PERFORMANCE OF BRRI dhan49 AS INFLUENCED BY MODIFIED CHITOSAN IN THE SEEDBED AND IN THE MAIN FIELD

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CERTIFICATE

This is to certify that thesis entitled, "PERFORMANCE OF BRRI dhan49 AS INFLUENCED BY MODIFIED CHITOSAN IN THE SEEDBED AND IN THE MAIN FIELD" 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 FAYSAL AHMED, Registration No. 10-03855 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: December, 2015
Place: Dhaka, Bangladesh

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DEDICATED

TO

MY BELOVED

PARENTS

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ABSTRACT

A field experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during Aman season (July to December, 2015) to assess the effect of modified chitosan on morphological, chemical, reproductive, and yield attributes, and yield in rice cv. BRRI dhan49. The experiment was laid out in a completely randomized block design having four treatments with three replications, T_1: seedbed applied modified CHT at 0 g/m^2 + field applied modified CHT at 0 t ha^{-1}; T_2: seedbed applied modified CHT at 0 g/m^2 + field applied modified CHT at 0.5 t ha^{-1}; T_3: seedbed applied modified CHT at 250 g/m^2 + field applied modified CHT at 0 t ha^{-1}; T_4: seedbed applied modified CHT at 250 g/m^2 + field applied modified CHT at 0.5 t ha^{-1}. Application of modified chitosan improved quality of the seedlings and 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 use of modified chitosan in different ways (seedbed applied method and field applied method). Maximum grain yield was observed in T4 treatment having modified chitosan applications in both ways. Our results indicate that primary tillers become earlier, effective tillers become higher, flowering and maturity time become earlier resulting more yield. Our results also indicate that seedbed applied method of modified chitosan would be more effective than field applied method. These results might be due some growth promoting hormones (especially GA3, Auxin etc.) could be realized in soil that induced the seedlings growth and early-flowering some genes (*ELF1, ELF2, ELF3*) could be induced by the application of modified chitosan in soil.

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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
Wt.	Weight

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food for the people of Bangladesh and it is the staple food for more than two billion people in Asia (Hien *et al.*, 2002). In Bangladesh, the geographical, climatic and edaphic conditions are favorable for year round rice cultivation. However, the national average rice yield in Bangladesh (4.2 t ha^{-1}) is very low compared to those of other rice growing countries, like China (6.30 t ha^{-1}), Japan (6.60 t ha^{-1}) and Korea (6.30 t ha^{-1}) (FAO, 2009). Sonarbangla-1 produced a 20% higher rice yield (7.55 t ha^{-1}) than the check variety, BRRI Dhan49, (6.26 t ha^{-1}) in Bangladesh (Parvez *et al*., 2003).

Bangladesh is an agro-based country. Rice belongs to the Gramineae family with the genus *Oryza* which contained about 22 different species (Wopereis *et al*., 2009). It is the dominant staple food for many countries of the world (Mobasser *et al*., 2007). It is also the most important food crop and a major food grain for more than a third of the world and 50% of the Global population (Zhao *et al*., 2011). Among the most cultivated cereals in the world, rice ranks at second to wheat (Abodolereza and Racionzer, 2009). Rice is grown in more than 10 countries with a total harvested area of nearly 160 million hectares, producing more than 700 M tons every year (IRRI, 2010). According to the FAO, of the UN, 80% of the world rice production comes from 7 countries.

In Bangladesh, rice covered an area of 28.49 million acres with a production of 33.54 million M tons while the average yield of rice in Bangladesh is around 1.18 tons acre (BBS 2012). In case of boro rice, it covers the largest area of 11788 (41.38% of total rice cultivation area) acre (local 195 + HYV 9968 + HYV1625 T acre) with a production of 1.86 million tons (55.50%) and the average yield is about 1177 kg $acre^{-1}$

during 2010-2011 (BBS, 2012). Besides, based on the rice cultivation, Bangladesh is the 5th largest country of the world (BBS, 2012). Alam (2012) reported that rice covers about 82% of the total cropped land of Bangladesh. It accounts for 92% of the total food grain production in the country and provides more than 50% of the agricultural value addition employing about 44% of total labour forces. According to the latest estimation made by BBS, per capita rice consumption is about 166 kg $year^{-1}$. Rice alone provides 76% of the calorie intake and 66% of the total protein requirement and shares about 95% of the total cereal food supply (Alam, 2012).

The population of Bangladesh is growing by two million every year 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 (BRRI, 2011). During this time total rice area will also shrink to 10.28 million hectares. Rice yield therefore, needs to be increased by 53.3% (Mahamud *et al*., 2013). In Bangladesh, food security has been and will remain a major concern because food requirement is increasing at an alarming rate due to increasing population. 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).

Chitosan (CHT) is produced commercially by deactylation of chitin, which is the structural element in the exoskeleton of crustaceans (such as crabs and shrimp) and cell walls of fungi. The degree of deacetylation (%DD) can be determined by NMR spectroscopy, and the %DD in commercial CHT ranges from 60 to 100%. On average, the molecular weight of commercially produced CHT is between 3800 and 20,000 Daltons. A common method for the synthesis of CHT is the deacetylation of chitin using sodium hydroxide in excess as a reagent and water as a solvent. This reaction pathway, when allowed to go to completion (complete deacetylation) yields up to 98% product. CHT 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 elements. The amino group in CHT has leads to a protonation in acidic to neutral solution with a charge density dependent on pH. This makes CHT water soluble and a bioadhesive which readily binds to negatively charged surfaces such as mucosal membranes. CHT enhances the transport of polar drugs across epithelial surfaces, and is biocompatible and biodegradable.

Chitosan is prepared from the Crustecean by-products through the deacetylation process. Whereas, modified chitosan is prepared from the sea shell by-products through sun drying, oven drying, milling, sieving and finally used the powder as the acetylated form having less than two millimeter in size and use the material directly in the main field.

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).

Keeping these facts in mind the following objectives are undertaken:

- To examine the efficacy of modified CHT on growth, yield and yield contributing character of BRRI dhan49.
- To evaluate the application methods of modified CHT for the yield improvement of BRRI dhan49.
- To find out the optimum doses of the modified CHT for the yield increment of BRRI dhan49.

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 *T. aman.*

2.1 Effect of chitosan on growth, yield parameter and yield

2.1.1. Plant 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 Pra Tew 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.

Kobayashi *et al. (*1989); Maskina *et al.* (1987) 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.

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.

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.

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.

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.

2.1.2. Number of tillers hill-1

Bhuvaneswari *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) , Tr 2- 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.

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.

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

Suchada *et al.* (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 applicaiton 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.

Afzal *et al*. (2005) were investigated that the effects of seed soaking with plant growth regulators (IAA, GA3, kinetin or prostart) on wheat (*Triticum aestivum* 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 applicaiton 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.

Siddique (2007) 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).

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.

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

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 *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.

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.

2.2.3 Panicle length (cm)

Chaweewan Boonreung *et al.* (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.

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.

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*.

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.

2.2.4 Thousand grain weight

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

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.

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.

Yadav and Christopher (2006) 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).

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

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.

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.

Nguyen Toah *et al.* (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.

Suchada Boonlertnirun *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.

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.

2.2.6 Harvest index

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.

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.

2.2.7 Desease Control

Li B, Liu B and Shan C *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.

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 *Pyricularia grisea.* Results revealed that seedlings obtained from seeds applied with chitosan and hydrolyzed chitosan (oligochitosan) showed stronger resistance to blast disease compared with non-applied plants (positive control).

Hien *et al*. (2010) 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%).

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

Hasegawa *et al* (2005) reported that corms with an increased diameter and height are obtained as a result of *Arisaematerna tipartitum* 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*.

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 *T. aman*, chitosan can increase the yield.

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.

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.

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%.

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.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods used in the experiment. It includes a short description of location of the experimental plot, characteristics of soil, climate crops, treatments, experimental design followed, land preparation, seedling transplanting, intercultural operations, harvesting, data recording, collection and statistical analysis used for the experiment. The details of the experiment are given below.

3.1 Experimental details of site

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).

Plate 1: **Experimental Site**

3.2 Soil

The experiment was carried out in a typical rice growing soil of Sher-e-Bangla Agricultural University (SAU) Farm, Dhaka, during kharif season of 2015. The farm belongs to the General soil type, **"**Red Brown Terrace Soil**"** under Tejgaon soil Series. The land was above flood level and sufficient sunshine was available during the experimental period. The soil characteristics were clay loam in texture with pH value 6.3. The morphological, physical and chemical characteristics of initial soil are presented in Tables 1 and 4.

3.3 Climate

The experimental area is under the subtropical climate. Usually the rainfall was heavy during Kharif season and scanty in Rabi season. The atmospheric temperatures increased as the growing period proceeded towards Kharif season. The weather conditions of crop growth period such as monthly mean rainfall (mm), mean temperature (^{o}C), sunshine hours and humidity (%) are presented in Appendix III.

3.4 Planting material

Rice (*Oryza sativa*) variety BRRI dhan49 was used as plant material. BRRI developed this variety and released in 2008. It is a most popular variety now due to its high yielding potentials and suitable for planted at 15th June-15th July. This variety attains a height of 100 cm. The life cycle of this variety is 135 days. Grain yield is 5 to 5.5 t ha^{-1} and 1000 grain weight is 19-20g. The seeds of this variety were collected from Bangladesh Rice Research Institute (BRRI), Gazipur. Seeds contain 76% carbohydrate and 8.5% protein.

Table 1: Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Farm, Dhaka
AEZ	Madhupur Tract
General Soil Type	Red Brown Terrace Soil
Land type	Medium high land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

3. 5 Seed Collection

Healthy and vigorous seeds of BRRI dhan49 were collected from Bangladesh Rice Research Institute (BRRI), Joydevpur, Gazipur.

3.6 Seed sprouting:

Healthy seeds were collected by specific gravity method. The selected seeds were soaked for 24 hours and then these were kept in gunny bags. The seed started sprouting after 48 hours and almost all seeds were sprouted after 72 hours.

3.7 Seedbed preparation and seed sowing

Seedbed was prepared on 1 August 2015 for sowing the sprouting seeds and proper care was taken for raising seedlings. The seedbed soil of those locations were cleaning, wetting by proper irrigation and leveling with ladder. Sprouted seeds were sown in the wet soil on 6 August 2015. Weeds were removed and irrigation was given in the seedbed as and when necessary.

3.8 Land preparation

The land was first opened with the tractor drawn disc plough. Ploughed soil was then brought into desirable fine tilth by 4 operations of ploughing and harrowing with country plough and ladder. The stubble and weeds were removed. The first ploughing was done 20 August and the final land preparation was done 22 August, 2015. Exp erimental land was divided into unit plots following the design of experiment.

3.9 Treatments of the experiment

The experiment was laid out in a completely randomized design with four replications as follows:

T_1: seedbed applied modified CHT at 0g/m^2 + field applied modified CHT at 0 t ha^{-1}

T_2: seedbed applied modified CHT at 0g/m^2 + field applied modified CHT at 0.5 t ha^{-1}

T_3: seedbed applied modified CHT at 250g/m^2 + field applied modified CHT at 0 t ha^{-1}

T_4: seedbed applied modified CHT at 250g/m^2 +field applied modified CHT at 0.5 t ha^{-1}

Every treatments received N, P, K, S and Zn as basal doses. The rates and sources of nutrients used in the study are given in Table-2.

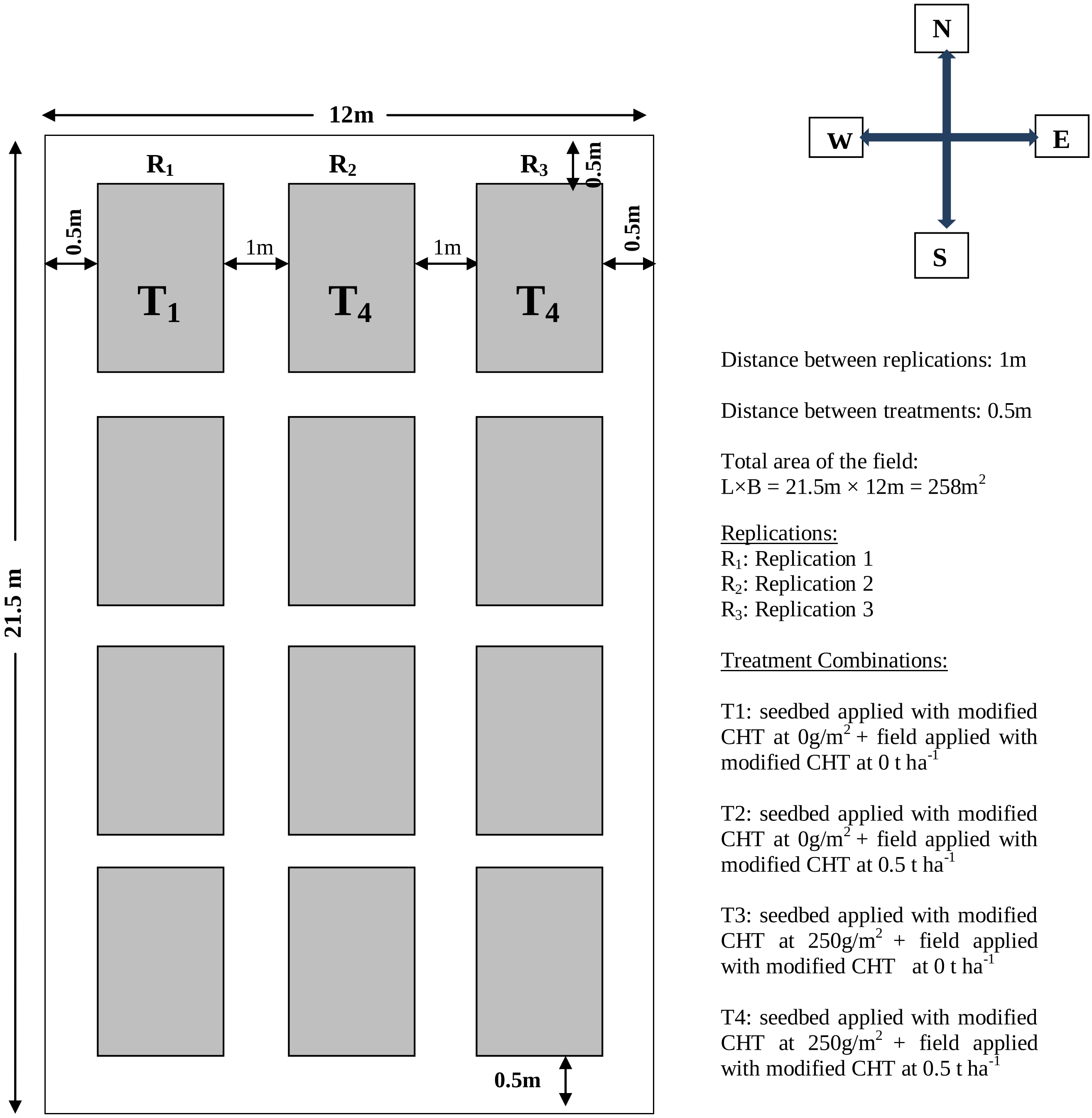
Table 2: Name of the element, rate (kg ha^{-1}) and name of the fertilizer used for the experiment:

Name of the element	**Rate (kg ha^{-1})**	**Name of the fertilizer**
N	120	Urea
P	20	Triple Super Phosphate(TSP)
K	60	Muriate of Potash (MOP)
S	16	Gypsum
Zn	2	Zinc sulphate

Ref. According to Fertilizer Recommendation Guide, 2012.

3.10 Experimental Design and Layout

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 3 m × 3 m. Total plots in the experimental field were 12. The treatments were randomly distributed to each blocks. The distance between two adjacent replications (block) was 1 m 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.



Distance between replications: 1m

Distance between treatments: 0.5m

Total area of the field:
L×B = 21.5m × 12m = 258m^2

Replications:
R_1: Replication 1
R_2: Replication 2
R_3: Replication 3

Treatment Combinations:

T1: seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}

T2: seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}

T3: seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0 t ha^{-1}

T4: seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}

Layout of experimental plot

3.11 Fertilizer application

All the fertilizers except N were added to the soil during final land preparation on 20 August, 2015. Urea was applied in three splits. The first split half of the total amount of N was applied, 25 August, 2015. Second split on 15 September, 2015 at early tillering stage and third split on 5 October, 2015.

3.12 Transplanting of seedling

Twenty days old seedlings were uprooted carefully from the seedbed and transplanted in the experimental plots on 26 August, 2015, following different spacing. One seedling was transplanted in each hill.

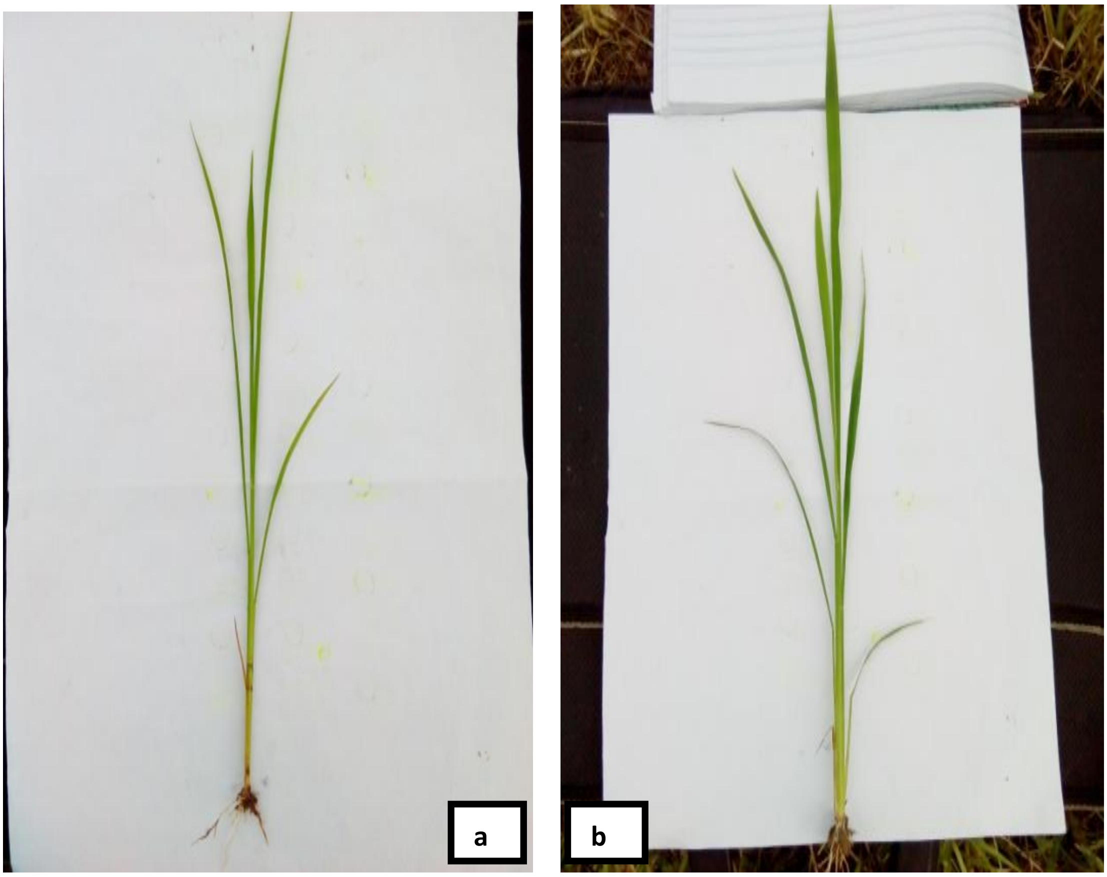


Plate 2: Uprooted seedlings from seedbed before transplanting. (a) Seedling from the seedbed not applied with modified CHT. (b) Seedling from the seedbed applied with modified CHT. Number (b) seedling shows the higher physical growth than number (a) seedling.

3.13 Intercultural operations

Intercultural operations were done for ensuring and maintaining the normal growth of the crop. The detailed intercultural operations were recorded in the (table 3).

3.13.1 Irrigation

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

3.13.2 Weeding

The crop was infested with some common weeds, which were controlled by uprooting and removed them three times from the field during the period of experiment. Weeding was done after 20, 30 and 45 days after transplanting.

3.13.3 Protection against insect and pest

There were some incidence in insects specially rice stem borer, grasshopper, rice bug etc. which were controlled by spraying Diaginon 50EC.

3.14 Application of modified CHT:

Modified CHT was applied in two different methods. One is the seedbed application method and another is the field application method. In the seedbed CHT was applied at a rate of 250 g/m^2, and in the main field CHT was applied at a rate of 0.5 ton ha^{-1}.

3.15 Crop sampling and data collection

The crop sampling was done at the time of harvest. Harvesting date were 04.12.15 and 10.12.15. At each harvest, ten plants were selected randomly from each plot. The selected plants of each plot were cut carefully at the soil surface level. The plant heights, panicle length, number of grain $panicle^{-1}$, 1000 grain weight and yield were recorded separately.

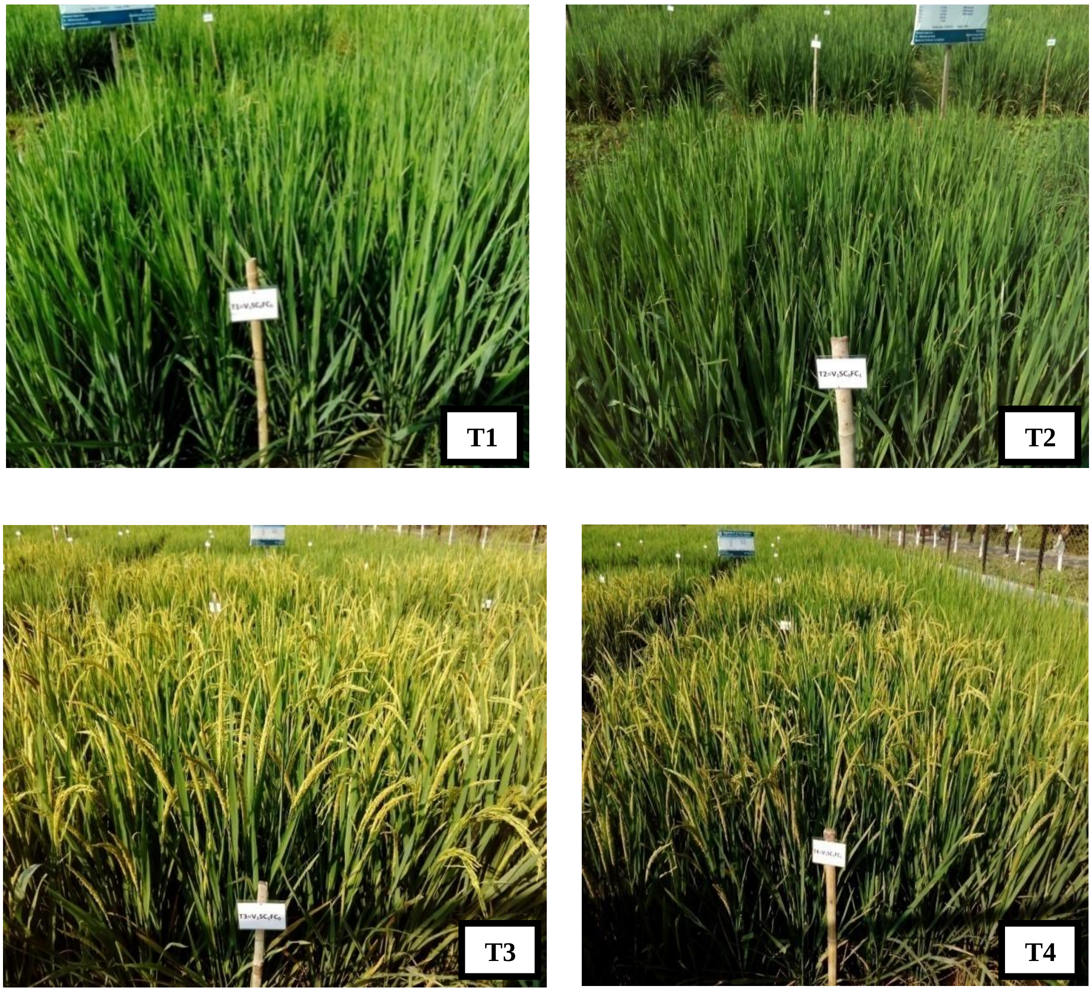


Plate 3: Early panicle initiatin observed at "Treatment 3" and "Treatment 4", where, at "Treatment 3" modified CHT was applied in seedbed and at "Treatment 4" modified CHT was applied in both seedbed and main field. On the other hand "Treatment 1" was Control and "Treatment 2 was applied with CHT in the main field only". The pictures were snapped at the same date.

3.16 Harvest and Threshing

Harvesting was done when 90% of the crops became brown in color. The matured crop were cut and collected manually from a pre demarcated area of 1 m^2 at the centre of each plot. The harvested crops were threshed, cleaned and processed. Grain yield and straw yield was recorded plot wise and moisture of straw was calculated on oven dry basis.

Table 3: Dates of different operations done during the field study

Operations	**Working Dates**
First ploughing of the field	20 August 2015
final land preparation	22 August 2015
Application of fertilizers (1/3rd Urea, TSP, MP, Gypsum, ZnO, Boric acid)	25 August 2015
Transplanting of seedlings	26 August 2015
Intercultural Operations	**Working Dates**
2nd split application of urea and weeding	15 September 2015
3rd split application of urea and 2nd weeding	5 October 2015
First step of CHT application in seedbed	8 August 2015
Insecticide application	8 September 2015
Second step ofCHT application in main field	25 August 2015
Harvesting and threshing	04.12.15 and 10.12.15

3.17 Data collection

Ten hills were selected randomly from each plot prior to harvest for recording data on crop parameters and the yield of grain straw were taken plot wise.

The following parameters were recorded at harvest:

1) Fresh weight of 10 hills at maximum tillering stage (g)

2) Oven dry weight of 10 hills at maximum tillering stage (g)

3) Plant height (cm)

4) Panicle length (cm)

5) Number of non-effective panicle plot^{-1} (m^{2})

6) Number of effective tillers hill^{-1}

7) Number of grain^{-1}panicle

8) Filled grain panicle^{-1}

9) Unfilled grain panicle^{-1}

10) 1000 grain weight (t ha^{-1})

11) Grain yield (t ha^{-1})

12) Straw yield (t ha^{-1})

13) Biological yield (t ha^{-1})

14) Soil sample from each plot (post harvest)

3.18 Procedure of data collection:

3.18.1 Fresh weight of ten hills at maximum tillering stage

Ten hills from each plot were collected at maximum tillering stage and then weighted by using a digital electric balance.

3.18.2 Oven dry weight of 10 hills at maximum tillering stage

Ten hills from each plot were collected at maximum tillering stage and then sun dried. The sun dried hills again dried in oven and weighted by using a digital electric balance.

3.18.3 Plant height

The heights of ten plants were measured with a meter scale from the ground level to tip of the plants and the mean heights were expressed in cm.

3.18.4 Panicle length

Panicle length was measured from the basal node of rachis to the trip of panicle and mean average length were expressed in cm.

3.18.5 Number of non-effective panicle plot^{-1} (m^2)

Number of affected panicle per plot was counted.

3.18.6 Number of effective tillers hill^{-1}

Total number of effective tillers per hill from each plot was counted at the time of harvest.

3.18.7 Number of grain panicle^{-1}

Total grain numbers were counted from total panicle that was obtained from pre-selected ten plants. After that it was averaged and expressed as number of grain per panicle.

3.18.8 Number of filled grain panicle^{-1}

Filled grain per panicle were counted from ten plants and then averaged.

3.18.9 Number of unfilled grain panicle^{-1}

Unfilled grain per panicle were counted from ten plants and then averaged.

3.18.10 Weight of 1000 grain

One thousands cleaned dried grain were counted randomly from each harvest sample and weighted by using a digital electric balance and mean weight was expressed in gram.

3.18.11 Grain yield (t ha^{-1})

Weight of grain of the demarcated area (1m^2) of each plot was taken and then converted to the yield in t ha^{-1}.

3.18.12 Straw yield (t ha^{-1})

Straw obtained from each plot were sun dried and weighted carefully. The dry weight was taken carefully. The dry weighted straw of central 1m^2 area and ten sample plants were added to the respective unit plot yield to record the final straw yield plot^{-1} and finally converted to t ha^{-1}.

3.18.13 Biological Yield (t ha^{-1})

Biological yield was calculated from addition of grain yield and straw yield.

3.18.14 Harvest Index (%)

The harvest index (HI) was calculated by dividing the actual yield of seeds by the biological yield of the crop. It was expressed as percentage.

$$\text{Harvest Index} = \frac{\text{SeedYield (t ha}^{-1}\text{)}}{\text{Biological Yield (t ha}^{-1}\text{)}} \times 100$$

3.19 Analysis of data

The data collected on different parameters were statistically analyzed to obtain the level of significance using the Statistic 10 software. 5% level of significance was used to compare the mean differences among the treatments.

3.20 Collection and preparation of initial soil sample

The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were drawn by means of an auger from different location covering the whole experimental plot mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were picked up and removed. Then the samples were dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis.

3.21 Chemical analysis of soil samples

Soil samples were analyzed for both physical and chemical properties in the laboratory of Soil science department, Sher-e-Bangla Agricultural University, Dhaka. The properties studied included soil texture, pH, organic matter, total N, available P, exchangeable k, and available S. The physical and chemical properties of postharvest soil have been presented in Appendix II. The soil was analyzed by standard methods:

Table 4: Physical and chemical properties of the initial soil sample

Characteristics	Value
Particle size analysis	
% Sand	30
% Silt	40
% Clay	30
Textural class	Clay loam
Consistency	Granular and friable when dry
pH	6.3
Bulk Density (g/cc)	1.45
Particle Density (g/cc)	2.53
Organic carbon (%)	0.68
Organic matter (%)	1.163
Total N (%)	0.06
Available P (ppm)	20
Exchangeable K (meq/100g soil)	0.12
Available S (ppm)	22

3.21.1 Particle size analysis

Particle size analysis of soil was done by Hydrometer Method and then textural class was determined by plotting the values for % sand, % silt and % clay to the “Marshal^{L-1}s Textural Triangular Coordinate” according to the USDA system.

3.21.2 Soil pH

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

3.21.3 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.

3.21.4 Total nitrogen

Total N content of soil were determined followed by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into micro kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100:10:1), and 6 ml H_2SO_4 were added. The flasks were swirled and heated 200^0C and added 3 ml H_2O_2 and then heating at 360^0C was continued until the digest was clear and colorless. After cooling, the content was taken into 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination.Then 20 ml digest solution was transferred into the distillation flask, Then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N-NaOH solutions in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink. The amount of N was calculated using the following formula:

$$\% N = (T-B) \times N \times 0.014 \times 100/S$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

3.21.5 Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve.

3.21.6 Exchangeable potassium

Exchangeable K was determined by 1N NH_4OAc (pH 7) extraction methods and by using flame photometer and calibrated with a standard curve.

CHAPTER IV

RESULT AND DISCUSSION

This chapter comprises of the presentation and discussion of the results obtained due to application of modified CHT in Seedbed and Main Field of *T. aman* rice (cv. BRRI dhan49). The results of the present investigation have been presented, discussed and compared as far as possible with the results of the researchers.

4.1 Growth and Yield Components

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 (105.33cm) was obtained in the T_4 treatment (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) and minimum plant height (92.33cm) was obtained in the T_1 treatment (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}) (Table 5). According to the plant height the treatments may be arranged as T_4>T_3>T_2>T_1.

The increased plant height through the application of modified CHT along with N, P, K and S was also reported by many other scientists (Kobayashi *et al.*, 1989; Maskina *et al.*, 1987)

4.1.2 Total Tillers hill^{-1}

The effects of different treatments on total tillers hill^{-1} was found statistically significant. The maximum number of total tillers hill^{-1} (18.333) was obtained in the T_3 (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0 t ha^{-1}) treatment which was significantly greater than that obtained in the T_1 control (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}) and statistically identical to T_2 (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) and T_4 (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) treatment. However the total tillers hill^{-1} did not differ significantly in T_2, T_3, T_4 treatments. The minimum number of total tillers hill^{-1} (13.667) was obtained in the T_1 (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}) control treatment. In producing total number of tillers hill^{-1} the treatments may be arranged as T_3>T_4>T_2>T_1. It was observed that, application of modified CHT in soil increases the total tillers hill^{-1}.

Bhuvaneswari *et al.* (2008) showed varying modified CHT application methods did not affect tiller numbers per plant. The maximum number tiller number obtained from treatment of seed soaking in modified CHT solution before planting and soil application, however did not significantly differ from the control. Their treatment combination were Tr 1- no modified CHT application (control) , Tr 2- seed soaking with modified CHT solution Tr 3 - seed soaking and soil application with modified CHT solution and Tr 4 - seed soaking and foliar spraying with modified CHT solution.

4.1.3 Non-Effective tillers hill^{-1}

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 (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0 t ha^{-1}) and minimum non-effective tillers (2.00) was obtained in the T_1 treatment (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}).

According to the number of non-effective tillers the treatments may be arranged as $T_3 > T_4 > T_2 > T_1$.

Table 5: Effects of different treatments on plant height (cm), total tillers hill^{-1} and non-effective tillers hill^{-1} of *T. aman* rice (BRRI dhan49) at harvest. Mean was calculated from three replicates for each treatment. Values in a column with similar letters are not significantly different at $p \leq 0.05$ applying LSD.

Treatments	Plant height (cm)	Total Tillers Hill^{-1}	Non-Effective Tillers Hill^{-1}
T_1	92.33	13.667	2.00
T_2	95.00	14.667	2.33
T_3	103.67	18.333	4.33
T_4	105.33	16.333	2.67
LSD (0.05)	14.768	4.3288	2.9783
CV (%)	7.46	13.76	52.61

T_1= seedbed applied with modified CHT at 0g/m^2+ field applied with modified CHT at 0 t ha^{-1}

T_2= seedbed applied with modified CHT at 0g/m^2+ field applied with modified CHT at 0.5 t ha^{-1}

T_3= seedbed applied with modified CHT at 250g/m^2+ field applied with modified CHT at 0 t ha^{-1}

T_4= seedbed applied with modified CHT at 250g/m^2+ field applied with modified CHT at 0.5 t ha^{-1}

4.1.4 Effective tillers $hill^{-1}$

Figure 1 shows the effects of different treatments on effective tillers $hill^{-1}$. The highest number of effective tillers $hill^{-1}$ (14) was obtained in the T_3 (seedbed applied with modified CHT at $250g/m^2$ + field applied with modified CHT at 0 t ha^{-1}) treatment which was significantly greater than that obtained in the T_1 control (seedbed applied with modified CHT at $0g/m^2$ + field applied with modified CHT at 0 t ha^{-1}) and T_2 treatment (seedbed applied with modified CHT at $0g/m^2$ + field applied with modified CHT at 0.5 t ha^{-1}) and statistically identical to T_4 (seedbed applied with modified CHT at $250g/m^2$ + field applied with modified CHT at 0.5 t ha^{-1}). The lowest number of effective tillers $hill^{-1}$ (11.67) was obtained in the T_1 (seedbed applied with modified CHT at $0g/m^2$ + field applied with modified CHT at 0 t ha^{-1}) control treatment. In producing effective number of tillers $hill^{-1}$ the treatments may be arranged as $T_3 > T_4 > T_2 > T_1$. It was observed that, modified CHT application in soil increases the effective 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 CHT in combination with mixed chemical fertilizer but did not differ from that of mixed chemical fertilizer application while their different treatment combination were Trl : CHT 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: CHT spraying at the concentration of 80 mgL^{-1} and Tr4: no application of CHT and mixed chemical fertilizer.

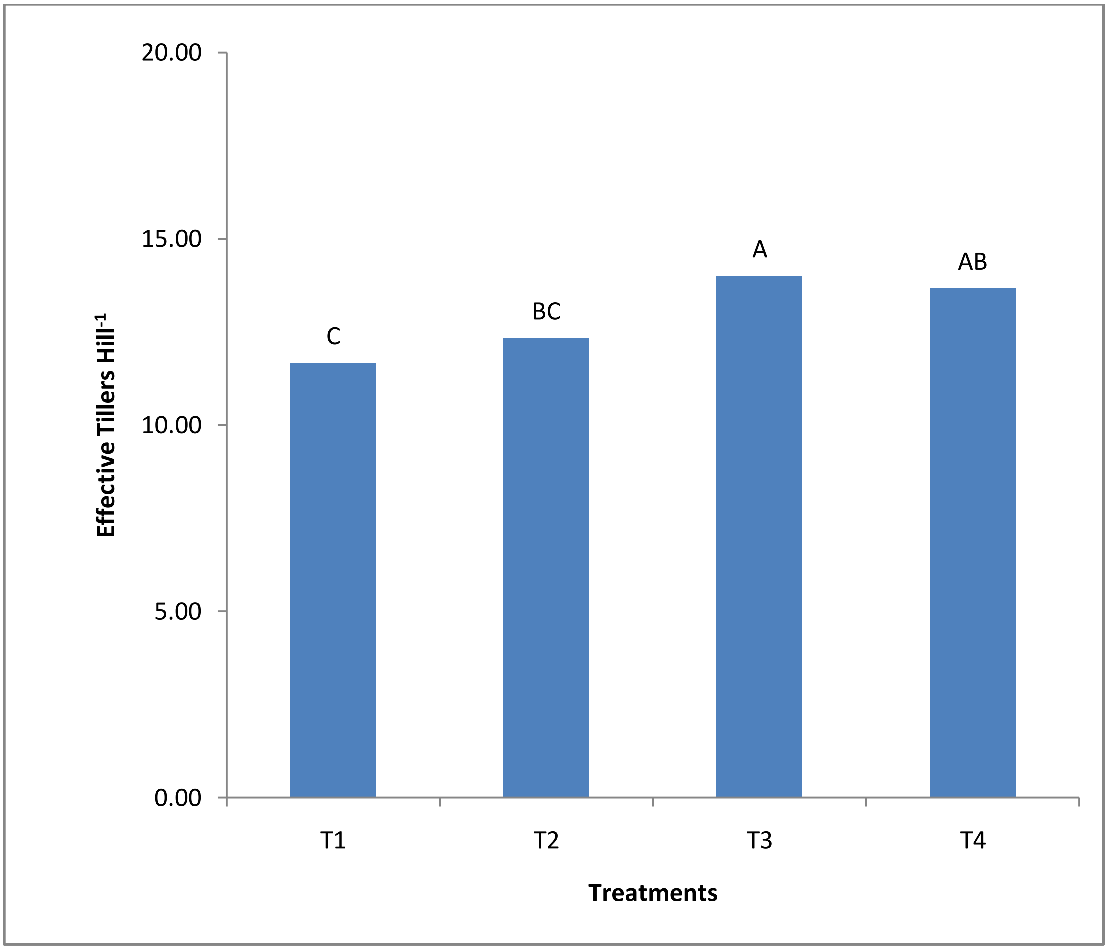


Figure 1. Effects of different treatments on number of effective tillers hill^{-1} of *T. aman* rice (BRRI dhan49). Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD.

T_1= seedbed applied with modified CHT at 0g/m^2+ field applied with modified CHT at 0 t ha^{-1}

T_2= seedbed applied with modified CHT at 0g/m^2+ field applied with modified CHT at 0.5 t ha^{-1}

T_3= seedbed applied with modified CHT at 250g/m^2+ field applied with modified CHT at 0 t ha^{-1}

T_4= seedbed applied with modified CHT at 250g/m^2+ field applied with modified CHT at 0.5 t ha^{-1}

4.1.5 Total Number of Grains Panicle^{-1}

Total number of grains panicle^{-1}, one of the agronomic characteristics, was found to be statistically insignificant in all of the treatments used in the experiment (Table 6). The maximum total number of grains panicle^{-1} (173.67) was obtained in the T_4 treatment (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) and minimum total number of grains panicle^{-1} (165.00) was obtained in the T_1 treatment (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}) (Table 6). According to the total number of grains panicle^{-1} the treatments may be arranged as $T_4>T_3>T_2>T_1$.

Seed numbers panicle^{-1} of rice plant cv. Suphan Buri 1 were significantly affected by various CHT concentrations (Boonlertnirun *et al.*, 2008). Present result agrees with the earlier report.

4.1.6 1000-grain weight

1000 seed weight was found to be statistically insignificant in all of the treatments used in the experiment (Table 6). The maximum 1000 seed weight was found in T_3 (19.567g) which were statistically similar with all other treatments T_4 (19.400g), T_1 (19.00g) and T_2 (19.00g). T_4 (19.400 g) was the second highest treatment in terms of 1000 seed weight. The minimum 1000 seed was observed in control T_1 (19.00g) and T_2 (19.00g).

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

This was contrary to the observations of Krivtsovm *et al.* (1996) found that thousand grain weight of wheat plants was increased with application of polymeric CHT at low concentration.

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

4.1.7 Panicle length (cm)

Panicle length was found to be statistically insignificant in all of the treatments used in the experiment. The maximum panicle length (23.00) was obtained in the T_4 treatment (seedbed applied with modified CHT at $250g/m^2$ + field applied with modified CHT at 0.5 t ha^{-1}) and minimum Panicle length (22.33) was obtained in the T_2 treatment and T_3 treatment (Table 6).These results indicate that application of modified CHT at seedbed and main field has no positive or negative effect on panicle length of BRRI dhan49.

Table 6: Effects of different treatments on Total number of grains panicle^{-1}, 1000-grain weight and panicle length of *T. aman* rice (BRRI dhan49) at harvest. Mean was calculated from three replicates for each treatment. Values in a column with similar letters are not significantly different at $p \leq 0.05$ applying LSD.

Treatments	**Total number of grains panicle^{-1}**	**1000-grain weight (gm)**	**Panicle length (cm)**
T_1	165.00	19.00	22.667
T_2	167.67	19.00	22.333
T_3	173.00	19.56	22.333
T_4	173.67	19.400	23.000
LSD (0.05)	10.671	1.0236	1.5969
CV (%)	3.14	2.66	3.54

T_1= seedbed applied with modified CHT at 0g/m^2+ field applied with modified CHT at 0 t ha^{-1}

T_2= seedbed applied with modified CHT at 0g/m^2+ field applied with modified CHT at 0.5 t ha^{-1}

T_3= seedbed applied with modified CHT at 250g/m^2+ field applied with modified CHT at 0 t ha^{-1}

T_4= seedbed applied with modified CHT at 250g/m^2+ field applied with modified CHT at 0.5 t ha^{-1}

4.1.8 Filled grains panicle^{-1}

It was found that filled grains panicle^{-1} was statistically significant. The highest number of filled grains panicle^{-1} (16.00) was obtained in the T_3 (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0 tha^{-1}) treatment which was significantly greater than that obtained in the T_1 control (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}) and T_2 treatment (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) and statistically similar to T_4 (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) tretment. The lowest number of filled grains panicle^{-1} (140.00) was obtained in the T_1 (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}) control treatment. The effect of treatments on number of filled grains panicle^{-1} may be arranged as T_3>T_4>T_2>T_1. It was observed that, modified CHT application in soil increases the Filled grains panicle^{-1}.

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

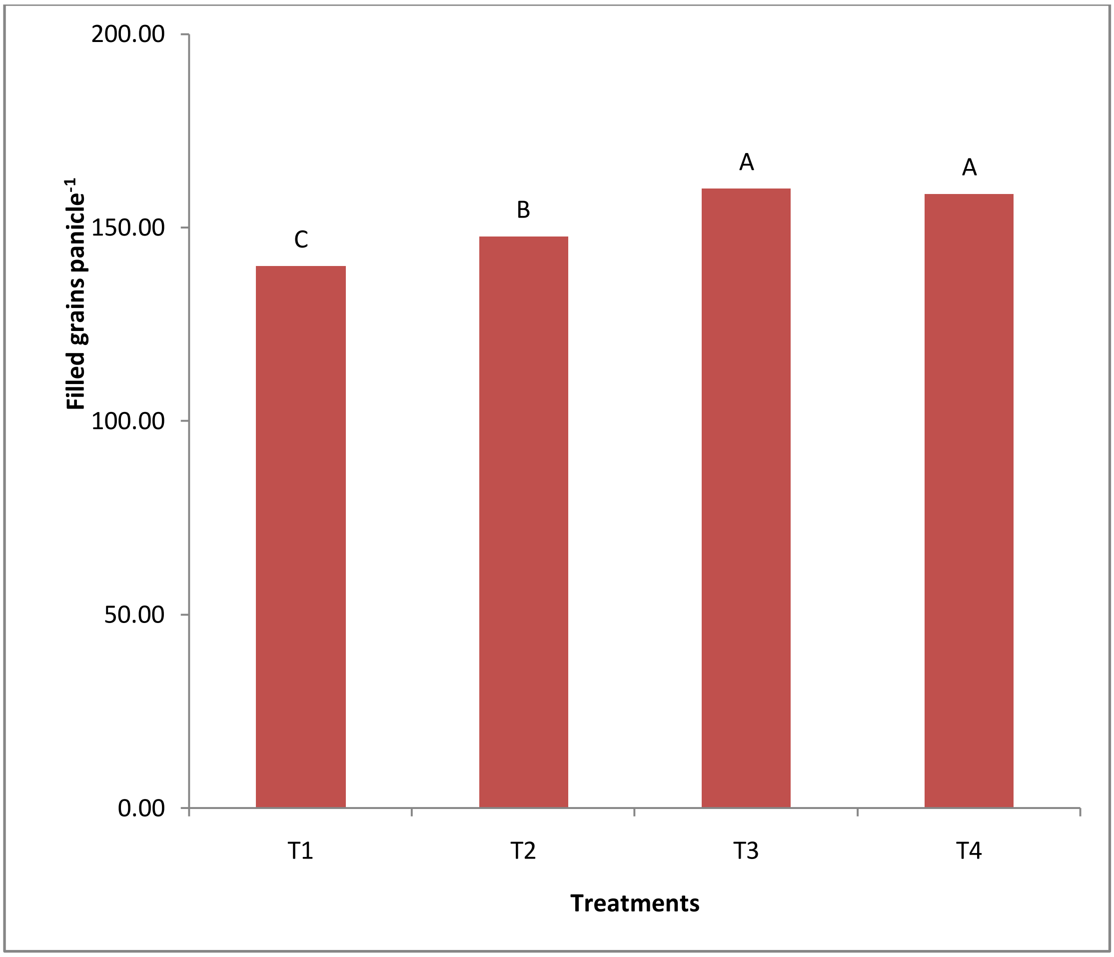


Figure 2. Effects of different treatments on Filled grains panicle^{-1} of *T. aman* rice (BRRI dhan49). Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD.

T_1= seedbed applied with modified CHT at 0g/m^2+ field applied with modified CHT at 0 t ha^{-1}

T_2= seedbed applied with modified CHT at 0g/m^2+ field applied with modified CHT at 0.5 t ha^{-1}

T_3= seedbed applied with modified CHT at 250g/m^2+ field applied with modified CHT at 0 t ha^{-1}

T_4= seedbed applied with modified CHT at 250g/m^2+ field applied with modified CHT at 0.5 t ha^{-1}

4.1.9 Unfilled grains panicle^{-1}

Figure 3 is showing the effects of different treatments on unfilled grains panicle^{-1}. It was found that unfilled grains panicle^{-1} were statistically significant due to application of filled treatments. The highest number of Unfilled grains panicle^{-1} (25.00) was obtained in the T_1 (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}) treatment which was significantly higher than that obtained in the T_3 (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0 t ha^{-1}) and T_4 treatment (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) and statistically similar to T_2 (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}). The lowest number of Unfilled grains panicle^{-1} (13.00) was obtained in the T_3 (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0 t ha^{-1}) which is statistically similar to T_2 (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) and T_4 (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) treatment. In producing Unfilled grains panicle^{-1} the treatments may be arranged as $T_1>T_2>T_4>T_3$. It was observed that, application of modified CHT in soil reduces the unfilled grains panicle^{-1} .

These results were corroborated with the findings of 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 CHT.

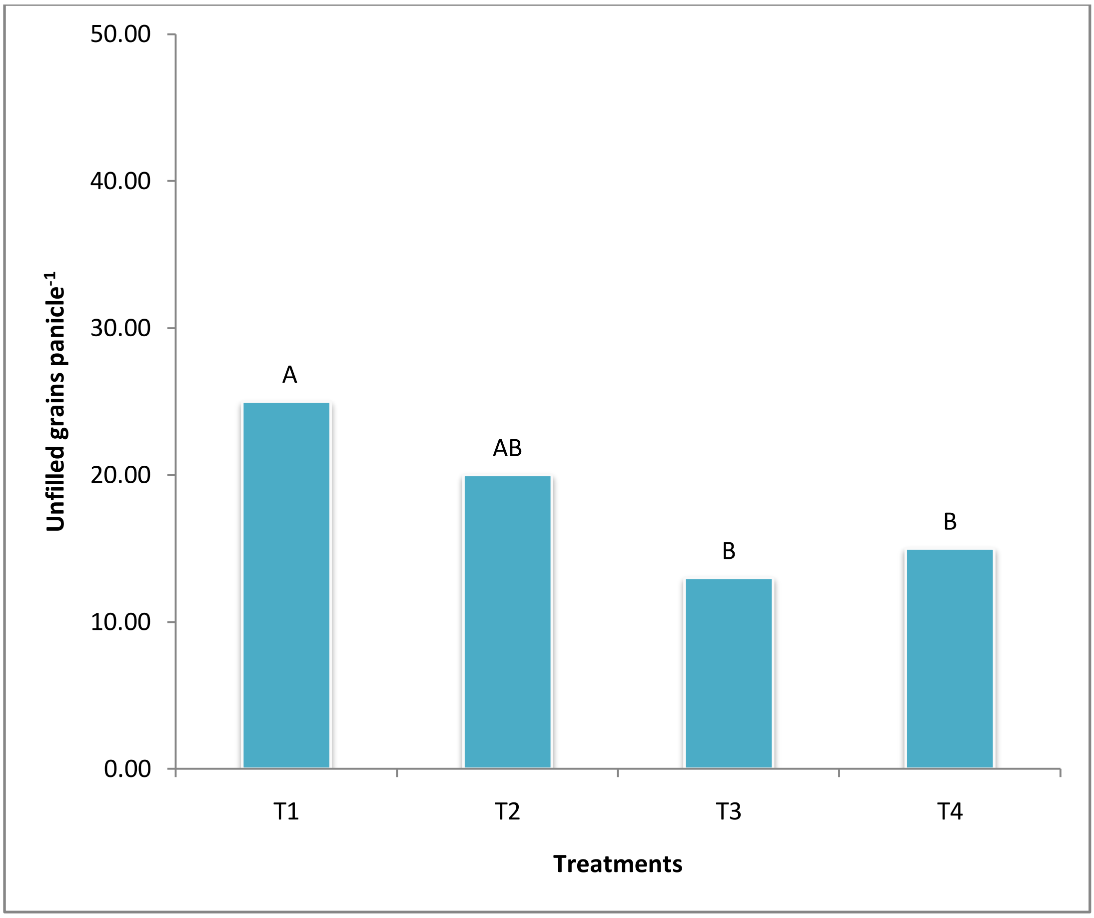


Figure 3. Effects of different treatments on Unfilled grains panicle^{-1} of *T. aman* rice (BRRI dhan49). Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD.

T_1= seedbed applied with modified CHT at 0g/m^2+ field applied with modified CHT at 0 t ha^{-1}

T_2= seedbed applied with modified CHT at 0g/m^2+ field applied with modified CHT at 0.5 t ha^{-1}

T_3= seedbed applied with modified CHT at 250g/m^2+ field applied with modified CHT at 0 t ha^{-1}

T_4= seedbed applied with modified CHT at 250g/m^2+ field applied with modified CHT at 0.5 t ha^{-1}

4.2 Yield Components

4.2.1 Grain yield (t ha^{-1})

Figure 4 shows the significant effects of different treatments on grain yield (t ha^{-1}). It was found that grain yield (t ha^{-1}) was statistically significant. The highest Grain yield (6.64 t ha^{-1}) was obtained in the T_4 (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) treatment which was significantly greater than that obtained in the T_1 control (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}) and T_2 treatment (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) and statistically identical to T_3 (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0 t ha^{-1}). The lowest Grain yield (5.28 t ha^{-1}) was obtained in the T_1 (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}) control treatment which is statistically identical to T_2 (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}). In producing grain yield (t ha^{-1}) the treatments may be arranged as $T_4 > T_3 > T_2 > T_1$. It was observed that, modified CHT application in soil increases the Grain yield of BRRI dhan49.

Lower grain yield of rice was obtained from no application of mixed chemical fertilizer and CHT and CHT application alone was not significantly different from them (Boonlertnirun *et al.*, 2010).

Yadav *et al.* (2010) reported that grain yield of rice was significantly increased due to application of chemical fertilizers and residual effects of CHT solution.

Abdel-Mawgoud *et al.* (2010) reported that application of CHT at 2 mgL^{-1} improved yield components (number and weight) of strawberry CHT application had a tendency to increase grain yield of rice plants over than unapplied seed.

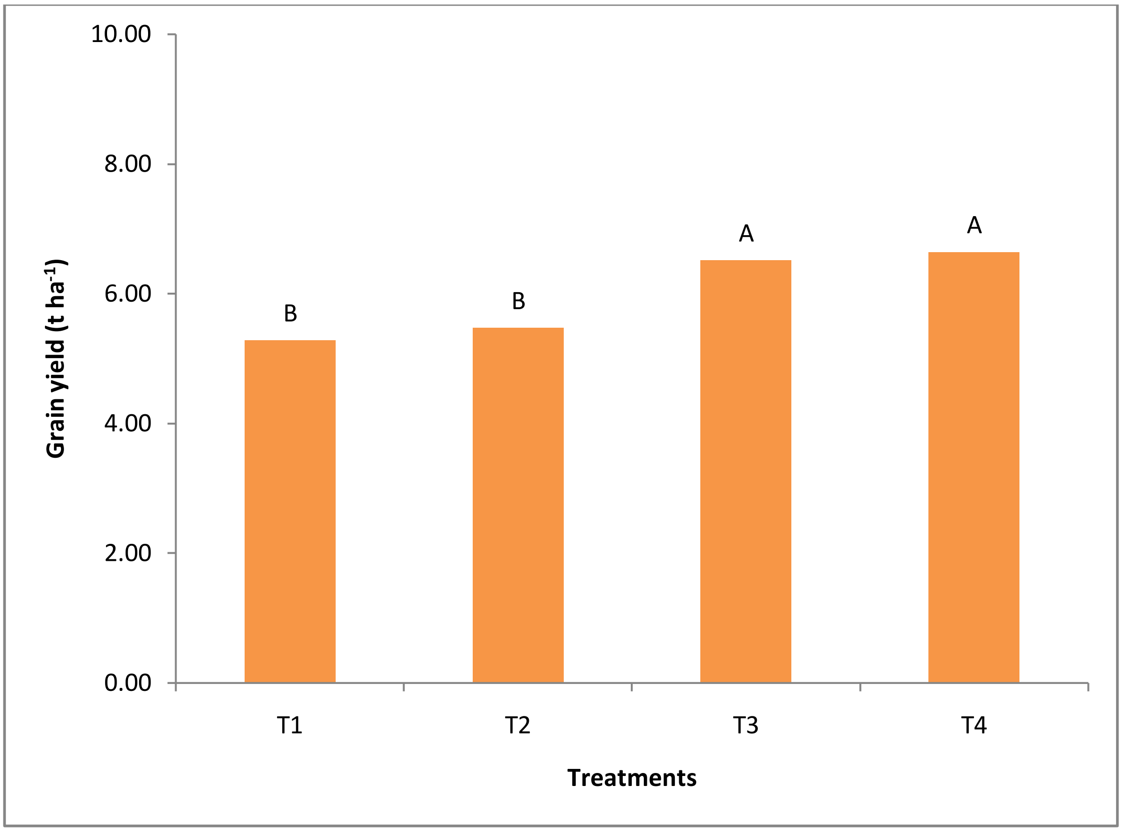


Figure 4. Effects of different treatments on Grain yield (t ha^{-1}) of *T. aman* rice (BRRI dhan49). Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD.

T_1= seedbed applied with modified CHT at 0g/m^2+ field applied with modified CHT at 0 t ha^{-1}

T_2= seedbed applied with modified CHT at 0g/m^2+ field applied with modified CHT at 0.5 t ha^{-1}

T_3= seedbed applied with modified CHT at 250g/m^2+ field applied with modified CHT at 0 t ha^{-1}

T_4= seedbed applied with modified CHT at 250g/m^2+ field applied with modified CHT at 0.5 t ha^{-1}

4.2.2 Straw Yield (t ha^{-1})

Straw yield was found to be statistically insignificant in all of the treatments used in the experiment (Table 7). The maximum straw yield (10.140 t ha^{-1}) was obtained in the T_4 treatment (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) and minimum straw yield (9.400 t ha^{-1}) was obtained in the T_1 treatment (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}). T_2 and T_3 treatments had straw yield of 9.830 t ha^{-1} and 9.790 t ha^{-1} respectively (Table 7).

These results indicate that application of modified CHT at seedbed and main field has no positive or negative effect on straw yield of BRRI dhan49.

Saha *et al.* (2007) reported that the straw yield was significantly increased due to application of chemical fertilizers and residual effects of organic manures.

4.2.3 Biological Yield (t ha^{-1})

Significant response was not observed in the Biological Yield due to the foliar application of modified CHT on BRRI dhan49. From the results, it was found that the highest Biological Yield (16.973 t ha^{-1}) was obtained from the treatment T_4 (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) and the lowest Biological Yield (14.50 t ha^{-1}) was obtained in the T_2 (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) treatment.

4.2.4 Harvest Index (%)

Table 7 shows the effects of different treatments on Harvest Index (%). It was found that Harvest Index (%) was statistically significant. The highest Harvest Index

(41.276 %) was obtained in the T_3 (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0 t ha^{-1}) treatment which was significantly greater than that obtained in the T_1 control (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}) and T_2 treatment (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) and statistically identical to T_4 (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) treatment. The lowest Harvest Index (35.850 %) was obtained in the T_2 (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) treatment which is statistically identical to T_1 (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}) and T_4 (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}). It was observed that, modified CHT application in soil increases the Harvest Index (%) of BRRI dhan49.

Table 7: Effects of different treatments on Straw yield (t ha^{-1}), Biological Yield (t ha^{-1}) and Harvest Index (%) of *T. aman* rice (BRRI dhan49) at harvest. Mean was calculated from three replicates for each treatment. Values in a column with similar letters are not significantly different at $p \leq 0.05$ applying LSD.

Treatments	**Straw yield (t ha^{-1})**	**Biological Yield (t ha^{-1})**	**Harvest Index (%)**
T_1	9.400	14.680	35.970
T_2	9.830	14.500	35.850
T_3	9.790	15.840	41.276
T_4	10.140	16.973	38.422
LSD (0.05)	1.7474	3.3238	4.9547
CV (%)	8.93	10.73	6.55

T_1= seedbed applied with modified CHT at 0g/m^2+ field applied with modified CHT at 0 t ha^{-1}

T_2= seedbed applied with modified CHT at 0g/m^2+ field applied with modified CHT at 0.5 t ha^{-1}

T_3= seedbed applied with modified CHT at 250g/m^2+ field applied with modified CHT at 0 t ha^{-1}

T_4= seedbed applied with modified CHT at 250g/m^2+ field applied with modified CHT at 0.5 t ha^{-1}

4.3 Chemical Properties of Post Harvest Soils

4.3.1 Organic Carbon status of post harvest soils

Figure 5 shows the effects of different treatments on organic carbon status of post harvest soils. It was found that organic Carbon status of post harvest soils statistically significant. The maximum percentage of organic Carbon (0.8333%) was obtained in the T_4 (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) treatment which was significantly greater than that obtained in the T_1 control (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}) and T_3 treatment (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0 t ha^{-1}) and statistically identical to T_2 (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}). The lowest organic Carbon (0.7067%) was obtained in the T_1 (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}) control treatment which is statistically identical to T_3 treatment (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0 t ha^{-1}).

It was observed that, modified CHT application in soil may increases the organic carbon status of post harvest soils.

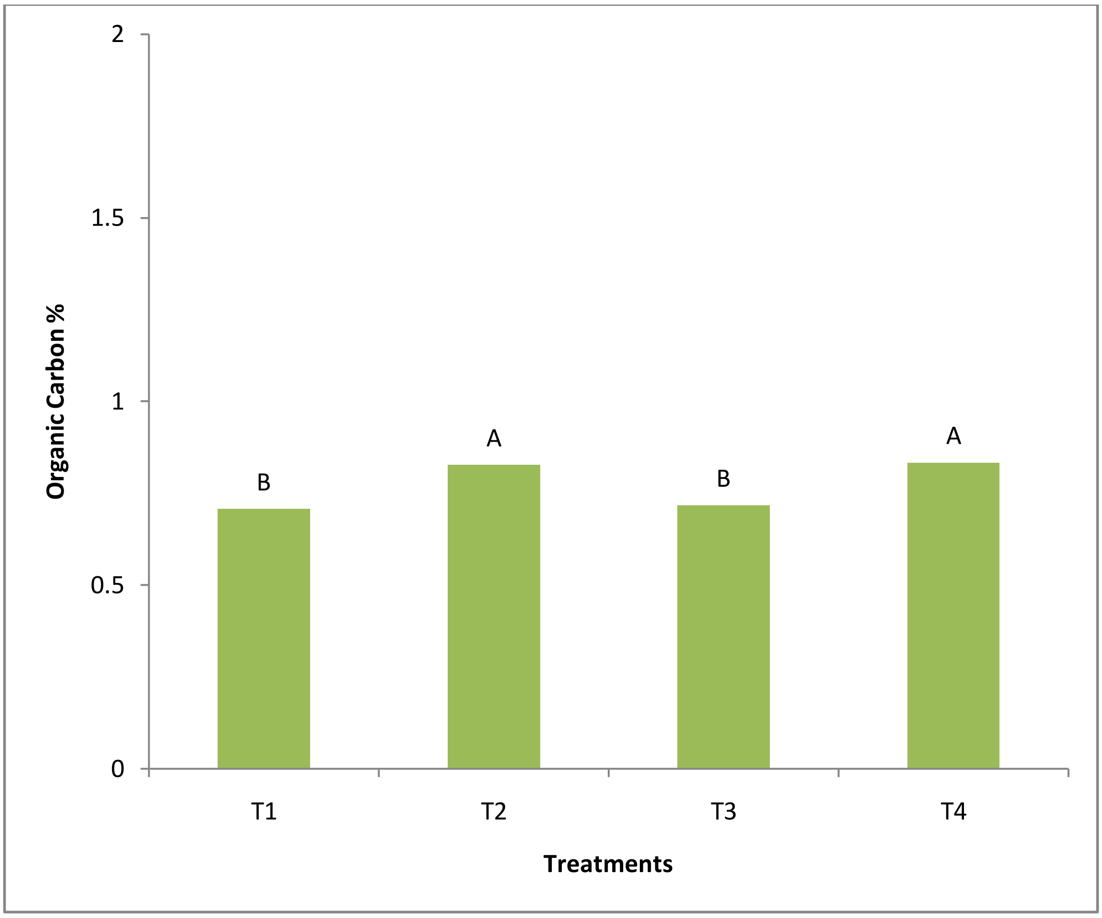


Figure 5. Effects of different treatments on Organic Carbon % of post harvest soils of *T. aman* rice (BRRI dhan49). Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD.

T_1= seedbed applied with modified CHT at 0g/m^2+ field applied with modified CHT at 0 t ha^{-1}

T_2= seedbed applied with modified CHT at 0g/m^2+ field applied with modified CHT at 0.5 t ha^{-1}

T_3= seedbed applied with modified CHT at 250g/m^2+ field applied with modified CHT at 0 t ha^{-1}

T_4= seedbed applied with modified CHT at 250g/m^2+ field applied with modified CHT at 0.5 t ha^{-1}

4.3.2 Organic Matter status of post harvest soils

Figure 6 is showing the effects of different treatments on organic matter status of post harvest soils. It was found that organic matter status of post harvest soil statistically significant. The organic matter status (1.4333%) was obtained in the T_4 (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) treatment which was significantly greater than that obtained in the T_1 control (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}) and T_3 treatment (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0 t ha^{-1}) and statistically identical to T_2 (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}). The lowest organic matter (1.2200%) was obtained in the T_1 (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}) control treatment which is statistically identical to T_3 treatment (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0 t ha^{-1}). In producing organic matter status of post harvest soil the treatments may be arranged as $T_4>T_2>T_3>T_1$. It was observed that, modified modified CHT application in soil increases the organic matter status of post harvest soil.

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.

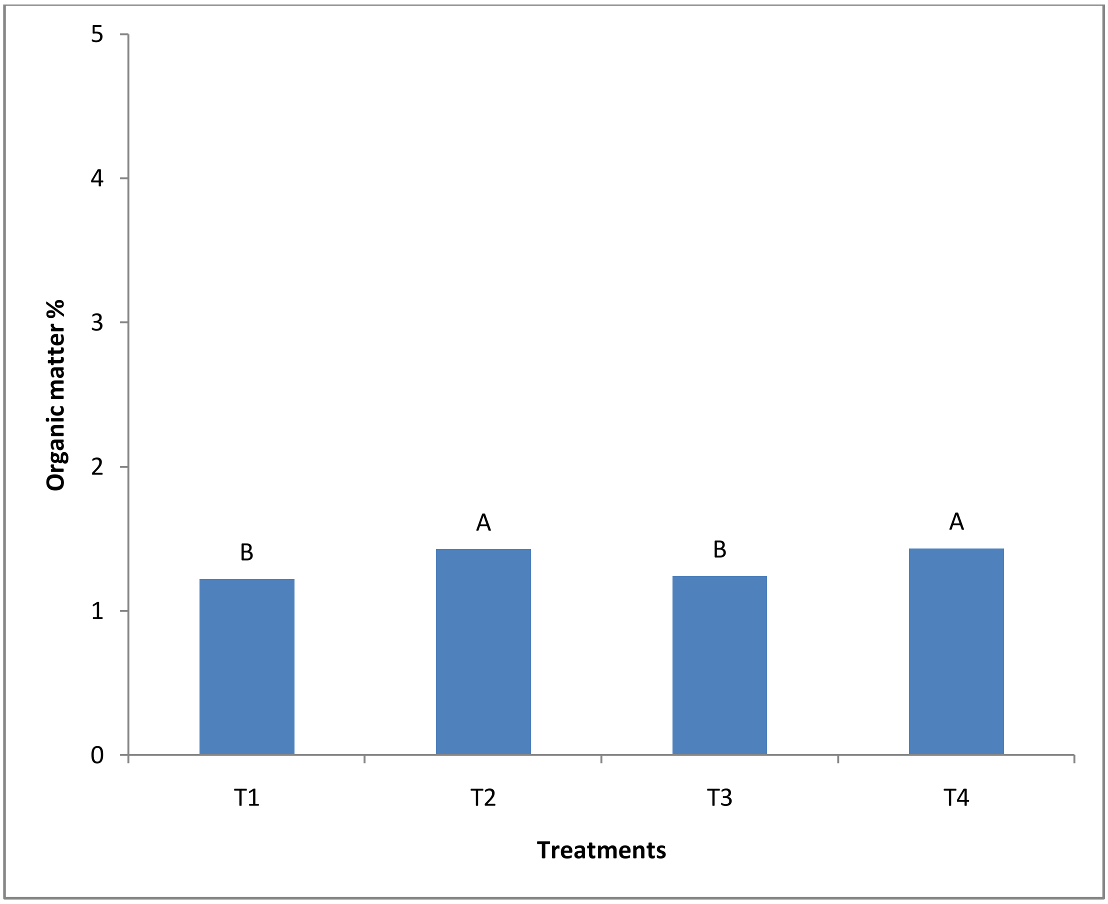


Figure 6. Effects of different treatments on Organic matter % of post harvest soils of *T. aman* rice (BRRI dhan49). Mean was calculated from three replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD.

T_1= seedbed applied with modified CHT at 0g/m^2+ field applied with modified CHT at 0 t ha^{-1}

T_2= seedbed applied with modified CHT at 0g/m^2+ field applied with modified CHT at 0.5 t ha^{-1}

T_3= seedbed applied with modified CHT at 250g/m^2+ field applied with modified CHT at 0 t ha^{-1}

T_4= seedbed applied with modified CHT at 250g/m^2+ field applied with modified CHT at 0.5 t ha^{-1}

4.3.3 pH of Post-Harvest Soils

The pH value of the post-harvest soils was not differ significantly due to the use of modified chitosan in the field. The pH remains almost similar among all the treatments. The ranges of pH value of those treatments are shown at the table 9.

Table 8: Effects of different treatments on pH of Post-Harvest Soils of *T. aman* rice (BRRI dhan49) at harvest.

Treatments	pH of Post-Harvest Soils
T_1	5.8
T_2	5.6
T_3	5.8
T_4	5.8

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 9: Composition of the modified CHT which was used in the research work.

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

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was conducted at the research field of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from August 1, 2015 to December 10, 2015 to study on the effect of modified CHT on growth and yield of BRRI dhan49 in Aman season under the Modhupur Tract (AEZ-28).

The experiment was comprised of four treatments. T_1= seedbed applied with modified CHT at 0 g/m^2 + field applied with modified CHT at 0 t ha^{-1}; T_2= seedbed applied with modified CHT at 0 g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}; T_3= seedbed applied with modified CHT at 250 g/m^2 + field applied with modified CHT at 0 t ha^{-1}; T_4= seedbed applied with modified CHT at 250 g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}. 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 noneffective 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. Modified CHT treatment showed that, the maximum plant height (105.33cm) was obtained in the T_4 treatment (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) and minimum plant height (92.33cm) was obtained in the T_1 treatment (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}); The maximum number of total tillers hill^{-1} (18.333) was obtained in the T_3 (seedbed applied with modified CHT at 250 g/m^2 + field applied with modified CHT at 0 t ha^{-1}) treatment and the minimum number of total tillers hill^{-1} (13.667) was obtained in the T_1 (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}) control treatment; The highest number of effective tillers hill^{-1} (14) was obtained in the T_3 (seedbed applied with modified CHT at 250 g/m^2 + field applied with modified CHT at 0 t ha^{-1}) treatment and The lowest number of effective tillers hill^{-1} (11.67) was obtained in the T_1 (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}) control treatment; The maximum non-effective tillers hill^{-1} (4.33) was obtained in the T_3 treatment (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0 t ha^{-1}) and minimum non-effective tillers hill^{-1} (2.00) was obtained in the T_1 treatment (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}); The maximum Total number of grains panicle^{-1} (173.67) was obtained in the T_4 treatment (seedbed applied with modified CHT at 250 g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) and minimum Total number of grains panicle^{-1} (165.00) was obtained in the T_1 treatment (seedbed applied with modified CHT at 0 g/m^2 + field applied with modified CHT at 0 t ha^{-1}); The highest number of Filled grains panicle^{-1} (16.00) was obtained in the T_3 (seedbed applied with modified CHT at 250 g/m^2 + field applied with modified CHT at 0 t ha^{-1}) and The lowest number of Filled grains panicle^{-1} (140.00) was obtained in the T_1 (seedbed applied with modified CHT at 0 g/m^2 + field applied with modified CHT at 0 t ha^{-1}) control treatment; The highest number of Unfilled grains panicle^{-1} (25.00) was obtained in the T_1 (seedbed applied with modified CHT at 0 g/m^2 + field applied with modified CHT at 0 t ha^{-1}) treatment and lowest number of Unfilled grains panicle^{-1} (13.00) was obtained in the T_3 (seedbed applied with modified CHT at

250 g/m^2 + field applied with modified CHT at 0 t ha^{-1}); The maximum 1000 seed weight was found in T_3 (seedbed applied with modified CHT at 250 g/m^2 + field applied with modified CHT at 0 t ha^{-1}) was (19.567g) and the minimum 1000 seed weight was observed in control T_1 (19.00g) and T_2 (19.00g); The maximum Panicle length (23.00) was obtained in the T_4 treatment (seedbed applied with modified CHT at 250g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) and minimum Panicle length (22.33) was obtained in the T_2 treatment and T_3 treatment; The highest Grain yield (6.64 t ha^{-1}) was obtained in the T_4 (seedbed applied with modified CHT at 250 g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) treatment and the lowest Grain yield (5.28 t ha^{-1}) was obtained in the T_1 (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}) control treatment; The maximum Straw yield (10.140 t ha^{-1}) was obtained in the T_4 treatment (seedbed applied with modified CHT at 250 g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) and minimum Straw yield (9.400 t ha^{-1}) was obtained in the T_1 treatment (seedbed applied with modified CHT at 0g/m^2 + field applied with modified CHT at 0 t ha^{-1}); the highest Biological Yield (16.973 t ha^{-1}) was obtained from the treatment T_4 (seedbed applied with modified CHT at 250 g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) and the lowest Biological Yield (48.69 %) was obtained in the T_2 (seedbed applied with modified CHT at 0 g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}) treatment; the highest Harvest Index (41.276 %) was obtained in the T_3 (seedbed applied with modified CHT at 250 g/m^2 + field applied with modified CHT at 0 t ha^{-1}) and the lowest Harvest Index (35.850 %) was obtained in the T_2 (seedbed applied with modified CHT at 0 g/m^2 + field applied with modified CHT at 0.5 t ha^{-1}).

The present study was conducted to improve our understanding of rice responses to modified CHT application. Our results indicated beneficial effects of modified CHT application. Application of modified 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. Modified 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 modified 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 (Plate 3) resulting more yield. The results also indicate that seedbed applied method of modified chitosan would be more effective than field applied method. These results might be due some growth promoting hormones (especially GA3, Auxin etc.) could be realized in soil that induced the seedlings growth and early flowering some some genes (ELF1, ELF2, ELF3) could be induced by the application of modified chitosan in soil.

The overall results of the present study demonstrated that yield maximization is induced by the application of modified chitosan both in the seedbed applied method and field applied method. Among the application methods seedbed application could be suggested for the rice growers.

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

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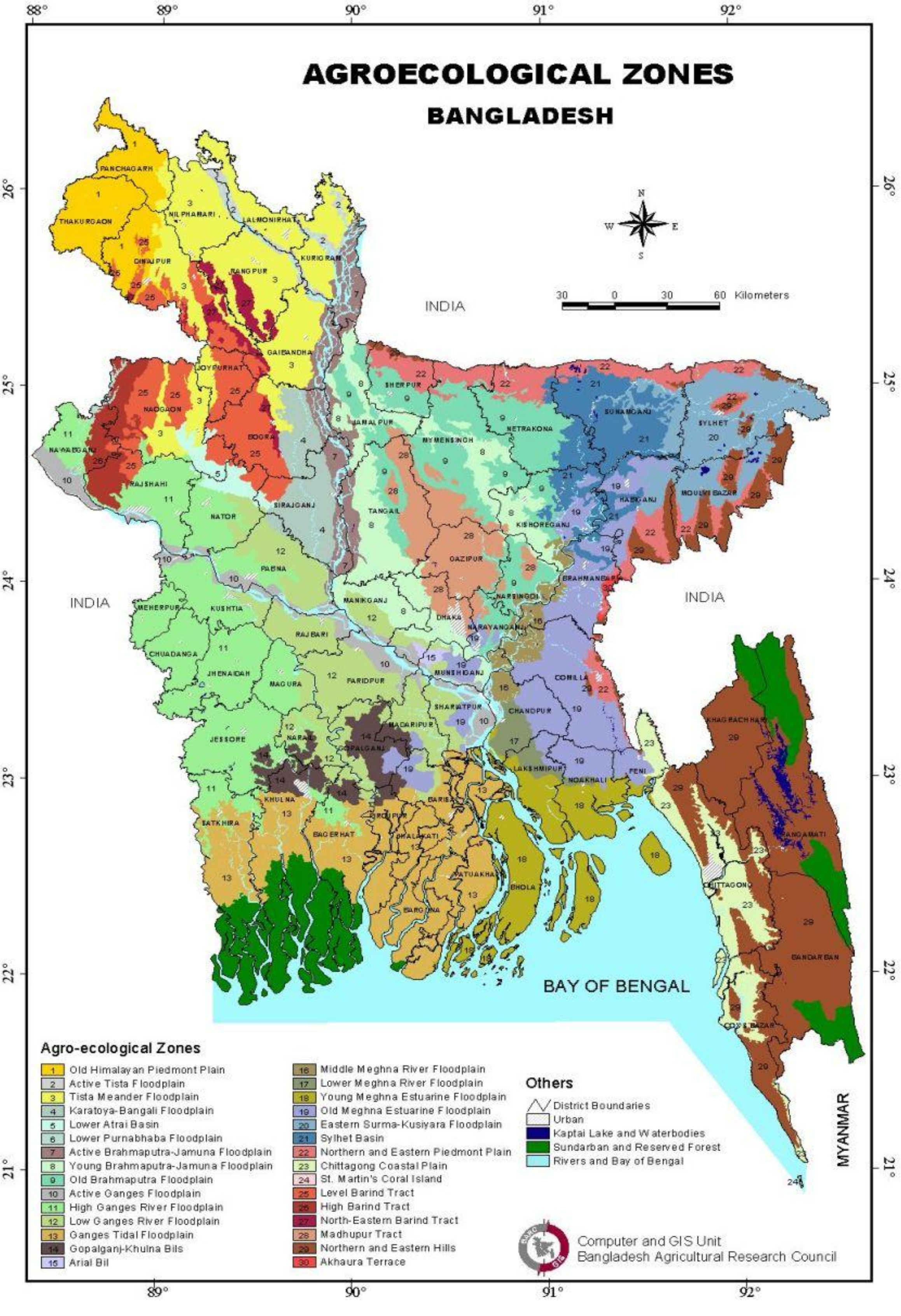
APPENDICES

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	30
% Silt	40
% Clay	30
Textural class	Clay loam
pH	6.3
Organic matter (%)	0.68
Total N (%)	0.06
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.12
Available S (ppm)	22

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

Appendix III. Monthly average air temperature, relative humidity, total rainfall, wind speed, sunshine hour and evaporation rate of the experimental site during the period from August to November, 2015.

Month	RH (%)	Temperature (ºC)		Wind speed (km hr^{-1})	Sunshine hour	Rain fall (mm day^{-1})	Evaporation rate (mm day^{-1})
		Maximum	*Minimum*				
August	74.41	31.02	15.27	3	5.11	5.1	2.07
September	73.20	31.46	14.82	2	4.15	6.3	2.05
October	67.82	30.18	14.85	1	7.48	4.2	2.05
November	58.18	28.10	6.88	1	7.85	1.56	1.82

Source: SAU Meteorological Yard ,Sher-e-Bangla Nagar, Dhaka-1207.

Apendix IV. Analysis of variance (mean square) of morphological and yield components of Transplant aman rice.

Source	DF	Plant height	Total tiller	Effective tiller	Non-effective tiller	Panicle length	Total grain	Filled grain	Unfilled grain	Grain yield	Staw yield	Biological yield	Harvest index	1000 grain wt	pH	OC%	OM%
Rep	2	15.083	9.2500	5.08333	2.33333	0.08333	3.0833	7.583	9.00	0.28391	0.77423	2.06043	8.4175	0.30583	1.578E-30	0.00031	0.0009
Treat	4	122.306NS	12.5278NS	3.63889*	3.22222NS	0.30556NS	52.7778NS	270.528**	86.75*	1.47007*	0.27620NS	3.95870NS	19.5969 NS	0.24750NS	0.03000 NS	0.0141**	0.0402 **
Error	8	54.639	4.6944	0.63889	2.22222	0.63889	28.5278	13.028	15.00	0.20291	0.76492	2.76777	6.1501	0.26250	2.107E-62	0.00011	0.00032

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

DF: Degrees of freedom

OC: Organic carbon

OM: Organic matter