket could remain in the puddle field.

3.16 Fertilizer dose and methods of application

Unit plots of the experiment were fertilized with 195, 72, 120, 68 and 5 kg/ha of urea, triple super phosphate (TSP), muriate of potash (MOP), gypsum and zinc sulphate 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. Urea was top-dressed in three equal splits. The first one-third urea applied on January 30, 2016 after transplanting in 15 days , second during the vegetation stage after 30days in first dose on March 02, 2016 and third dose at 15 later when panicle initiation is starting .

3.17 Transplanting of seedlings

40 days old seedlings were uprooted carefully from the nursery beds on 14 January, 2016 for transplantation. For this purpose the nursery beds were made wet by the application of water in previous day before uprooting the seedlings to minimize mechanical injury of roots. One seedling was transplanted in each hill.

3.18 Intercultural operations

3.18.1 Irrigation

After transplanting 5-6 cm water was maintained in each plot through irrigation during the growth period.

3.18.2 Gap filling

After one week of transplantation, a minor gap filling was done as and where necessary using the seedling or separated tillers from the previous source as per treatment.

3.18.3 Weeding

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

3.18.4 Application of CHT:

CHT was applied in two split doses. In seedbed CHT was applied at a rate of 250g/m^2,and in main field CHT was applied at a rate of 0.5 ton ha^{-1} at 25/8/2015.

3.18.5 Plant protection measures

Plants were infested with rice stem borer (*Scirphophagain certolus*) and leaf hopper (*Nephotettixni gropictus*) to some extent which were successfully controlled by applying Diazinon @ 10 ml/10 liter of water for 5 decimal lands and by Ripcord @ 10 ml/10 liter of water for 5 decimal lands as and when needed. Crop was protected from birds during the grain filling period. For controlling the birds watch man was deep attention , especially during morning and afternoon.

3. 18.6 General observation of the experimental field

The field was investigated time to time 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 disease was observed in the field.

3.18.7 Harvesting and post harvest operation

Maturity of crop was determined when 90% of the grains became golden yellow in color. Harvesting was done on May 02, 2016. Three hills per plot were preselected randomly from which different growth and yield attributes data were collected and 1m^2 areas from middle portion of each plot was separately harvested and 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 to a moisture content of 14 % approximately. Straw was also sun dried properly. . Finally grain and straw yields $plot^{-1}$ were recorded and converted to t ha^{-1}.

3.18.8 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 non effective 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 (%)

3.18.9 Procedure of data collection

A. Crop growth characters

3.18.10 Plant height (cm) at harvest

Plant height was measured from the ground level to the top of the tallest panicle. Plants of 3 hills were measured and averaged for each plot

3.18.11 Number of tillers/hill

Number of tillers/hillwere 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

3.18.12 Effective tillers/hill (no.)

The panicles which had at least one grain was considered as effective tillers. The number of effective tillers/hill was recorded and finally averaged for counting effective tillers number /hill.

3.18.13 Non effective tillers/hill (no.)

The tiller having no panicle was regarded as ineffective tillers. The number of ineffective tillers/hill was recorded and finally averaged for counting ineffective tillers number/m^2.

3.18.14 Panicle length (cm)

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 3 panicles.

3.18.15 Filled grains/panicle(no.)

Grain was considered to be filled if any kernel was present there in. The number of total filled grains present on five panicles were recorded and finally averaged.

3.18.16 Unfilled grains/panicle(no.)

Unfilled grains means the absence of any kernel inside and such grains present on each of 3 panicles were counted and finally averaged.

3.18.17 Total grains/panicle(no.)

The number of filled grains/panicle plus the number of unfilled grains/paniclegave the total number of grains/panicle.

3.18.18 Weight of 1000 grains (g)

One thousand cleaned 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.

3.18.19 Grain yield (t/ha)

Grain yield was determined from the central 1m^2 areas of each plot and expressed as t/ha on about 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

3.18.20 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.

3.18.21 Biological yield (t/ha)

Grain yield and straw yield were all together regarded as biological yield. Biological yield was calculated with the following formula:

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

3.18.22 Harvest Index (%)

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

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.18.23 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.

3.18.23.1 Soil p^H

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

3.18.23.2 Organic C

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

Chapter IV

Results and Discussion

CHAPTER IV

RESULT AND DISCUSSION

This chapter comprises of the presentation and discussion of the results obtained due to application of different rate of chitosan on growth and yield of BRRI dhan29 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 Growth and Yield Components

4.1.1 Fresh weight production of Boro rice seedlings (BRRI dhan29) are notably increased at 25 DAS

Fresh weight production of Boro rice seedlings were significantly increased with the chitosan powder treatments in the seedbed. The maximum fresh weight production (29.14 g) was found in the treatment T4 having 400 g powder/m2 which was statistically different than all other treatments. The second highest fresh weight production (27.92 g) was found in the treatment T5 which was statistically identical with the treatment T3 (27.2 g). The production of fresh weight in the treatment T1 was 25.78 g which was statistically identical with the treatment T2 (25.5 g). The lowest fresh weight production (12.6 g) was found in the treatment T6 which was significantly different than all other treatments. These results indicate that fresh weight productions of boro rice seedlings were influenced by the chitosan powder treatments and this might be due its nutritional supplementations to the soil. Results are supported by the following research results. Chitosan promotes shoot and root growth (Tsugita *et al*., 1993; Arif *et al.*, 2015). Application of CHT can increase the microbial population by large numbers and transforms organic nutrient into inorganic nutrient which is easily absorbed by the plant roots (Bolto *et al*., 2004). The organic manures viz.

sludge and spray of CHT increases the efficiency of applied N (Saravanan *et al.*, 1987).

4.1.2 Oven dry weight production of Boro rice seedlings (BRRI dhan29) are impressively increased at 25 DAS

Oven dry weight production of the Boro rice seedlings were significantly increased due to the application of chitosan powder. The maximum oven dry weight (6.43 g) was found in the treatment T4 having 400 g powder/m2 which was statistically different than all other treatments. The second highest oven dry weight production (6.23 g) was found in the treatment T5 which was statistically identical with the treatment T1 (6.1 g). The production of oven dry weight in the treatment T2 was 6.07 g which was statistically identical with the treatments T3 (6.00 g) and T1. The lowest oven dry weight production (3.5 g) was found in the treatment T6 (control) which was significantly lower than all other treatments (Tsugita *et al.*, 1993; Arif *et al.*, 2015) These results indicate that oven dry weight productions of boro rice seedlings were influenced by the chitosan powder applications and this might be due its nutritional support to the seedlings, improvement of growth promoting hormonal activity and could be improve the biological as well as physioco-chemical properties of the seedbed soils.

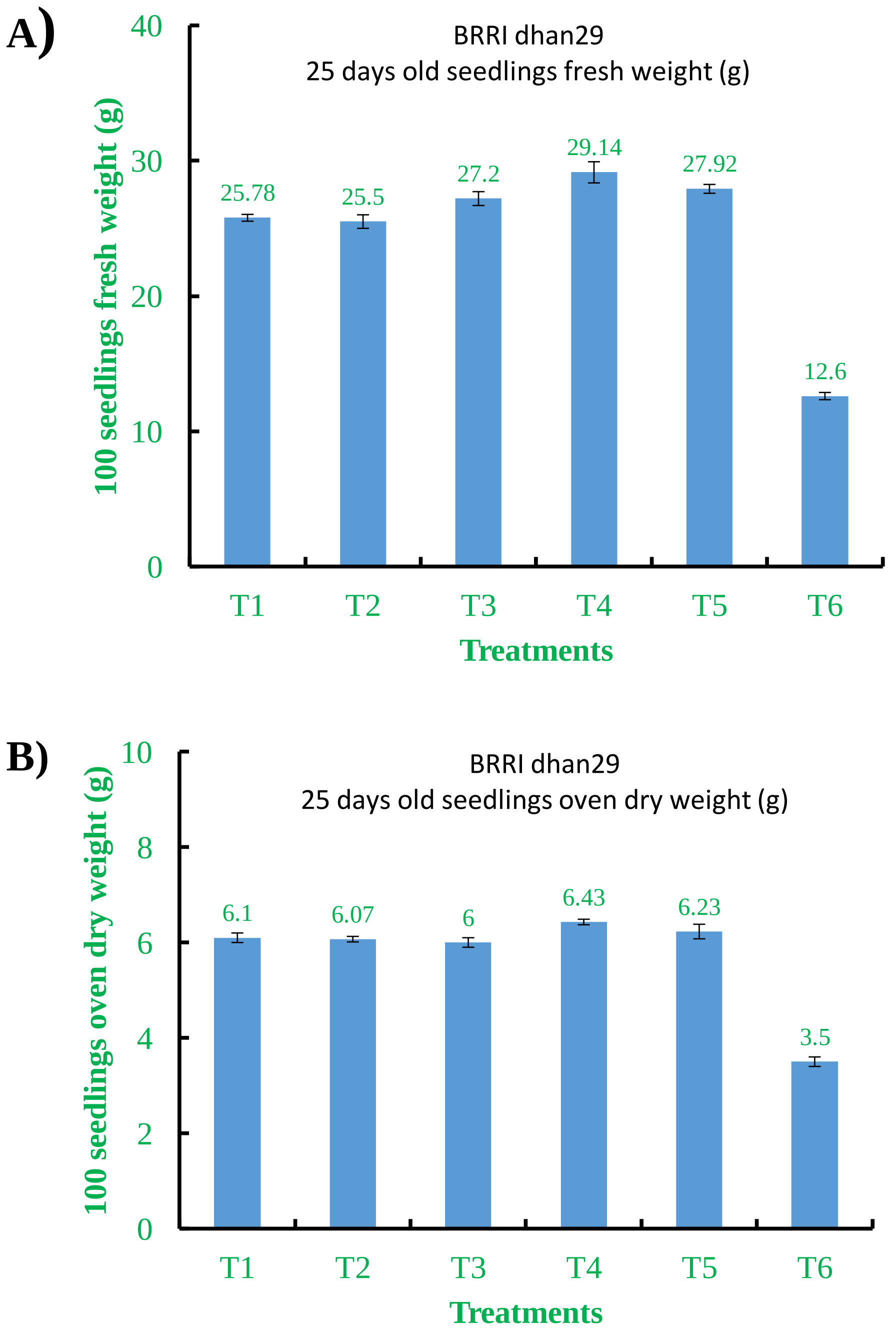

Figure 1: Effect of chitosan powder on the biomass production of 25 days old Boro rice seedlings (BRRI dhan29); A) Chitosan powder-induced fresh weight (g) production of Boro rice seedlings. B) Chitosan powder-induced oven dry weight (g) production of Boro rice seedlings. T_1=100 g powder/m2, T_2=200 g powder/m2, T_3=300 g powder/m2, T_4=400 g powder/m2, T_5=500 g powder/m2, T_6=0 g powder/m2.

4.1.3 Fresh weight production of 35 days old Boro rice seedlings are notably increased

Fresh weight production of Boro rice seedlings were significantly increased with the chitosan powder treatments. The maximum fresh weight production (44.95 g) was found in the treatment T_5 having 500 g powder/m2 which was statistically different than all other treatments. The second highest fresh weight production (42.2 g) was found in the treatment T_4 which was statistically identical with the treatment T_3 (39.8 g). (Fig 2A) The production of fresh weight in the treatment T_2 was 35.9 g which was statistically identical with the treatment T_1 (31.95 g). The lowest fresh weight production (17.9 g) was found in the treatment T_6 which was significantly different than all other treatments. These results indicate that fresh weight productions of boro rice seedlings were influenced and this might be due its nutritional supplementations to the soil as well as the improvement of growth promoting hormonal activity. Results are supported by the following research results. Chitosan promotes shoot and root growth (Tsugita*et al*., 1993). Application of CHT can increase the microbial population by large numbers and transforms organic nutrient into inorganic nutrient which is easily absorbed by the plant roots (Bolto *et al*., 2004). The organic manures viz. sludge and spray of CHT increases the efficiency of applied N (Saravanan *et al.*, 1987).

4.1.4 Oven dry weight production of 35 days old Boro rice seedlings are impressively increased

Oven dry weight production of the Boro rice seedlings were significantly increased due to the chitosan powder application. The maximum oven dry weight (9.6 g) was found in the treatment T_5 having 500 g powder/m2 which was statistically different than all other treatments (Fig 2B). The second highest oven dry weight production (8.65 g) was found in the treatment T_4 which was statistically identical with the treatment T_3 (8.25 g). The production of oven dry weight in the treatment T_2 was (7.75 g) which was statistically identical with the treatments T_1 (6.65 g) . The lowest oven dry weight production (3.65 g) was found in the treatment T_6 (control) which was significantly different than all other treatments. These results indicate that oven dry weight productions of (BRRI dhan29) seedlings were influenced by the chitosan powder applications and this might be due its macro-micro nutritional supports alkalization of the soil environment, improvement of growth promoting hormonal activity with could be improve the biological as well as physioco-chemical properties of the seedbed soils.

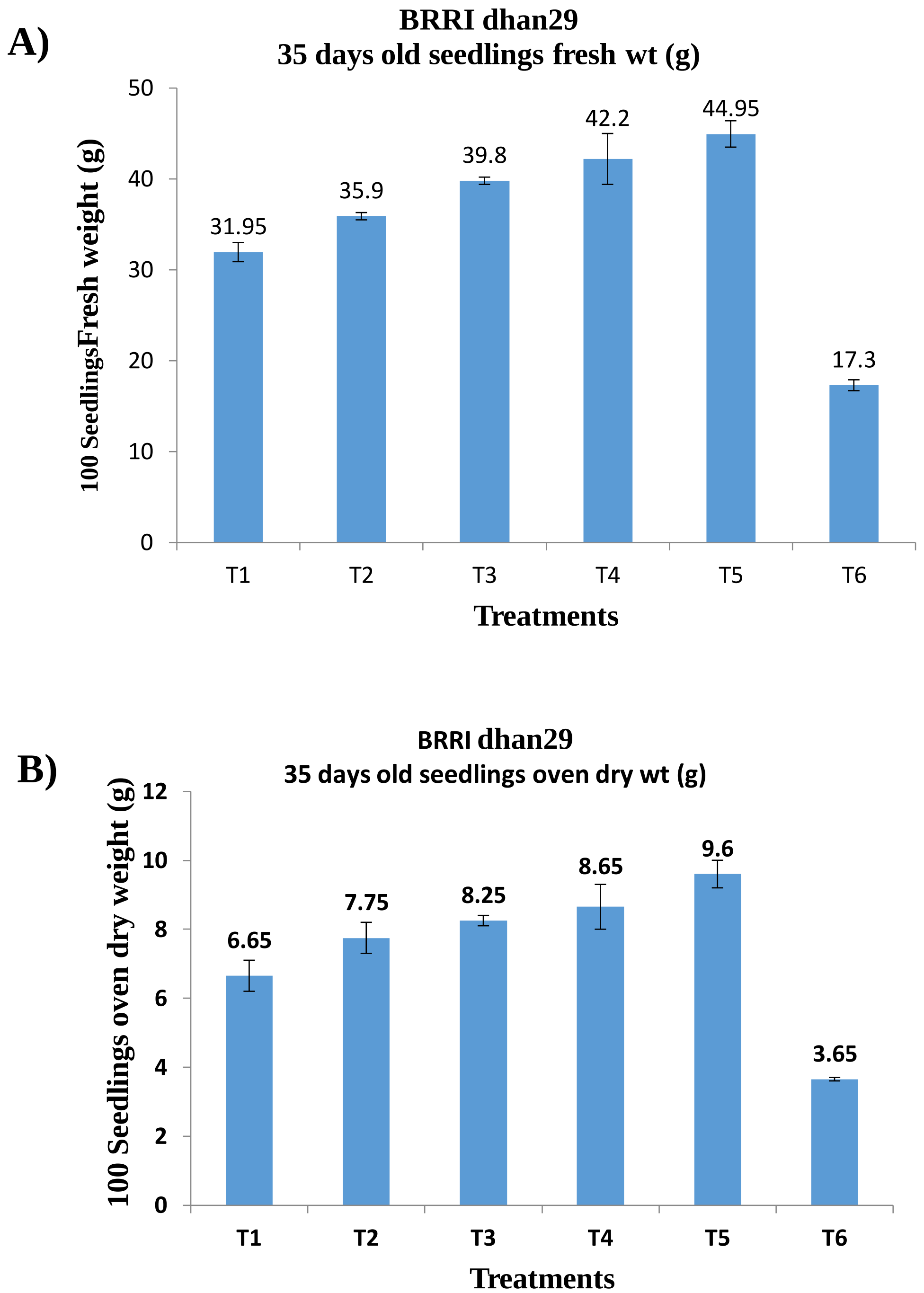

Figure 2: Effect of chitosan powder on the biomass production of 35 days old Boro rice seedlings (BRRI dhan29); A) Chitosan powder-induced fresh weight (g) production of Boro rice seedlings. B) Chitosan powder-induced oven dry weight (g) production of Boro rice seedlings. T_1=100 g powder/m2, T_2=200 g powder/m2, T_3=300 g powder/m2, T_4=400 g powder/m2, T_5=500 g powder/m2, T_6=0 g powder/m2.

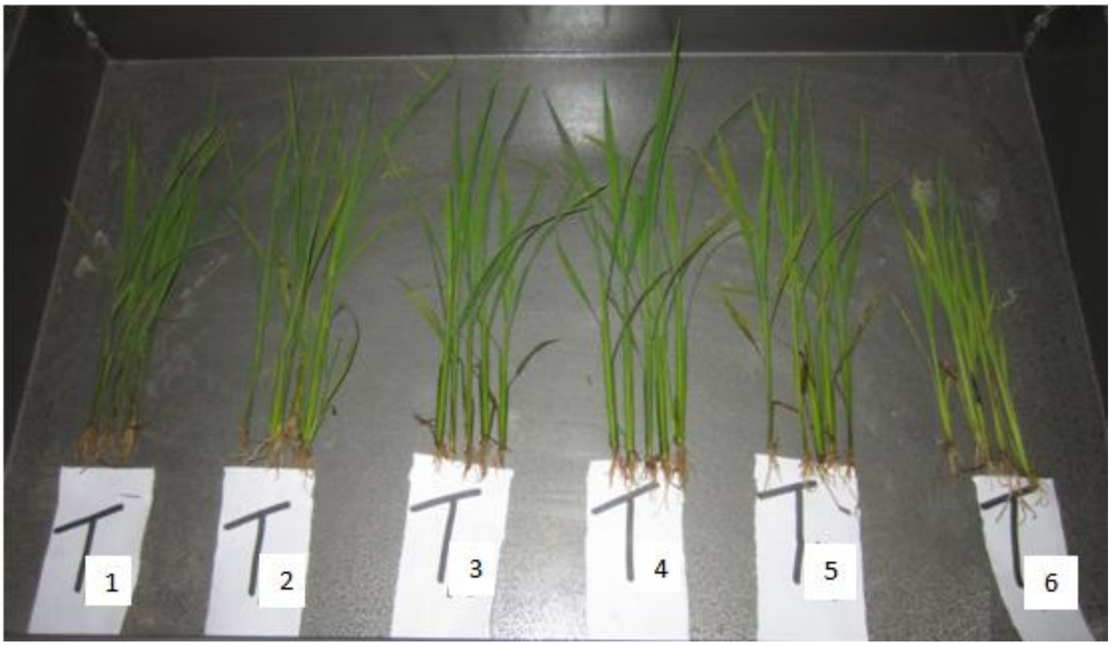

Figure 3: Typical picture of the 35 days old boro rice seedlings produced with the treatments of chitosan powder in the seedbed. T_1 = 100 g powder/m^2, T_2 = 200 g powder/m^2, T_3 = 300 g powder/m^2, T_4 = 400 g powder/m^2, T_5 = 500 g powder/m^2, T_6 = 0 g powder/m^2.

4.1.5 **Seedling height (cm)**

Seedling height was found to be statistically significant in all of the treatments used in the experiment. The maximum seedling height (17.13 cm) was obtained in the T_4 treatment having CHT powder @ 400 g/m^2 and minimum seedling height(12.83 cm) was obtained in the control treatment T_6 having CHT powder @ 0 g/m^2 (Table 2). According to the seedling height the treatments combinations can be arranged as T_4> T_5>T_3>T_2>T_1>T_6. These results were supported by Boonlertnirun *et al.* (2008) who found that application of chitosan stimulate the seedling height significantly.

4.1.6 **Single Seedling oven dry wt. (mg)**

Single seedling oven dry weight was found to be statistically significant in all of the treatments used in the experiment. The maximum single seedling oven dried weight (359.60 mg) was obtained in the T_5 treatment having CHT powder @ 500g/m^2 and minimum seedling weight (138.40 mg) was obtained in the T_6 control treatment having CHT powder @ 0 g/m^2 (Table 2). According to the seedling strength the treatments were arranged as $T_5 > T_4 > T_3 > T_1 > T_2 > T_6$. These results were supported by Boonlertnirun *et al.* (2008) who found that application of chitosan stimulate the seedling dry matter weight significantly.

4.1.7 **Seedling strength (mg/cm)**

Seedling strength is a strong indicator of measuring good quality seedlings. Seedling strength was found to be statistically significant in all of the treatments used in the experiment. The maximum seedling strength (21.79mg/cm) was obtained in the T_5 treatment having CHT powder @ 500 g/m^2 and minimum seedling strength (10.80 mg/cm) was obtained in the T_6 treatment having CHT powder at 0 g/m^2 (Table 2). According to the seedling strength the treatments may be arranged as $T_5 > T_4 > T_3 > T_2 > T_1 > T_6$. The seedlings strength was approximately double due to the treatments indicating a very good quality Boro rice seedling that might be increase the growth and yield. These results were supported by Boonlertnirun *et al.* (2008) who found that application of chitosan stimulate the seedling strength significantly.

Table 2. Effects of chitosan powder on seedling strength (mg/cm) of BRRI dhan29 at 35 DAS. SAU, 2016.

Treatments	Seedling height (cm)	Single seedling oven dry wt (mg)	Seedling strength (mg/cm)
T_1	15.35	255.60	16.66
T_2	16.18	287.20	17.70
T_3	16.37	318.40	19.47
T_4	17.13	337.60	19.72
T_5	16.51	359.60	21.78
T_6	12.83	138.40	10.80
LSD (0.05)	0.65	22.09	1.60
CV (%)	2.27	3.27	4.96
Level of significance	*	**	**

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

T_1: seedbed applied CHT powder @ 100 g/m^2

T_2: seedbed applied CHT powder @ 200g/m^2

T_3: seedbed applied CHT powder @ 300g/m^2

T_4: seedbed applied CHT powder @ 400g/m^2

T_5: seedbed applied CHT powder @ 500g/m^2

T_6: seedbed applied CHT powder @ 0g/m^2

4.1.8 Plant height (cm)

The plant height was not found to be statistically insignificant in all of the treatments used in the experiment. The maximum plant height (91.8cm) was obtained in the T_1 treatment and minimum plant height (83.1 cm) was obtained in the T_4 treatment (Fig 4). According to the plant height the treatments may be arranged as T_1> T_6 >T_3>T_2>T_5>T_4. 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.

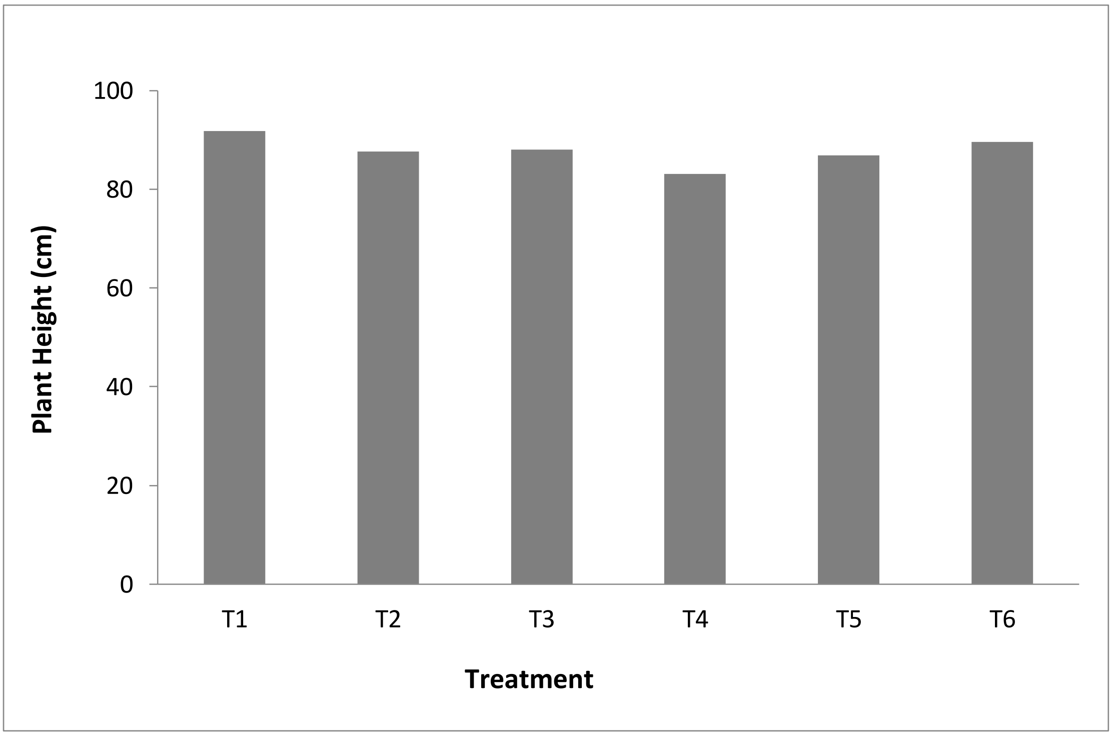

Figure 4. Effect of different treatments on plant height of BRRI dhan29. Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD.

4.1.9 Non effective tillers/hill

Non-Effective tillers hill^{-1}, one of the agronomic characteristics, was found to be statistically insignificant in all of the treatments used in the experiment. The maximum non-effective tillers (4.33) was obtained in the T_3 treatment CHT powder at 300 g/m^2 and minimum non-effective tillers (2.00) was obtained in the T_1 treatment CHT powder at 100 g/m^2. According to the number of non-effective tillers the treatments may be arranged as $T_3>T_6>T_4>T_5>T_2>T_1$.

Table 3: Effects of different treatments on yield contributing characters of BRRI dhan29at harvest.Mean was calculated from three replicates for each treatment.

Treatments	Plant height (cm)	Non-Effective Tillers Hill^{-1}
T_1	91.82	2.00
T_2	87.67	2.33
T_3	87.97	4.33
T_4	83.05	2.67
T_5	86.90	2.45
T_6	89.56	3.33
LSD (0.05)	4.77	2.9783
CV (%)	3.0	52.61

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

T_1: seedbed applied CHT powder @ 100 g/m^2
T_2: seedbed applied CHT powder @ 200g/m^2
T_3: seedbed applied CHT powder @ 300g/m^2
T_4: seedbed applied CHT powder @ 400g/m^2
T_5: seedbed applied CHT powder @ 500g/m^2
T_6: seedbed applied CHT powder @ 0g/m^2

4.1.10 Effective tillers/hill

Effective tillers/hill was found to be statistically insignificant in all of the treatments used in the experiment. The maximum number of effective tillers/hill (12.37) was obtained in the T_4 treatment and the minimum no of effective tillers/hill (10.63) was obtained in the T_6 control treatment having not applied of modified chitosan. (Table 4). According to the no of effective tiller the treatments may be arranged as T_4> T_3 >T_5>T_2>T_1>T_6.

4.1.11 1000-grain weight (g)

Table 4 shows the effects of different treatments on 1000-grain weight. It was found that 1000-grain weight statistically non significant. The highest 1000-grain weight (133.36g) was obtained in the T_4 (seedbed applied CHT powder at 400g/m^2) and lowest 1000-grain weight (120.14g) was obtained in the T_3 (seedbed applied CHT powder at 300g/m^2). However the 1000-grain weight did not differ significantly in T_1, T_2, T_4, T_5 treatments. In case of 1000-grain weight the treatments may be arranged as T_4>T_1>T_6>T_5>T_2>T_3.

Table 4. Effects of chitosan on effective tillers/hill , Panicle length (cm) and 1000-grain weight(g) 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.

Treatment (dose)	Effective tiller/hill	Panicle length(cm)	1000-grain weight(gm)	No. of filled grain/panicle	No. of unfilled grain/panicle
T_1	11.49	25.86	130.52	90.30	12.50
T_2	11.51	26.20	121.57	95.15	12.09
T_3	12.24	26.05	120.14	97.10	13.13
T_4	12.37	26.50	133.36	98.70	11.13
T_5	11.93	26.14	126.10	89.90	11.69
T_6	10.63	26.17	127.78	87.90	10.20
LSD(0.05)	2.97	1.07	13.02	11.05	1.40
CV (%)	13.97	2.27	2.67	2.73	11.79
Level of significance	NS	NS	NS	NS	NS

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

T_1: seedbed applied CHT powder at 100 g/m^2

T_2: seedbed applied CHT powder at 200g/m^2

T_3: seedbed applied CHT powder at 300g/m^2

T_4: seedbed applied CHT powder at 400g/m^2

T_5: seedbed applied CHT powder at 500g/m^2

T_6: seedbed applied CHT powder at 0g/m^2

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

4.1.12 Panicle length (cm)

Panicle length was found to be statistically insignificant in all of the treatments used in the experiment (Table 4). Panicle length was not influenced significantly although there Was some apparent difference in panicle length in different treatments.The maximum Panicle length (26.50cm) was obtained in the T_4 treatment (seedbed applied CHT powder at 400g/m^2) and minimum panicle length (25.86cm) was obtained in the T_1 treatment (seedbed applied CHT powder at 100 g/m^2). According to the Panicle length the treatments may be arranged as $T_4>T_2>T_6>T_5>T_3>T_1$.

4.1.13 Number of filled grains/panicle

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 (98.70) was obtained in the T_4 treatment (seedbed applied CHT powder at 400g/m^2) and lowest number of filled grains/panicle (87.90) was obtained in the T_6control treatment (seedbed applied CHT powder at 0 g/m^2). According to the filled grains/panicle the treatments may be arranged as $T_4>T_3>T_2>T_1>T_5>T_6$.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

4.1.14 Number of unfilled grains/panicle

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 (13.13) was obtained in the T_3 treatment CHT powder at 300g/m^2 and lowest number of unfilled grains/panicle (10.20) was obtained in the T_6,control treatment CHT powder at 0 g/m^2. According to the unfilled grains/panicle the treatments may be arranged as T_3>T_1>T_2>T_5>T_4>T_6.

4.2 Yield Components

4.2.1 Grain yield (t/ha)

Figure 5 shows the effects of different treatments on grain yield. Grain yield was significantly influenced by the chitosan treatment. Grain yield was increased due to the chitosan treatment compare to the control treatment. The highest grain yield (8.90 t/ha) was obtained in the T_4 (CHT powder at 400g/m^2) treatment which was significantly greater than that obtained in the T_6 control (CHT powder at 0g/m^2)and T_1 treatment (CHT powder at 100 g/m^2) and statistically identical to T_2 (CHT powder at 200 g/m^2) and T_3 (CHT powder at 300 g/m^2) treatment. However the grain yield did not differ significantly in T_2, T_3, T_4, T_5 treatments. The lowest grain yield (7.80 t/ha) was obtained in the T_6(seedbed applied modified CHT powder at 0g/m2)control treatment which is statistically identical to T_1 treatment. In terms of grain yield the treatments may be arranged as T_4>T_3>T_5>T_2>T_1>T>T_6. It was observed that, as the rate of 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).

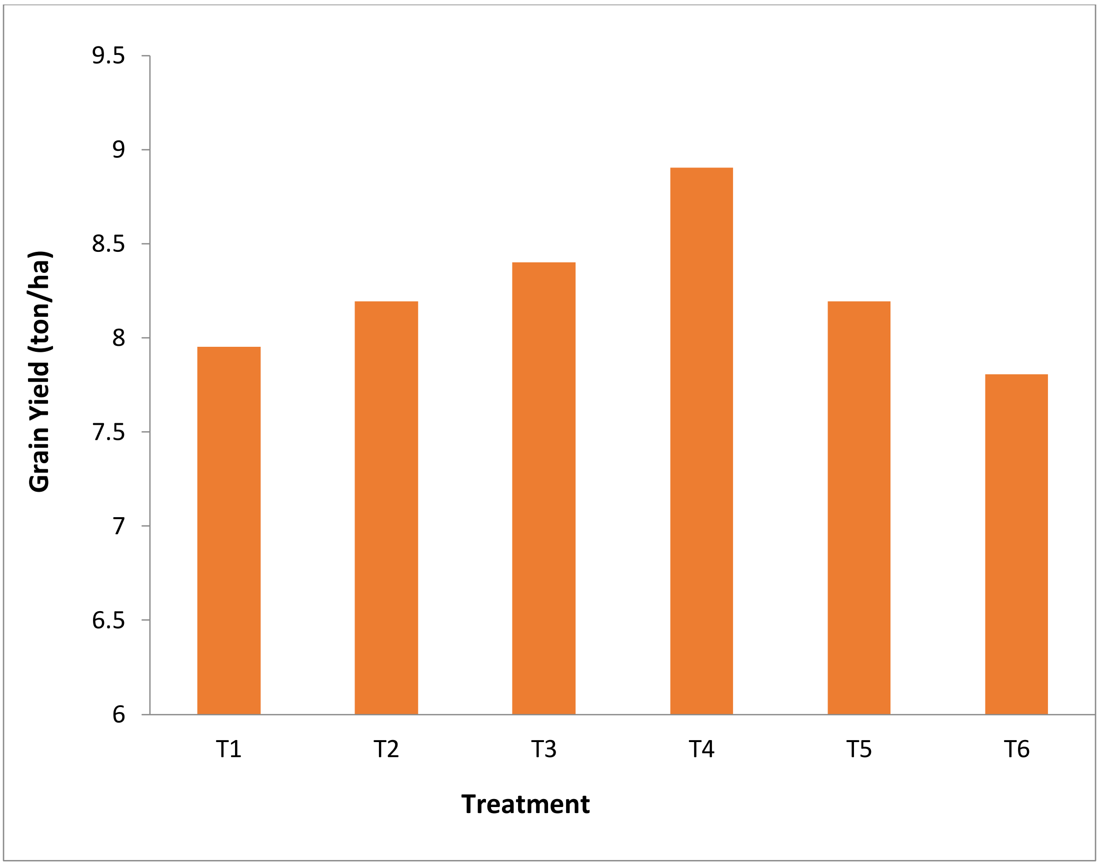

Figure 5. Effects of different doses of chitosan on grain yield of BRRI dhan29. Mean was calculated from three replication for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT. SAU, 2016.

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

T_1: seedbed applied CHT powder @ 100 g/m^2

T_2: seedbed applied CHT powder @ 200g/m^2

T_3: seedbed applied CHT powder @ 300g/m^2

T_4: seedbed applied CHT powder @ 400g/m^2

T_5: seedbed applied CHT powder @ 500g/m^2

T_6: seedbed applied CHT powder @ 0g/m^2

4.2.2 Straw yield (t/ha)

The effects of different treatments on straw yield were significantly influenced by the chitosan treatment (Fig 6). Straw yield was increased due to the chitosan treatment compare to the control treatment. The highest straw yield (11.83 t/ha) was obtained in the T_4 (CHT powder at 400g/m^2) treatment which was significantly greater than that obtained in the T_6 control (CHT powder at 0g/m^2)and T_1 treatment (CHT powder at 100g/m^2) and statistically identical to T_2 (CHT powder at 200g/m^2) and T_3 (CHT powder at 300g/m^2) treatment. However the straw yield did not differ significantly in T_2, T_3, $T_{4,}$ T_5 treatments. The lowest straw yield (9.83 t/ha) was obtained in the T_6(CHT powder at 0g/m^2)control treatment which is statistically identical to T_1 treatment. In terms of straw yield the treatments may be arranged as $T_4>T_5>T_3>T_2>T_1>T_{6.}$ It was observed that, as the rate of chitosan application in soil increases straw 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 straw yield of rice show significant differences between control plants and foliar sprayed chitosan plants.

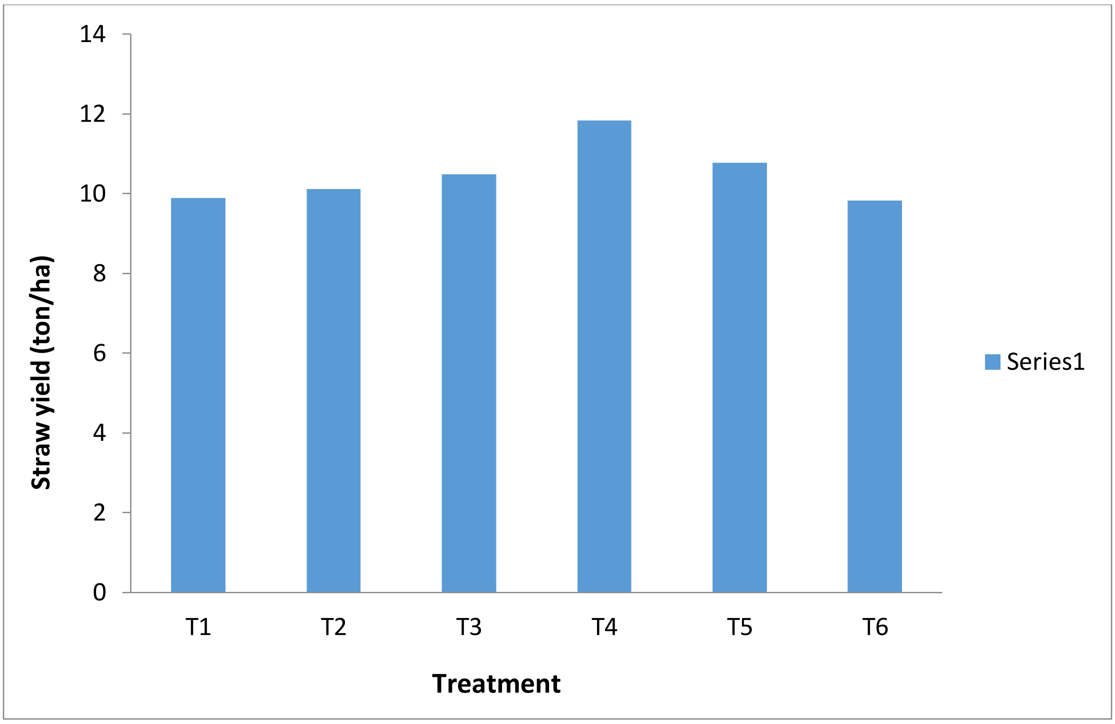

Figure 6.Effects of different doses of chitosan on straw yield of BRRI dhan29.Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT. SAU, 2016.

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

T_1: seedbed applied CHT powder @ 100 g/m^2

T_2: seedbed applied CHT powder @ 200g/m^2

T_3: seedbed applied CHT powder @ 300g/m^2

T_4: seedbed applied CHT powder @ 400g/m^2

T_5: seedbed applied CHT powder @ 500g/m^2

T_6: seedbed applied CHT powder @ 0g/m^2

4.2.3 Biological yield (t/ha)

Biological yield were significantly influenced by the chitosan treatment. Biological yield was increased due to the chitosan treatment compare to the control treatment. The highest biological yield (20.73 t/ha) was obtained in the T_4 (CHT powder at 400g/m^2) treatment which was significantly greater than that obtained in the T_6 control (CHT powder at 0 g/m2)and T_1 treatment (CHT powder at 100g/m^2) and statistically identical to T_2 (CHT powder at 200g/m^2) and T_3 (CHT powder at 300g/m^2) treatment. However the biological yield did not differ significantly in T_2, T_3, T_4 treatments. The lowest biological yield (17.64 t/ha) was obtained in the T_6(seedbed applied modified CHT powder at 0 g/m2)control treatment which is statistically identical to T_1 treatment. In terms of biological yield the treatments may be arranged as $T_4>T_5>T_3>T_2>T_1>T_6$. It was observed that, as the rate of chitosan application in soil increases biological yield also increases.

4.2.4 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 chitosan treatments on BRRI Dhan29 (Table 5). From the results, it was found that the highest harvest index (44.85%) was obtained from the treatment T_3 (CHT powder at 300g/m^2) and the lowest harvest index (43.00%) was obtained in the T_4 control treatment (CHT powder at 400g/m^2)

Table 5.Effects of different doses of chitosan on Biological yield and harvest index of BRRI dhan29 at harvest.SAU, 2016.

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
T_1	7.95	9.88	17.84	44.58
T_2	8.19	10.10	18.30	44.81
T_3	8.40	10.48	18.89	44.85
T_4	8.90	11.83	20.73	43.00
T_5	8.19	10.77	18.96	43.35
T_6	7.80	9.83	17.64	44.30
LSD (0.05)	0.28	0.83	0.70	5.30
CV (%)	2.38	6.37	2.84	6.25
Level of significance	*	**	**	NS

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

T_1: seedbed applied CHT powder @ 100 g/m^2

T_2: seedbed applied CHT powder @ 200g/m^2

T_3: seedbed applied CHT powder @ 300g/m^2

T_4: seedbed applied CHT powder @ 400g/m^2

T_5: seedbed applied CHT powder @ 500g/m^2

T_6: seedbed applied CHT powder @ 0g/m^2

4.3 Role of chitosan on the chemical properties of post transplanted seedbed soils

4.3.1 Organic carbon status of the post transplanted seedbed soils

Application of chitosan in the seedbed soil tends to increment of organic carbon content. The organic carbon content was increased with increasing the level of chitosan in the seedbed soils. Maximum organic carbon content (1.18 %) was found in the treatment T5 having applications of 500 g/m^2 of chitosan in the seedbed which was statistically identical with the treatments T4 (1.08%) and T3 (0.97%). However, minimum carbon content (0.62%) was found in the treatment T6 which was statistically identical with the treatment T2 (Table 6). The organic carbon content was increased in a dose dependent manner, it might be due to the use of chitosan containing high amount of organic carbon level. This result suggests that chitosan application might be increase the level of organic matter in soils (Arif et. al, 2015).

Table 6. Organic carbon and organic matter status of the Post transplanted Rice seedbed soil induced by the chitosan powder, SAU, 2016.

Treatments	**Post transplanted Rice seedbed soil**	
	% OC	%OM
T1	0.77e	1.32f
T2	0.87d	1.49d
T3	0.97c	1.67c
T4	1.08b	1.87b
T5	1.18a	2.04a
T6	0.62f	1.06f
CV	3.69	3.70
LSD	0.095	0.165

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

T_1: seedbed applied CHT powder @100 g/m^2

T_2: seedbed applied CHT powder @ 200g/m^2

T_3: seedbed applied CHT powder @ 300g/m^2

T_4: seedbed applied CHT powder @ 400g/m^2

T_5: seedbed applied CHT powder @ 500g/m^2

T_6: seedbed applied CHT powder @ 0g/m^2

4.3.2 Organic matter status of the post transplanted rice seedbed soil

Organic matter content of rice seedbed soil showed significant differences among treatments. Organic matter content of rice seedbed soil was varied from 2.04% to 1.06% respectively among the treatments (Tab. 6). Maximum organic matter content (2.04%) was found in the treatment T5 having500 g/m^2 chitosan in the soils, which was statistically identical with the treatments T4 (1.87%) and T3 (1.67%). Whereas minimum organic matter content (1.06%) was found in the treatment T6 having no chitosan application and it was statistically identical with the treatment T2 (1.49%) having chitosan application at 200 g/m^2. Increasing organic matter content for the sustainable agriculture is a big challenge to the Bangladesh soils; however, the chitosan application could play a crucial role to increase the organic matter content in soils. (Arif et at., 2015)

4.3.3 Chotosan-induced alkalizationof the post transplanted rice seedbed soil

A significant variation was found in the rice seedbed soil alkalization at 35 days after sowing due to the different treatment combinations (Fig. 7). The alkalization value of the rice seedbed soil was ranged from 6.13 to 7.17 (Fig. 7). The highest alkalization value (7.17) was recorded in T_5 treatment having 500 g/m^2 chitosan. On the other hand, seedbed soil alkalization of the control treatment T6 was 6.13 having no chitosan in the seedbed soils. The alkalization of the control seedbed soil T_6 was the lowest; it might be due to the non-application of the chitosan in the seedbed soils. Application of chitosan might be neutralized the seedbed soils, which might be improved the seedbed soil environment due to the increment of soil alkalization levels. Many causes could be involved in the improvement of seedbed soil environment due to the application of the chitosan in the seedbed soils. Nutrient supplementation will be increased due to the increment of alkalization levels which will improve the biological and physico-chemical properties of soil.

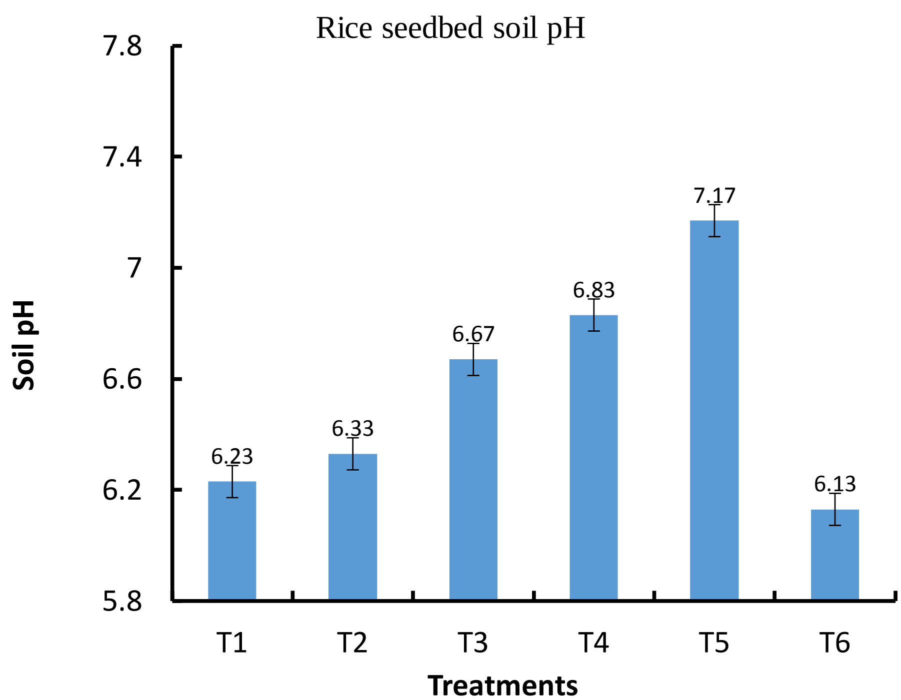

Fig.7. Chitosan-powder-induced alkalization of the post transplanted rice seedbed soils of BRRI dhan29. Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD.

4.3.4 Analytical composition of the modified CHT

Analytical results revealed that a number of essential (macro and micro elements) were supplied due to the application of the modified CHT in the BRRI dhan49 soils. With the alkaline behavior of the materials increased the pH level of the seedbed soils. Many factors could be involved in the supper growth, development and yield increment of the rice seedlings. The above mentioned nutritional supplementation and some other growth promoting hormone could be involved in the mechanisms.

Table 7: Composition of the CHT which was used in the research work

Name of the nutrients	**Nutrient content**
Nitrogen (N)	4.06 %
Phosphorus (P)	.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 CHT	8.73

Chapter V

Summary and Conclusion

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SUMMARY AND CONCLUSION

The field experiment was conducted at the research field of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from December 2015 to May 2016 to study on the effect of CHT on the performance of BRRI dhan29 in the seedbed and the main field in Rabi season under the Madhupur Tract (AEZ-28).

The experiment was comprised of six treatments. T_1= seedbed applied CHT powder at 100g/m^2; T_2= seedbed applied CHT powder at 200g/m^2; T_3= seedbed applied CHT powder at 300g/m^2; T_4= seedbed applied CHT powder at 400g/m^2; T_5= seedbed applied CHT powder at 500g/m^2;T_6= seedbed applied CHT powder at 0g/m^2 .The experiment was laid out in RCBD design with three replications.

The data on crop growth and yield characters (plant height, number of effective tiller hill^{-1}, number of non-effective tiller hill^{-1}, total number of tiller, panicle length, number of filled and unfilled grains panicle^{-1}, number of total grain panicle^{-1},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. CHT treatment showed that, the maximum plant height (91.82cm) was obtained in the T_1 treatment (seedbed applied CHT powder at 100g/m^2) and minimum plant height (83.05cm) was obtained in the T_4treatment (seedbed applied CHT powder at 400g/m^2); The maximum number of total tillers hill^{-1} (18.33) was obtained in the T_4 (seedbed applied CHT powder at 400g/m^2) treatment and the minimum number of total tillers hill^{-1} (15.28) obtained in the T_6 (seedbed applied CHT powder at 0g/m^2) control treatment; The highest number of effective tillers $hill^{-1}$ (12.37) was obtained in the T_4 (seedbed applied CHT powder at $400g/m^2$) treatment and The lowest number of effective tillers $hill^{-1}$ (10.63) was obtained in the T_6 (seedbed applied CHT powder at $0g/m^2$) control treatment; The maximum non-effective tillers $hill^{-1}$ (4.33) was obtained in the T_3 treatment (seedbed applied CHT powder at $300g/m^2$) and minimum non-effective tillers $hill^{-1}$ (2.00) was obtained in the T_1 treatment (seedbed applied CHT powder at $100g/m^2$); The maximum Total number of grains $panicle^{-1}$ (108.90) was obtained in the T_4 treatment (seedbed applied CHT powder at $400g/m^2$) and minimum Total number of grains $panicle^{-1}$ (98.77) was obtained in the T_6 treatment (seedbed applied CHT powder at $0g/m^2$); The highest number of Filled grains $panicle^{-1}$ (98.70) was obtained in the T_4 (seedbed applied modified CHT powder at $400g/m^2$) and the lowest number of Filled grains $panicle^{-1}$ (87.90) was obtained in the T_6 (seedbed applied CHT powder at $0g/m^2$) control treatment; The highest number of Unfilled grains $panicle^{-1}$ (13.13) was obtained in the T_3 (seedbed applied CHT powder at $300g/m^2$) treatment and the lowest number of Unfilled grains $panicle^{-1}$ (10.20) was obtained in the T_6 (seedbed applied CHT powder at $0g/m^2$); The maximum 1000 seed weight was found in T_4(seedbed applied CHT powder at $400g/m^2$) was (133.36g) and the minimum 1000 seed weight was observed in control T_3 (seedbed applied CHT powder at $300g/m^2$) was (120.14g); The maximum Panicle length (26.50cm) was obtained in the T_4 treatment (seedbed applied CHT powder at $400g/m^2$) and minimum Panicle length (25.86cm) was obtained in the T_1 treatment and ; The highest Grain yield (8.9t ha^{-1}) was obtained in the T_4 (seedbed applied CHT powder at $400g/m^2$) treatment and the lowest Grain yield (7.8t ha^{-1}) was obtained in the T_6 (seedbed applied CHT powder at $0g/m^2$) control treatment; The maximum Straw yield (11.83t ha^{-1}) was obtained in the T_4 treatment (seedbed applied CHT powder at $400g/m^2$) and minimum Straw yield (9.83t ha^{-1}) was obtained in the T_6 treatment (seedbed applied CHT powder at 0g/m^2); the highest Biological Yield (20.73 t ha^{-1}) was obtained from the treatment T_4 (seedbed applied CHT powder at 400g/m^2) and the lowest Biological Yield (17.64ha^{-1}) was obtained in the T_6(seedbed applied CHT powder at 0g/m^2) treatment; the highest Harvest Index (44.85 %) was obtained in the T_3 (seedbed applied CHT powder at 300g/m^2) and the lowest Harvest Index (43.00 %) was obtained in the T_4 (seedbed applied CHT powder at 400g/m^2).

The present study was conducted to improve our understanding of rice responses to CHT application. My results indicated that beneficial effects of CHT application. Application of CHT did not affect dry matter production, plant height, panicle length and total number of grain $panicle^{-1}$, however did have a profound effect on effective tillers $hills^1$, 1000 grain weight, filled grain $panicle^{-1}$, unfilled grain $panicle^{-1}$, number of affected panicle $plot^{-1}$, grain yield, straw yield & biological yield. CHT application might be increased the amount of photosynthesis, thereby increasing the number of filled grains $panicle^{-1}$, hence increased spikelet fertility. Combined application of CHT along with chemical nitrogen fertilizer 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. Moreover, our results indicate that primary tillers become earlier, effective tillers become higher, flowering and maturity time become earlier resulting more yield. The results also indicate that seedbed applied method of chitosan would be highly effective to produce quality boro rice seedlings that could play influncial role to increase grain yield of boro rice .The overall results of the present study demonstrated that rice may be grown successfully for obtaining maximum yield with the application of CHT in the seedbed applied method and in the field applied method.

However, before making conclusion concerning the appropriate dose of CHT, further investigation is needed in different Agro Ecological Zones (AEZs) of Bangladesh. Varietal trial also needed for the country-wide recommendation of using chitosan in rice cultivation.

Recommendations

From the above experimental findings, it is apparent that the application @ seedbed applied CHT powder @ 400 g/m^2 (T_4) in the seedbed , performed better on seedling , yield and yield parameters of BRRI dhan29 . 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 effect of chitosan applications for the seedbed and main field for the better grain yield of rice.

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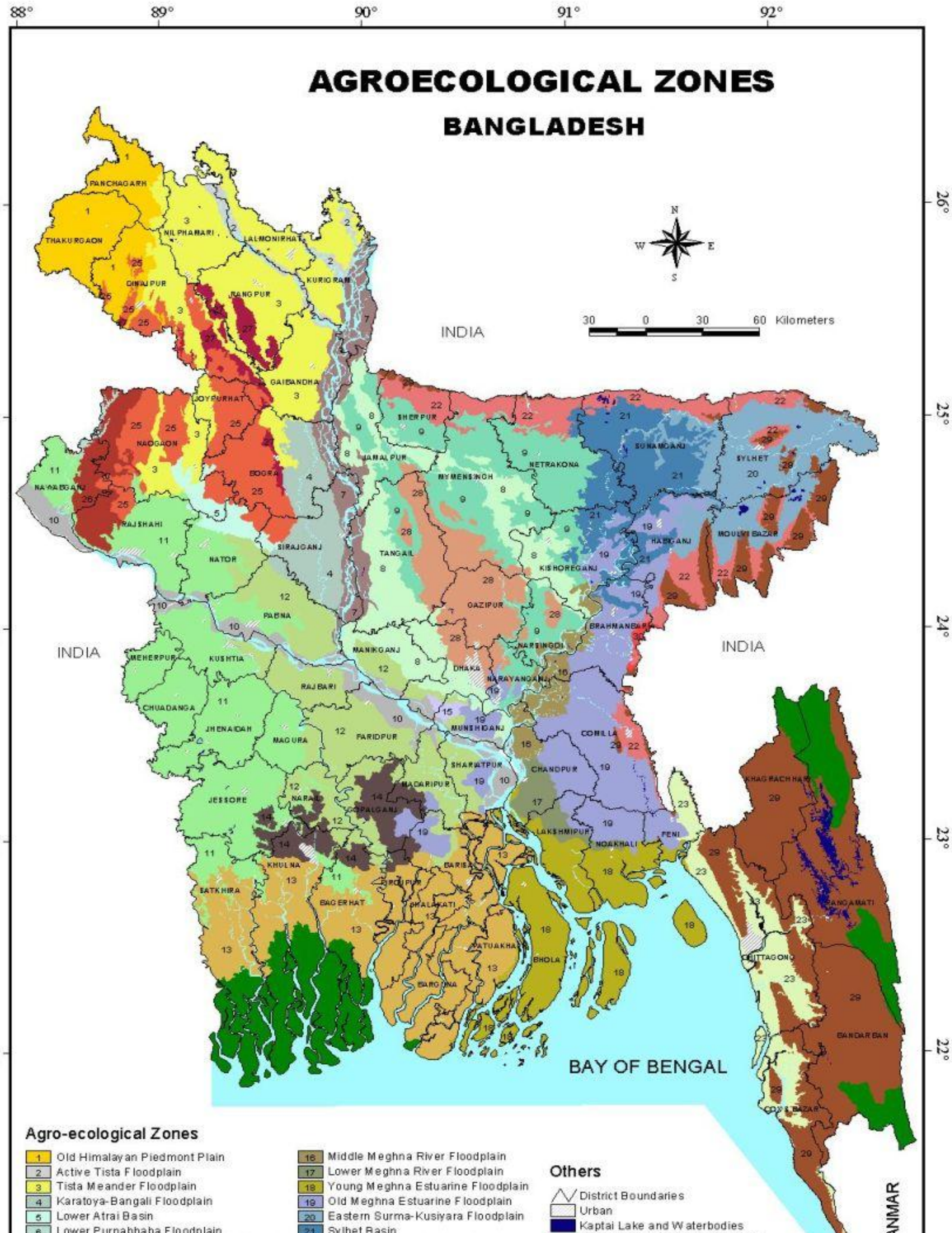
APPENDICES

Appendix I. Agro-Ecological Zones of Bangladesh



Appendix II. Characteristics of soil of the experimental field

A. Morphological characteristics of of the experimental field

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

B. Physical and chemical characteristics of initial soil

Characteristics	Value
% Sand	12
% Silt	50
% Clay	38
Textural class	Silty-clay loam
pH	5.43
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

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

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

Month (2015-2016)	Air temperature(^{0}C)		Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
December	35.5	23.2	78	312	5.4
January	36.0	24.5	83	563	5.1
February	36.0	23.5	81	319	5.0
March	34.5	24.4	81	279	4.4
April	26.5	19.4	81	22	6.9
May	25.8	16.0	78	00	6.8

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