YIELD PERFORMANCE OF RICE (BRRI hybrid dhan4) INFLUENCED BY CHITOSAN RAW MATERIAL POWDER

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A Thesis

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CERTIFICATE

This is to certify that thesis entitled, **"YIELD PERFORMANCE OF RICE (BRRI HYBRID DHAN4) INFLUENCED BY CHITOSAN RAW MATERIAL POWDER"**submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE** in **SOIL SCIENCE**, embodies the result of a piece of bona fide research work carried out by **MD. RAJU MIAH**, Registration No. **19-10101,** 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.

Date:
Place: Dhaka, Bangladesh

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Dedication

To my beloved parents.

Thanks for your endless affection, supports and sacrifices

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ABSTRACT

During the months of July to November 2020, a pot experiment was done under the net house at Sher-e-Bangla Agricultural University in Dhaka, Bangladesh, to investigate the performance of a rice variety (BRRI hybrid dhan4) as influenced by chitosan raw material powder. Fourteen (14) inches size pots were used in the experiment, having length (10.5 inches) and diameter (9.5 inches). The pots were filled with 10 kg of moist field soil with a silty clay loam texture. The experiment was set up in a Randomized Complete Block Design (RCBD). The experiment was comprised of six (6) treatments i.e. T_1 = 0% chitosan raw material powder, T_2 = 0.1% chitosan raw material powder, T_3 = 0.2% chitosan raw material powder, T_4 = 0.3% chitosan raw material powder ,T_5 = 0.4% chitosan raw material powder and T_6 = 0.5% chitosan raw material powder. Forty eight (48) replications were used in the experiment and the total number of experimental pots were two hundred eighty eight (6 x 48=288). All of the treatments applied in the experiment resulted in significant increases in seedling characteristics such as 100 seedling fresh weight, 100 seedling oven dry weight, seedling height, and seedling strength. The T_5 treatment had the maximum seedling strength (4.97mg/cm), while the T_1 control treatment had the minimum seedling strength (4.2mg/cm). The trend of the seedling strength was $T_5>T_6>T_4>T_3>T_2>T_1$. At the maximum tillering (MT) stage, biomass production increased. The growing tendency of seedling characteristics had a significant impact on early tiller production, tiller number, fresh and dry matter production, and yield at the maximum tillering stage. The T_2 treatment had the highest effective tillers/pot 15.7, while control T_1 had the lowest effective tillers/pot production (14.1). T_2 treatment produced the maximum grain yield (40.25 g/pot), while T_1 produced the minimum grain yield (34.46 g/pot). Taken together, the research findings showed that chitosan raw material powder had a significant impact on seedling strength improvement, which in turn influenced maximum effective tiller production, resulting higher grain yield. The findings suggested that chitosan raw material powder could be used as an effective tool in yield-increasing strategy of rice in Bangladesh under Climate Smart Agriculture.

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AEZ	Agro-Ecological Zone
BRRI	Bangladesh Rice Research Institute
BBS	Bangladesh Bureau of Statistics
cv.	Cultivar
DAE	Department of Agricultural Extension
DAP	Diammonium phosphate
DAS	Days after sowing
^{0}C	Degree Celsius
CRMP	Chitosan raw material powder
et al	And others
FAO	Food and Agriculture Organization
g	gram(s)
ha^{-1}	Per hectare
kg	Kilogram
Max	Maximum
mg	Milligram
Min	Minimum
MoP	Muriate of Potash
N	Nitrogen
No.	Number
MT stage	Maximum Tillering stage
%	Percent
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
TSP	Triple Super Phosphate
Wt.	Weight

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food for the people of Bangladesh and in Asia rice is the staple food for more than two billion people (Hien et al., 2010). Rice is the vital food for more than two billion people in Asia and four hundreds millions of people in Africa and Latin America (IRRI 2010). Rice is the principle food in most of the countries of Asia and Africa. Rice belongs to the Gramineae family and the genus is *Oryza* which contains about 22 different species (Wopereis et al., 2009). The people in Bangladesh depend on rice as staple food and have tremendous influence on agrarian economy of Bangladesh. Rice alone constitute of 95% of the food grain production in Bangladesh (Julfiquare et al., 1998). It is also the most important food crop and a dominant food grain for more than one third of the world and the most important source of the food energy for 50% of the Global population (Zhao et al., 2011). Rice has the second largest cereal production after wheat with over 685 million tones recorded in 2009 (Abodolereza and Racionzer, 2009). Rice is grown in 114 countries of the world in about 150 million hectares of land and the annual production of rice is over 525 million tones, nearly 11 per cent of the world`s cultivated land is used for rice cultivation (Rai, 2006). According to the Food and Agricultural Organization (FAO) of the UN, 80% of the world rice production comes from 7 countries (UAE-FAO, 2012). Annual production of rice in Bangladesh is about 36.28 million tons from 11.52 million ha of land (BBS, 2018). According to the USDA report in 2021 rice production for the 2020-21 marketing year is expected to rise to 36.3 million tons in Bangladesh as further cultivation of hybrid and high yield variety plantings increase. The country is expected to import 200,000 tons of rice in the 2020-21 marketing year to ease food security tensions brought on by the COVID-19 pandemic (USDA, 2021). The average yield of rice in Bangladesh is 3.14 t ha^{-1} (BBS, 2019). Rice is the staple food for about 156 million people of Bangladesh (Israt et al., 2016). According to the Bangladesh Economic Review, 2021, Bangladesh is the 3rd largest country of the world based on the rice cultivation. The contribution of agriculture sector in GDP is 13.47 percent in 2020-21 fiscal years (Bangladesh Economic Review, 2021). In the agriculture sector, the crop sub-sector dominates with 10.74 percent in GDP of which rice alone contributes about 53 percent as well as about one-sixth of the national income comes from the rice sector (Rahman et al., 2015). Among the three rice growing seasons in Bangladesh, Boro contributes lion's share (53%) in total rice production. Aman, the second biggest crop after Boro in terms of production, provided 38.8% of total 36.6 million tons of rice output in 2019-2020 fiscal year (BBS, 2020). But rice production is affected by various biotic and abiotic constraints. It is estimated that, about 220 hectares of agricultural lands are decreased per year due to urbanization, industrialization, housing and road construction purposes. Fifty lac acres of agricultural land decreased during last 20 years (Anon, 2007). Therefore, attempts must be made to increase the yield per unit area by adopting modern rice cultivars, nutrient management practices and applying improved technology.

Chitosan is a naturally occurring polymer that became available in the 1980s in industrial quantities enabling it to be tested as an agricultural chemical. This biopolymer stimulates growth and increases yield of plants as well as induces the immune system of plants (Boonlertnirun et al., 2008). Chitosan is a natural polymer and one of the chitin derivatives when the degree of deacetylation of chitin reaches about 50% . Chitin is one such product, which is cationic amino polysaccharide made up of N-acetyl D-glucosamine (GlcNAc) repeat blocks, joined by β-1, 4 glycosidic bonds (Rinaudo, 2006). The functional properties of chitosan such as solubility, biodegradability, and diverse bioactive attributes are related to molecular weight and the degree of deacetylation (Rajoka et al., 2019). Many studies have differently determined classes of chitosan based on its molecular weight; however, the specific categories are still unclear. Commercially, chitosan is classified into three main different classes: low (50-190 kDa), medium (190-310 kDa), and high (310-375 kDa) molecular weight (MW) (Prashanth and Tharanathan, 2007). Chitosan, the deacetylated form of one of the most abundant polymers in nature, namely chitin (Muxika *et al.* 2017), has been proposed to be a potential alternatives to synthetic cytokinins and jasmonic acid in tissue cultures of plants. It can be extracted from the marine crustacean like prawn, shrimps and crab or from the exoskeletons of most insects. They are inherent to have specific properties of being environmentally friendly and easily degradable (Boonlertnirun *et al.*, 2008). In plants, chitosan elicits numerous defence responses related to biotic and abiotic stresses. It has been utilized effectively in many plant related applications to increase plant productivity as well as protect plants against the attack of pathogens (Malerba and Cerana, 2018). Significantly greater number of branches/plant is observed in case of chitosan treated plant than untreated control (Reddy et al., 2000). In agriculture, chitosan is used primarily as a natural seed treatment and plant growth enhancer and also as an ecologically friendly biopesticidal substance that boosts the innate ability of plants to defend themselves against fungal infections (Linden et al., 2000). Plants with high content of chitin show better disease resistance (Khan et al., 2003).

In Bangladesh, there is limited information on the impact of organic growth promoters such chitosan on rice growth and yield. A field experiment was undertaken in the AEZ-28 area to study the influence of chitosan raw material powder on seedling characters, yield and yield attributes of T. Aman rice cultivars (BRRI Hybrid dhan4) in order to gather data.

Considering the above facts in mind the following objectives are undertaken:

1. To examine seedling characters of hybrid rice as influenced by chitosan raw material powder
2. To evaluate yield and yield contributing characteristics of BRRI Hybrid dhan4 as influenced by chitosan raw material powder.

CHAPTER II

REVIEW OF LITERATURE

In this section, an attempt was made to gather and study relevant information available in the country and abroad about the tillering pattern of BRRI Hybrid dhan4 using chitosan raw material powder in the seedbed in order to gain knowledge useful in conducting the current research and writing up the results and discussion.

2.1 Effect of chitosan on growth, yield parameter and yield

2.1.1 Seedling height (cm)

Ahmed *et al*. (2020) reported that the use of chitosan-raw-material in the seedbed enhanced seedling height.

Issak and Sultana (2017) conducted an experiment to determine how chitosan powder affected the production of BRRI dhan29 rice seedlings. They reported that utilizing chitosan powder in the seedbed boosted the development of Boro rice seedlings.

Sultana et al. (2015) conducted a rice plant field experiment. This study used four distinct concentrations of oligomeric chitosan (0, 40, 80, and 100 ppm) and four different foliar sprays after germination. Plant height had no statistically significant variations between control and 40 ppm oligo-chitosan sprayed plants in this experiment. However, rice plants treated with 80 and 100 ppm oligo-chitosan demonstrate significant differences when compared to control.

Ma et al. (2013) used oligochitosan to treat wheat seeds by soaking them in a 0.0625 percent oligochitosan solution for 5 hours. Treatment of seeds with oligochitosan increased chlorophyll concentration, according to the findings. It was observed that treating seeds with oligochitosan increased photosynthesis. They also confirmed that oligochitosan had a good effect on plant growth and salt tolerance.

In comparison to untreated seeds, seeds treated with chitosan resulted in superior seedling growth (e.g. longer and better developed radicle and greener hypocotyls) and a lower likelihood of being affected by fungus, according to Ziani et al. (2010). The assimilation of nutrients (nitrogen) from chitosan could potentially explain the observed growth improvement.

Boonlertnirun *et al*. (2008) did an experiment to study the effect of chitosan application in rice production and found that chitosan is a real biopolymer that boosts plant growth and yield while also inducing the immune system.

Bolto *et al.* (2004) conducted an experiment on ion exchange for the removal of natural organic matter and discovered that CHT (chitosan) can boost microbial populations and convert organic nutrients to inorganic nutrients that are easily absorbed by plant roots.

Ouyang and Langlai (2003) reported that seed treatment with 0.4-0.6 mg/g seed and leaf spraying 20-40 micro g/ml improved plant height and leaf area of Chinese cabbage (*Brassica campestris*) cv. Dwarf hybrid No. 1.

Hoque (2002) conducted a field experiment on a high-yielding wheat variety (Shatabdi) to assess the effects of CI-IAA, GABA, and TNZ-303 by soaking seeds in 0.16 ml/L, 0.33 ml/L, and 0.66 ml/L aqueous solutions, and found that GABA at 0.33 ml/L generated the tallest shoot at 60 and 90 DAS. The shoot height was substantially higher than in the control group.

Chitin oligosaccharides induce lignification in damaged Rice leaves was studied by Tsugita *et al.* (1993), who proved that chitosan increases shoot and root growth.

2.1.2 Seedling Fresh weight (g)

Issak and Sultana (2017) conducted an experiment and shown that chitosan powder treatments in the seedbed greatly boosted fresh weight production of BRRI dhan29 rice seedlings. The treatment T_4 with 400 g Chitosan powder/m2 produced the most fresh weight (29.14 g) of 100 seedlings, which was substantially different from all other treatments. The treatment T_6 (control) had the lowest fresh weight production (12.6 g), which was substantially different from all other treatments.

According to Phothi and Theera karunwong (2017), Chitosan+EO340 and Chitosan+EO370 accumulated considerably more shoot biomass than EO340 and EO370, respectively (p 0.05).Furthermore, chitosan has been shown to minimize the detrimental impacts of ozone while also increasing physiology and photosynthesis rates.

According to Guan *et al*. (2009), oligo-chitosan treatment increased maize mineral absorption and accelerated maize seedling growth. Spraying oligochitosan at a 60 mg/L concentration. Chitosan has been found to have a favorable influence on the growth of roots, shoots, and leaves of a variety of crop plants (Chibu and Shibayama, 2001). Chitosan enhanced shoot height and root length in maize plants when grown at a low temperature, compared to the control.

Ouyang and Langlai (2003), found that non-heading Chinese cabbage seeds treated with chitosan at a rate of 0.4-0.6 mg/g seed and leaf spraying with 20-40 micro g/ml enhanced fresh weight.

Saravanan et al. (1987) conducted an experiment to determine the effect of combining bio-organic and chemical fertilizers on physical properties, nitrogen transformation, and yield of rice in submerged soils, and noticed that organic manures, such as sludge and CHT spray, improve the efficiency of applied nitrogen.

2.1.3 Seedling Oven Dry weight (g)

Ahmed *et al.* (2020) reported that the use of chitosan-raw-material in the seedbed increased seedling oven dry weight.

According to Issak and Sultana (2017), chitosan powder applications influenced oven dry weight productions of BRRI dhan29 rice seedlings, which could be due to nutritional support for the seedlings, increased growth promoting hormonal activity, and improved biological and physio-chemical properties of the seedbed soils.

In a pot experiment, John Berber *et al*. (2012) found no significant differences in any evaluated attributes of inoculated and non-inoculated rice plants applied using varied application methods. On leaf greenness, plant height, dry matter, grain yield, and panicle numbers, chemical fertilizer in combination with chitosan was not substantially different from chemical fertilizer alone, but it was significantly different from those without both chemical fertilizer and chitosan. However, various application methods had a significant impact on dirty panicle disease seeds; the lowest numbers were obtained from the application of chemical fertilizer in combination with chitosan, whereas no application of both chemical fertilizer and chitosan had a negative effect on controlling dirty panicle disease in inoculated and non-inoculated rice plants.

Boonlertnirun *et al*. (2008) investigated the effect of chitosan treatment on rice production and found that chitosan application greatly increases seedling dry matter weight.

Martinez et al. (2007) conducted an experiment to investigate the effects of seed treatment with chitosan on tomato (*Lycopersicum esculentum* L.) plant growth and found that, in general, the best response was obtained when seeds were treated with 1 mg/L chitosan for four hours, as this concentration significantly increased plant dry weight, despite the fact that the other indicators were unchanged.

2.1.4 No of tillers/pot

Ahmed *et al*. (2020) conducted an experiment at the research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, and showed that the application of chitoan-raw-material in soil increases the total tillers/pot.

Ahmed *et al.* (2013) conducted an experiment and found that foliar spraying of Chitosan has a substantial impact on rice tiller/pot production. The results demonstrated that Chitosan-treated plants generated more tillers than control plants. At 30, 60, and 90 DAT, the highest number of tillers/pot (9.33, 13.67, and 16.67) was found in 50 mg/L, followed by 75 mg/L Chitosan (8.33, 12.33, and 15.33). Control, on the other hand, had the smallest number of tillers/pot (7.33, 10.33, and 13.33, respectively).

Boonlertnirun *et al*. (2008) conducted an experiment and found that soaking seeds in chitosan solution before planting resulted in the highest number of tillers, which was subsequently applied to the soil, but that this did not differ significantly from the control with no chitosan application.

Hoque (2002) tested the effect of seed soaking with 0.16 ml/L, 0.33 ml/L, and 0.66 ml/L of CI-IAA, GABA, and TNZ-303 on seed germination and seedling growth in different wheat cultivars. At 0.33 ml/L of PGR, the number of tillers dramatically increased as compared to the control.

2.1.5 Number of effective tillers/pot

Ahmed *et al.* (2020) conducted a field experiment in the Sher-e-Bangla Agricultural University's research field in Dhaka, Bangladesh, to investigate the effect of chitosan-raw-material on yield maximization BRRI dhan49. The results of the experiment demonstrated that varying levels of chitosan have substantial effects on effect tillers/pot, with the largest number of effective tillers/pot (14) in the T_3 treatment and the lowest number of effective tillers/pot (11.67) in the T_1 control treatment. The use of chitosan-raw-material in the soil was found to increase the number of effective tillers/pot.

Boonlertnirun *et al.* (2012) showed that application methods of chitosan significantly affected tiller number per plant.

2.1.6 Grain yield (g/pot)

Ahmed *et al*. (2020) conducted an experiment at the research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, to examine effect of chitosan-raw-material of on yield maximization of BRRI dhan49 laid out in RCBD having four treatments with five replications. Minimum grain yield (5.28 t/ha) was found in the control treatment T_1 which was statistically identical with the grain yield of treatment T_2.Seedlings, treated with chitosan-raw-material, had a profound effect on grain yield and yield traits of T. aman rice (BRRI dhan49).

Al-Tawaha *et al.* (2020) did an experiment to see how fertilizer and chitosan application affected the quality and production of barley. As subplot treatments, chitosan in three different concentrations (0, 5, and 10 g/L) was administered randomly to all fertilized plots. In the presence and absence of chitosan treatment, significant variance (P0.01) was also found between the lines. The foliar administration of 10 g/L chitosan to barley plants during the tillering stage resulted in the maximum number of grain yield, number of spikes, and grains/spike. Similarly, grain quality was shown to be significantly improved over control, notably in terms of protein and starch.

Priyaadharshini *et al*. (2019) tested the effect of chitosan nanoemulsion in pearl millet grown in a water deficiency environment. At the flowering stage, a foliar spray of 0.1 percent chitosan nanoemulsion was applied, along with a control, under moisture stress conditions. The results demonstrated that chitosan treatment reduces stomatal conductance, restricting photosynthesis, transpiration rate, and leaf temperature in comparison to unsprayed plants. Under drought conditions, the yield of treated plants was considerably higher than that of control plants

Behboudi *et al*. (2018) found that using chitosan increased the number of grains per spike and grain production substantially when compared to control.

Sultana *et al.* (2015) conducted a rice plant field experiment. This study used four distinct concentrations of oligomeric chitosan (0, 40, 80, and 100 ppm) and four different foliar sprays after germination. Grain yield showed substantial variations between foliar sprayed chitosan plants and control plants, according to the findings.

Ahmed *et al.* (2013) conducted a research to investigate the effect of chitosan on growth and yield of rice cv. BRRI dhan29 and observed significant effect of Chitosan on grain yield of rice. The results showed that 50 mg/L Chitosan treated plants provided the maximum grain yield (7.05 t/ha), followed by 75 mg/L (6.77 t/ha) and 100 mg/L (6.14 t/ha) Chitosan. The control treatment, on the other hand, had the lowest grain production (5.83 t/ha).

Nguyen and Tran (2013) conducted an experiment in Vietnam to see how chitosan solutions impacts on rice yields. They found that chitosan made from shrimp shells using dilute acetic acid was helpful in reducing plant infection by microbial agents, resulting in increased yields. Rice yields improved dramatically (31%) after using chitosan solution in the field, according to the study. In general, using chitosan increased rice yield while drastically lowering production costs.

According to Abdel-Mawgoud *et al*. (2010), chitosan application at 2 mg/L improved yield components (number and weight) of strawberry plants, while chitosan application increased grain yield of rice plants above unapplied seed.

Sultana (2010) from BAEC, Bangladesh stated that oligochitosan was tested on the development and productivity of maize (*Zea mays*. L) plants to see if it could be used as a plant growth enhancer. Using oligochitosan (molecular weight 7,000 Da) as a foliar spray at concentrations of 25, 50, and 75 mg/L. The results showed that at a concentration of 75 mg/L, oligochitosan had a substantial impact on the weight of cobs and seeds per maize, as well as maize production.

2.1.7 Straw yield (g/pot)

Phothi and Theerakarunwong (2017) investigated the effects of chitosan on rice cultivar RD47 physiology, photosynthesis, and biomass. Rice samples were grown in climate-controlled indoor chambers with inlet air passing through charcoal filters. The findings clearly demonstrated that ozone at both 40 and 70 ppb had deleterious effects on rice physiology, photosynthesis, and biomass. The 70 ppb concentration, in particular, was quite harmful. Furthermore, chitosan has been shown to minimize the detrimental impacts of ozone while also increasing physiology and photosynthesis rates.

Kananont *et al.* (2015) conducted an experiment with fermented chitin waste (FCW) at three levels (0.25 percent, 0.50 percent, and 1.0 percent (w/w)), as well as CF = chemical fertilizer-supplemented soil and CMF = chicken manure fertilizer-supplemented soil. FCW @ 1% straw yield differed considerably from 0.5 percent FCW, 0.25 percent FCW, and the remainder of the treatments, according to the results.

Sultana *et al*. (2015) conducted a rice plant field experiment. This study used four distinct concentrations of oligomeric chitosan (0, 40, 80, and 100 ppm) and four different foliar sprays after germination. Finally, it stated that straw production differed significantly between control and foliar sprayed chitosan plants, with the highest straw yield occurring at 100 ppm oligomeric chitosan and the lowest straw yield occurring at 0 ppm oligomeric chitosan.

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

Sultana and Issak (2020) conducted an experiment at Sher-e-Bangla Agricultural University's research field in Dhaka, 1207, and found that the treatment T_4 had the highest pH (7.01), organic carbon content (0.72%), and organic matter content (1.24%) in post-harvest soils, while the control treatment had the lowest values (T_5). These findings suggested that the residual effect of CHT powder's basic material could play a key role in improving long-term soil health.

Berger et al. (2013) conducted an experiment that indicated the potential for plant production and nutrient uptake of a rock biofertilizer mixed with an earthworm compound seeded with free live diazotrophic bacteria and C. elegans (Fungi chitosan). A biofertilizer, such as, can be used as an alternative to NPK fertilization since it slows the release of nutrients, allowing for longer-term soil fertility.

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

According to Van et al. (2013), the increase in chlorophyll content as a result of chitosan application could be due to increased nutrient uptake by plants, as observed in Nguyen's study on coffee seedlings.

CHAPTER III

MATERIAL AND METHODS

The experiment was conducted at a net house of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from July to November, 2020. This chapter provides a brief overview of the experimental site, climate, soil, land preparation, experimental design, layout, intercultural operations, data collection and their analysis.

3.1 Experimental site

The research was carried out under the net house at Sher-e-Bangla Agricultural University in Dhaka. The soil of the experimental plots belonged to the Agro Ecological Zone Madhupur Tract (AEZ-28). The Map of Bangladesh's AEZ is presented in Appendix-I for a better understanding of the experimental site.

3.2 Soil

The experiment was carried out in a typical rice growing soil in pot under net house of Sher-e-Bangla Agricultural University (SAU), Dhaka, during kharif-II season of 2020. The texture of the soil was silty clay loam, and the pH was 5.6. During the experiment, the pots were above flood level and there was plenty of sunlight. Appendix II contains the physical and chemical parameters of the experimental soil.

3.3 Climate

In the Kharif-II season, this area is marked by high temperatures, high relative humidity, and heavy rainfall, with occasional gusty wind.(mid-July to mid-November). Weather information regarding temperature, relative humidity and rainfall prevailed at the experimental site during the study period were presented in Appendix IV.

3.4 Planting material

T. Aman rice (*Oryza sativa*) variety BRRI Hybrid dhan4 was used as planting material. This is one of the most popular types because of its high yielding potential and the fact that it can be planted from mid-June to mid-July. This cultivar has a lifespan of 110-117 days. Grain yield of BRRI Hybrid dhan4 is 6.0-6.5 t/ha. The seeds of this variety was collected from Bangladesh Rice Research Institute (BRRI), Gazipur

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 hybrid dhan4 was collected from Bangladesh Rice Research Institute (BRRI), Joydevpur, Gazipur.

3.6 Seed sprouting

Specific gravity method was used to collect healthy seeds. The chosen seeds were soaked for 24 hours before being stored in gunny bags. By 48 hours, the seed began to sprout, and after 72 hours, almost all of the seeds had sprouted.

3.7 Seedbed preparation and seed sowing

Seedbed pots (4.5 inch with 1.25 kg) were prepared on 15 July, 2020 for sowing the sprouting seeds and proper care was taken for raising seedlings. The seedbed soil was appropriately cleaned and irrigated. On July 19, 2020, sprouted seedlings were sown in wet soil. Weeds were eradicated, and the pots where seedlings were sown were irrigated as needed.

3.8 Application of Chitosan raw material powder

Chitosan raw material powder prepared from shrimp shell in the form of powder was applied in the pot seedbed soil at a rate of 0.0% in T_1, 0.1% in T_2, 0.2% in T_3, 0.3% in T_4, 0.4% in T_5 and 0.5% in T_6 treatment on 19th July, 2020.

3.9 Transplanting pot preparation

The tractor-drawn disc plough was used to open the field for the first time. The ploughed soil was then harrowed and ploughed four times using a country plough and ladder to get the desired fine tilth. The weeds and stubble were removed. Finally, they were placed in experimental pots. The first ploughing took place on August 6th, 2020, and the final land preparation took place on August 8th, 2020. After the final field preparation, 10 kg of soil was taken for each pot. Plastic pots were then divided into unit plots following the design of experiment.

3.10 Treatments of the experiment

T_1 = 0% chitosan raw material powder

T_2 = 0.1% chitosan raw material powder

T_3 = 0.2% chitosan raw material powder

T_4 = 0.3% chitosan raw material powder

T_5 = 0.4% chitosan raw material powder and

T_6 = 0.5% chitosan raw material powder.

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) and name of the fertilizer used for the experiment:

Name of the element	Rate (kg/ha)	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.

3.11 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD). Fourteen (14) inches size plastic pots having 10.5 inches length and 0.5 inches diameter with a hole at the centre of the bottom were used. Each treatment had 48 pots and total pots in the experimental field were 48×6=288. The layout of the experimental plot was presented in Appendix III.

3.12 Fertilizer application

On August 8, 2020, all fertilizers, including a 1/3 dose of urea, were applied to the soil during final site preparation. In three equal splits, urea was applied. At maximum tillering stage, the second split (1/3rd of total quantity of N) was applied on August 30, 2020, and the third split (1/3rd of total amount of N) was applied on September 19, 2020.

3.13 Transplanting of seedling

On August 10, 2020, twenty-one-day-old seedlings were carefully uprooted from the seedbed pot and transferred into experimental pots. In each pot, a single seedling was transplanted.

3.14 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.

3.14.1 Irrigation

During the growing stage, irrigation was used to keep 5-6 cm of water in each pot after transplantation. After panicle emergence and grain filling, irrigation water frequency was lowered. Before harvesting, the field was allowed to dry for seven days.

3.14.2 Weeding

During the early stages of crop establishment, the crop was infected with weeds. To limit weed competition with the crop, three-handed weeding was used. The first weeding took place 20 days after transplanting, followed by the second weeding 15 days later, after that the third weeding was carried out.

3.14.3 Protection against insect and pest

Insects such as rice stem borer, grasshopper, rice bug, and others were found and were controlled by spraying Diazinon 50 EC. During grain filling period, the crop was safeguarded from birds and rats. To control birds, the net house was kept under constant supervision, especially in the morning and afternoon.

3.15 Harvest and Threshing

Depending on the plant's maturity, the crop was harvested. Each pot was carefully harvested using serrated edged sickles. When 80% of the grains had matured, the crop was considered mature. Each pot's harvested crops were packaged, properly tagged, and carried to the threshing floor for grain and straw yield recording. The pedal thresher was used to thresh the crops plot by plot. The grains were cleaned and dried in the sun until they had a moisture level of 12%. Straw was also properly dried in the sun. Finally, the yields of grain and straw per pot were calculated and represented in grams (g).

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

Operations	Working Dates
Application of chitosan raw material in seedbed	19 July, 2020
First ploughing	6 August, 2020
Transplanting pot preparation	8 August, 2020
Application of fertilizers (1/3rd Urea, TSP, MP, Gypsum, ZnO, Boric acid)	9 August, 2020
Transplanting of seedlings	10 August, 2020

Intercultural Operations	
2nd split application of urea and weeding	30 August, 2020
3rd split application of urea and 2nd weeding	19 September, 2020
Insecticide application	10 September, 2020
Harvesting and threshing	13 November, 2020; 15 November, 2020

3.16 Data collection

The following parameters were recorded.

1) Seedling height (cm)
2) Seedling Fresh weight (g)
3) Seedling Oven Dry weight (g)
4) Seedling strength (mg/cm)
5) No of tillers/pot at 20 DAT
6) No of tillers/pot at 30 DAT
7) No of tillers/pot at 40 DAT
8) No of tillers/pot at 50 DAT
9) Fresh weight production of tillers/6 pots at MT stage
10) Effective tiller/pot
11) Grain yield (g/pot)
12) Straw yield (g/pot)

3.17 Procedure of data collection:

3.17.1 Seedling height (cm)

The heights of 21-days-old seedlings were measured on a meter scale from the ground level to the tip of the seedlings. 100 seedlings average height were measured and then and then heights were expressed in centimetres.

3.17.2 Seedling Fresh weight (g)

Fresh seedlings of 21 days old were collected and then weighed by using a digital electric balance. Hundreds seedlings fresh weight were measured and expressed in gram. To get the single seedling fresh weight, the seedlings fresh weight were divided by 100 and was got single seedling fresh weight and was expressed in milligram.

3.17.3 Seedling Oven Dry weight (g)

Seedlings of 21 days old were dried in oven and weighed by using a digital electric balance. The hundred seedlings oven dry weight were measured and expressed in gram. To get the single seedling oven dry weight, the seedlings oven dry weight were divided by 100 and was got single seedling oven dry weight and was expressed in milligram.

3.17.4 Number of tillers/pot at 20 DAT

At 20 DAT, the number of tillers/pot was carefully counted and averaged.

3.17.5 Number of tillers/pot at 30 DAT

At 30 DAT, the number of tillers/pot was carefully counted and averaged.

3.17.6 Number of tillers/pot at 40 DAT

At 40 DAT, the number of tillers/pot carefully counted and averaged.

3.17.7 Number of tillers/pot at 50 DAT

At 50 DAT, the number of tillers/pot carefully counted and averaged.

3.17.8 Fresh weight of tillers/6 pots at MT stage

Fresh tillers from 6 pots at maximum tillering stage were collected and weighed in electrical balance.

3.17.9 Effective tillers/pot

The panicle-bearing tiller was regarded as an effective tiller. At harvest, the number of effective tillers/pot carefully counted, recorded and averaged to set the effective tillers/pot.

3.17.10 Grain yield (g/pot)

Harvested bundles of the rice plants from each pot were threshed and winnowed separately. After winnowing the grain was sun dried pot wise up to 12% moisture content and then their weight was recorded by digital electrical balance. Grain yield from each pot were expressed as gram (g).

3.17.11 Straw yield (g/pot)

After separating the grains, the straw from each pot was sun dried and meticulously weighed on a digital electrical balance before being stated as gram (g/pot).

3.18 Analysis of data

The data were collected on various factors and statistically analysed using standard deviation and standard error of mean in graphical format.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter contains a presentation and discussion of the results obtained by applying different rate of chitosan raw material powder on BRRI hybrid dhan4 on growth and yield. The findings of this study have been reported, discussed, and compared to the findings of other researchers.

4.1 Seedling height (cm)

In all of the treatments utilized in the experiment, seedling height of BRRI Hybrid dhan4 showed significant variation with the application of chitosan raw material. The T_5 treatment had the highest seedling height at 21 days (15.55 cm), which was statistically similar to the T_6 (15.50 cm) and T_4 (14.55 cm) treatments. T_1 treatment produced minimum seedling height at 21 days (12.5 cm), which was statistically similar to T_2 (13 cm) and T_3 (13.45 cm) treatments (Fig-1). The height of the seedlings was increased in a dose-dependent manner. Similar findings were found by Rahman et al., (2015), Ahmed et al., (2020), and Sultana et al.,(2020).

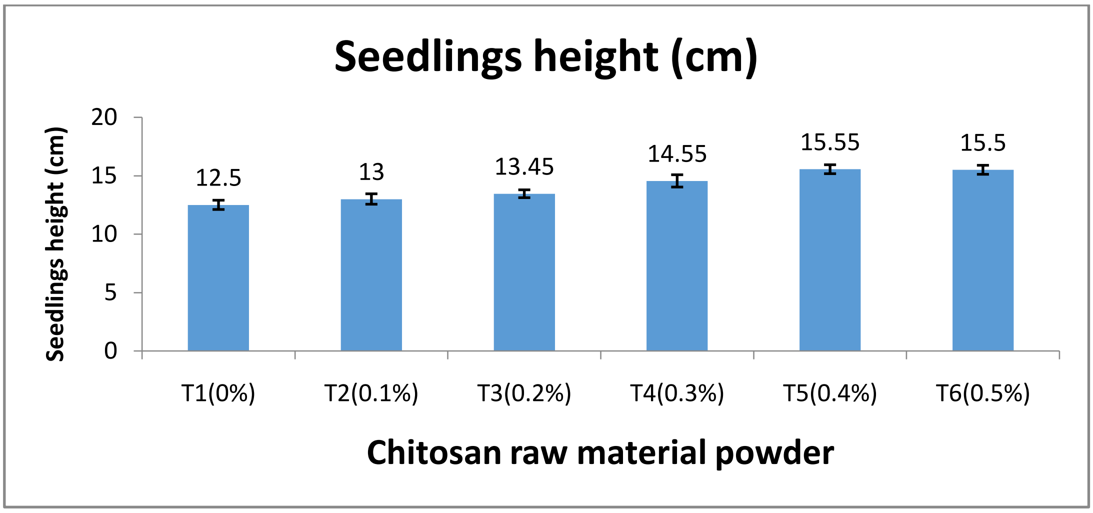

Fig 1. Effect of chitosan raw material powder on the production of BRRI Hybrid dhan4 on seedling height(cm) at 21 days.

4.2 Seedling fresh weight (g)

Seedling fresh weight production of BRRI hybrid dhan4 showed significant variation with the application of chitosan raw material in seedbed. The results revealed that production of maximum 100 seedling fresh weight at 21 days (15.45 g) was observed in T_5 treatment. Whereas minimum 100 seedling fresh weight at 21 days (13.68 g) was observed in T_1 (control) treatment (Fig 2). Increasing trend of seedlings fresh weight production was observed among the treatments. The results indicated that the fresh weight production of seedlings was influenced by the application of chitosan raw material in the seedbed and this might be due its supplementation of different plant nutrients and plant growth regulators (PGR). Chitosan raw material promotes shoot and root growth of rice seedling. (Issak and Sultana 2017; Phothi*et al*., 2017; Tsugita*et al*., 1993). Present findings were also supported with the similar findings of Rahman *et al*., (2015); Ahmed *et al*., (2020) and Sultana *et al*., (2020).

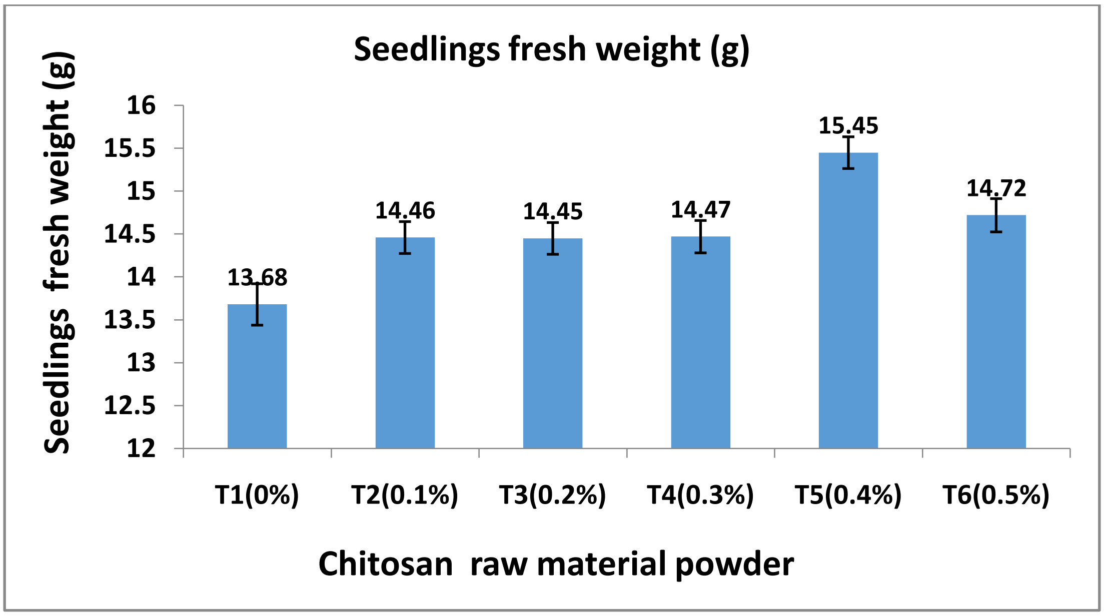

Fig 2. Effect of chitosan raw material powder on the production of BRRI Hybrid dhan4 on seedling fresh weight (g) at 21 days

4.3 Seedling oven dry weight (g)

The maximum oven dry weight of 100 seedlings of BRRI hybrid dhan4 (7.73 g) was recorded in T_5 treatment, which was statistically equal to T_6 treatment. In T_1 treatment, the minimum oven dry weight of 100 seedlings of BRRI hybrid dhan4 (5.25 g) was recorded after 21 days, which was statistically similar to the T_2 treatment (Fig 3). Among the treatments, there was an increasing trend in seedling dry weight production. The present findings agree with the findings of earlier studies of Al-Tawaha *et al*., 2018;Issak and Sultana 2017 and Phothi *et al*., 2017.

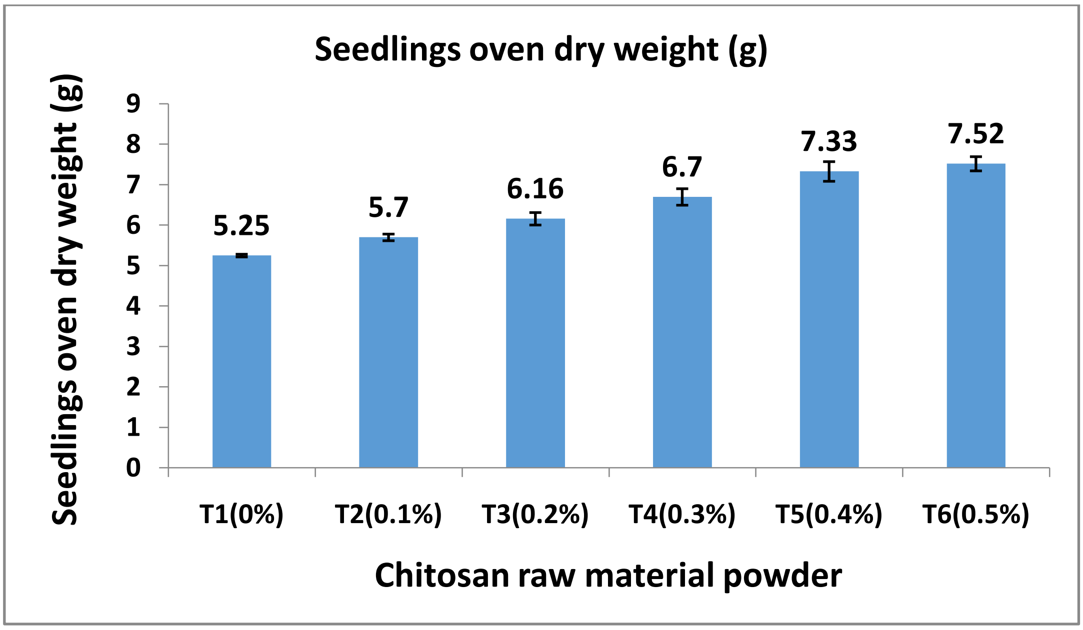

Fig 3. Effect of chitosan raw material powder on the production of BRRI Hybrid dhan4 on seedling oven dry weight (g) at 21 days

4.4 Seedling strength (mg/cm)

Seedling strength of BRRI hybrid dhan4 showed significant variation with the application of chitosan raw material in all the treatments. The results revealed that maximum seedling strength (mg/cm) of 21 days (4.97 mg/cm) was observed in T_5 (0.4%) treatment (Fig 4). Whereas minimum seedling strength of 21 days (4.2 mg/cm) was observed in T_1(control) treatment. Chitosan raw material have positive role on seedling strength modification (Ahmed *et al.*, 2020;Issak and Amena, 2017).

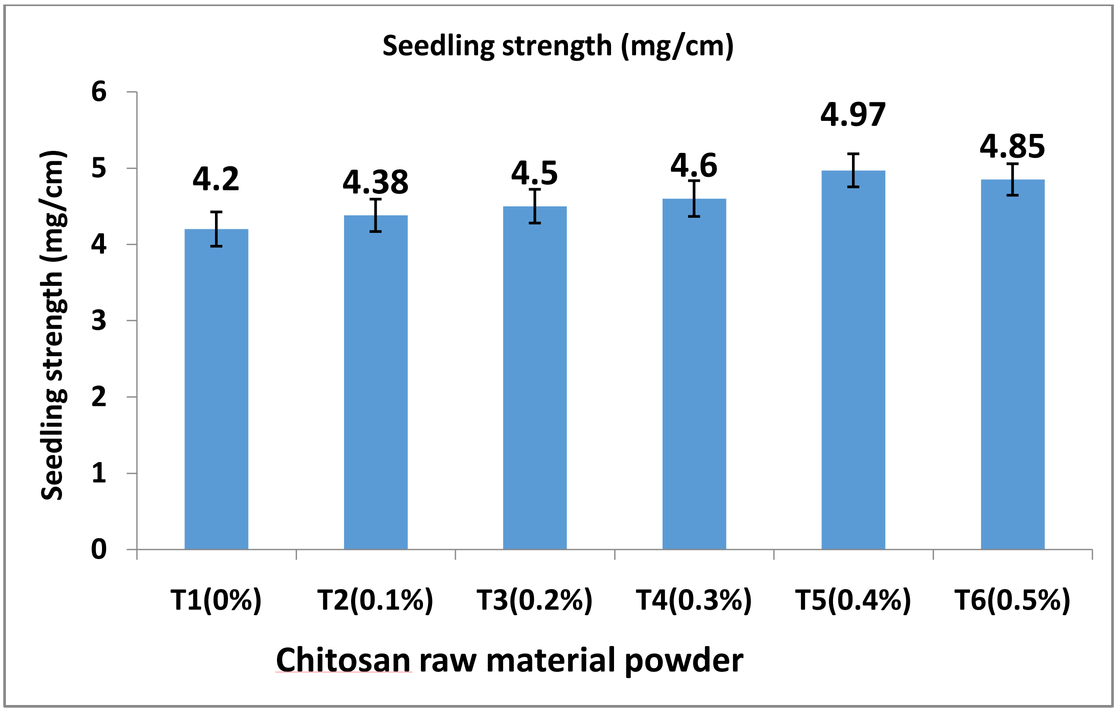

Fig 4. Effect of chitosan raw material powder on the production of BRRI Hybrid dhan4 on seedling strength (mg/cm) at 21 days

4.5 Effect of chitosan raw material powder influenced seedling strength on average tiller production capacity of rice at different tillering stage

Tiller production capacity of chitosan raw material powder treated seedlings was significantly improved. Seedling strength strongly improved the average tiller production capacity of BRRI hybrid dhan4 at different day after transplantation (DAT).

Tiller production at 20 DAT showed significant variation among all the treatments used in the experiment. The results showed that maximum tiller number/pot (6.54) was observed in T_5 treatment which was statistically similar with T_6 (6.32) treatment and followed by T_4 (6.12), T_3 (5.92) and T_2 (5.5) (Fig 5). Whereas minimum tiller number/pot (4.91) was observed in T_1(control) treatment. All the treatments produced higher tillering number/pot than the control treatment at 20 DAT.

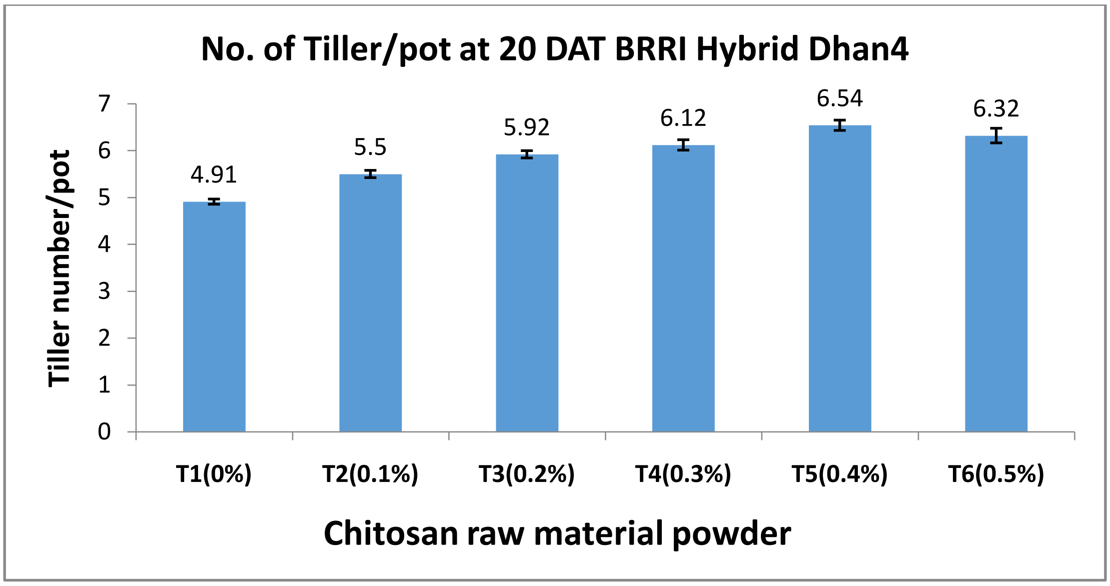

Figure 5: Effect of chitosan raw material powder influenced seedling strength on average tiller production capacity of rice at 20 DAT

At 30 DAT tiller production showed significant differences with the effects of chitosan raw material on seedling strength. T_4 treatment had the highest tiller number/pot (17.25), which was statistically equivalent to T_3 (17.13) treatment, and was followed by T_2 (15.85), T_6 (15.32), and T_5 (15.13) treatments (Fig 6). In T_1 (control) treatment, the minimum tiller number/pot (14.71) was recorded. At 30 DAT, all of the treatments produced more tillering number/pot than the control treatment.

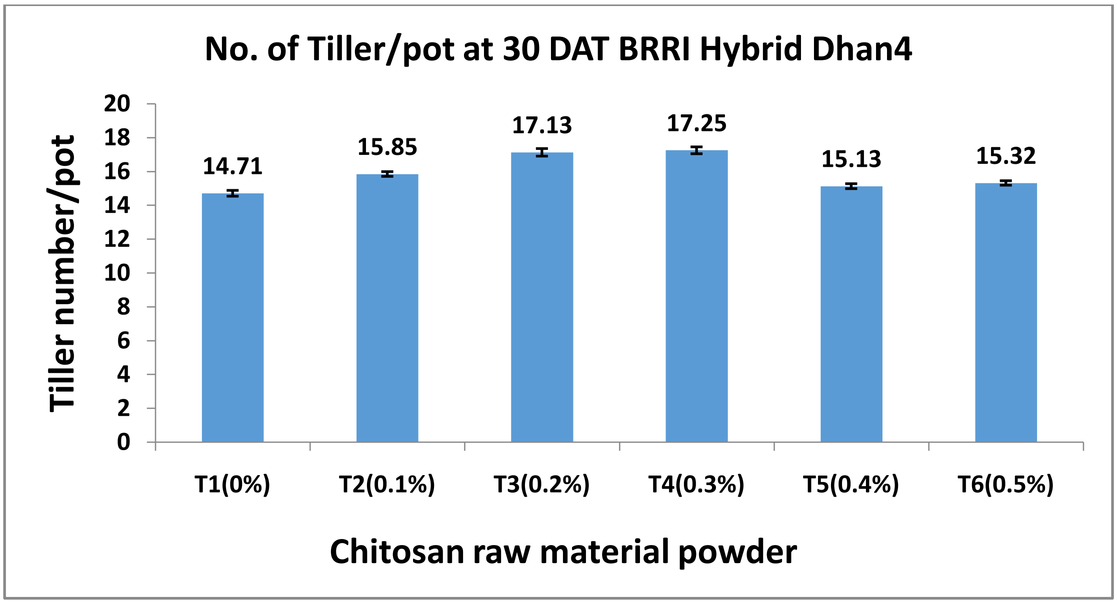

Figure 6: Effect of chitosan raw material powder influenced seedling strength on average tiller production capacity of rice at 30 DAT

Similar to the above two results, at 40 DAT tiller number/pot showed significant variation among the treatments used in the experiment. The results showed that maximum tiller number/pot (21.12) was observed in T_2 treatment which was statistically similar with T_3 (21.05) and T_4 (20.88) and followed by treatments T_5 (18.14) and T_6 (18.14) (Fig 7). Whereas minimum tiller number/pot (17.91) was observed in T_1 (control) treatment that was statistically identical with T_5 and T_6

treatments. At 40 DAT all the treatments also produced higher tillering number/pot than the control treatment.

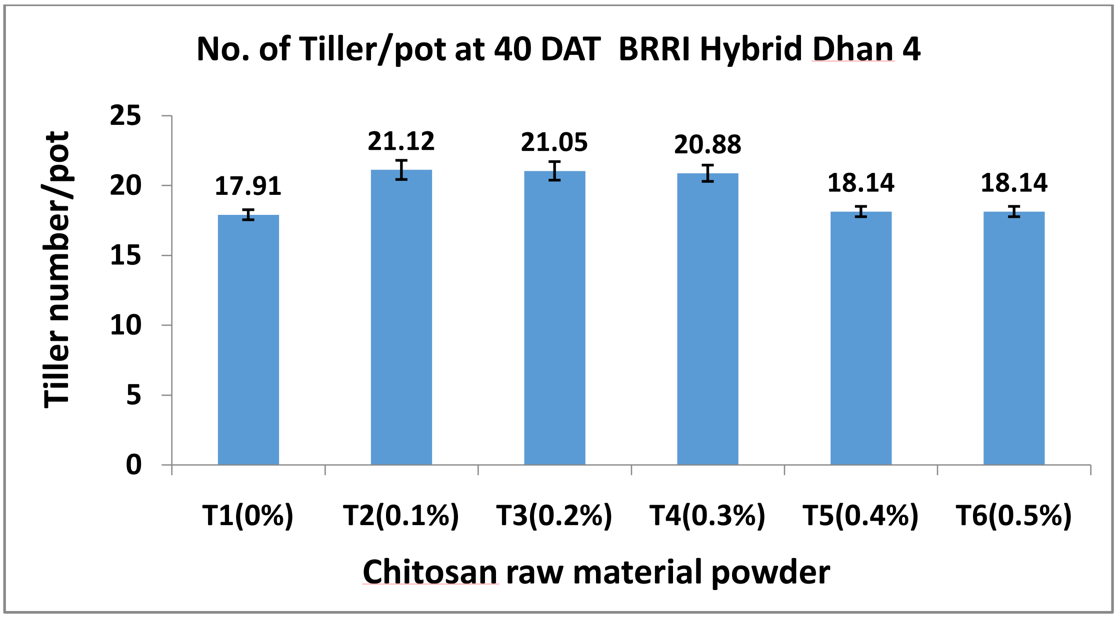

Figure 7: Effect of chitosan raw material powder influenced seedling strength on average tiller production capacity of rice at 40 DAT

There was also a significant difference between the treatments at 50 DAT tiller number/pot. The T_3 treatment produced the maximum number of tillers per pot (22.36), which was statistically identical to the T_2 (22.11) and T_4 (21.89) treatments (Fig 8). T_1 (control) treatment had the minimum tiller number/pot (19.85), although T_5 (20.31) and T_6 (20.42) treatments were statistically identical. At 50 days after treatment, all treatments had a higher tiller number/pot than the control.

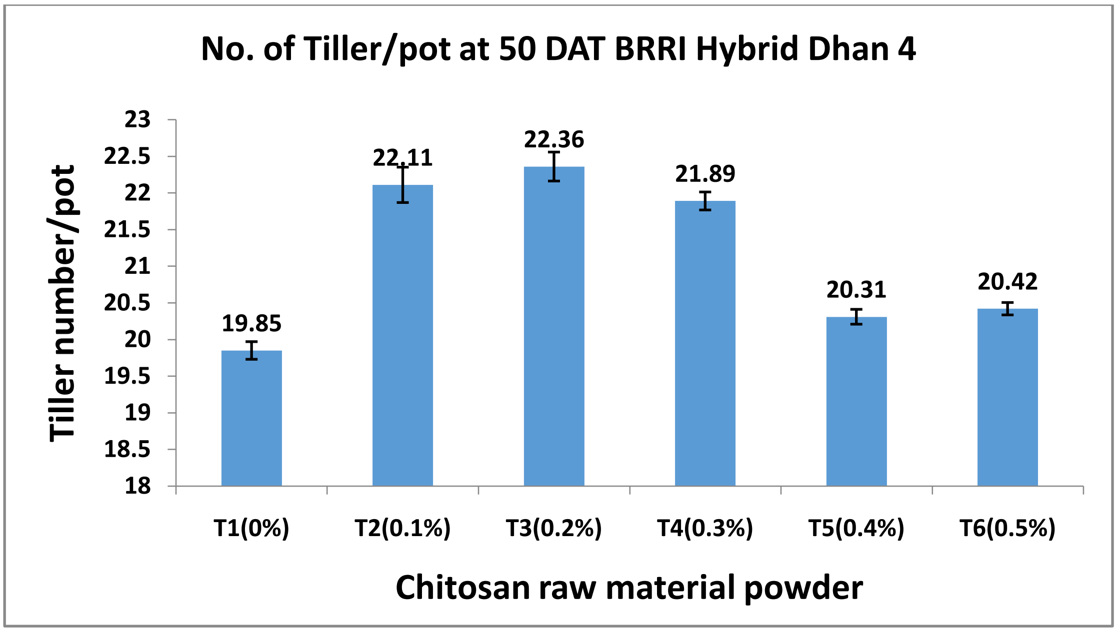

Figure 8: Effect of chitosan raw material powder influenced seedling strength on average tiller production capacity of rice at 50 DAT

Improved seedlings, boosting with chitosan raw material powder in the seedbed, play influential role on early tiller production and significantly higher number of tiller production/pot in the T_2, T_3 and T_4 treatments. The results indicated that early tiller production and higher tiller production could play significant role on yield maximization. Application of chitosan raw material powder in the seedbed at different rates exhibited the production of higher tiller number/pot in all the tillering stages as compared with the control treatment. The growth-promoting effect of chitosan raw material was similar to chitosan-induced enhancement in primary metabolic pathways, like photosynthesis, glycolysis, and nitrogen assimilation. In addition, the effect was linked with stimulation of some signalling pathway related plant hormone like gibberellins and auxin etc. The result obtained from the present study was similar with the findings of Phothi.,*et al*. (2017).

4.6 Effect of chitosan raw material powder influenced seedling strength on fresh weight production of BRRI hybrid dhan4 at maximum tillering stage

The fresh weight at maximum tillering stage showed significant differences due to the higher seedling strength which was the effect of CRMP application in the seedbed. The results revealed that maximum fresh weight production (462g/6 pots) was observed in T_6 treatment at MT stage and followed by T_3 (434g/6 pots), T_4 (398g/6 pots), T_2 (395g/6 pots) and T_5 (391g/6 pots) (Fig. 9, A). Whereas minimum fresh weight production (348g/6 pots) was observed in T_1 (control) treatment. All the treated seedlings produced higher dry matter at MT stage than the control treatment.

The maximum average fresh weight production per pot (77 g) was found in T_6 and minimum average fresh weight production was observed in T1 (58 g) treatment (Fig. 9, B). The trend of the average fresh weight production was $T_6>T_3>T_4>T_2>T_5>T_1$.
The result revealed that higher fresh weight production at MT stage was increased in all the treated plants over control. The maximum higher fresh weight production was found in T_6 (32.75%) and followed by T_3 (24.66%), T_4 (14.31%), T_2 (13.44%) and T_5 (12.24%) treatments (Fig. 9, C). The results indicated that healthy seedlings (having more seedling strength) had the capacity to produce higher fresh weight production than control which was the effect of CRMP application in seedbed.

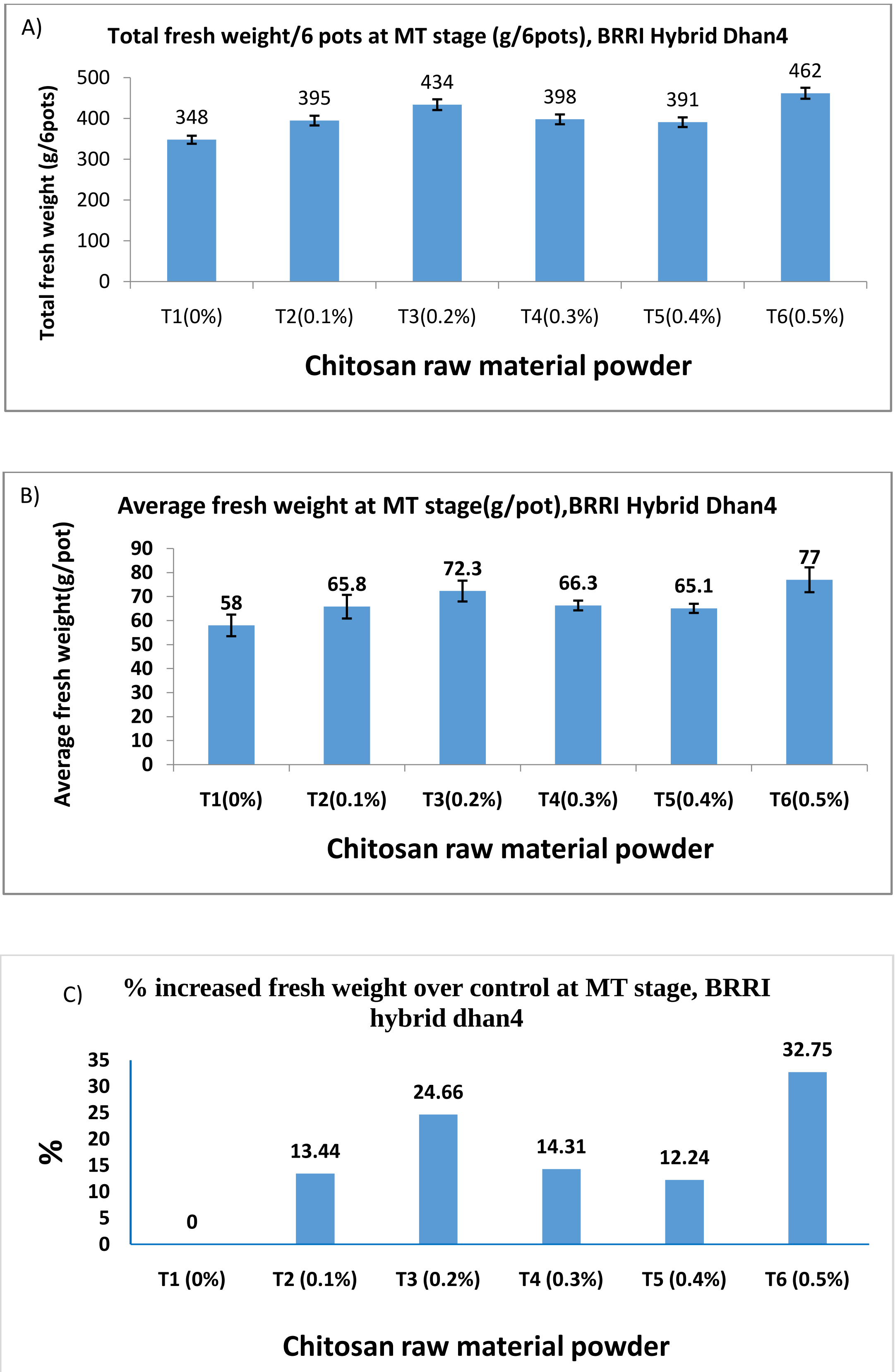

Figure 9.Effect of chitosan raw material powder influenced seedling strength on fresh weight production of BRRI hybrid dhan4 at maximum tillering stage

4.7 Total tillers/pot and effective tillers/pot at harvest

Among the treatments, there were significant differences in total tillers/pot and effective tillers/pot at harvest. The treatments all resulted in a higher effective tiller/pot than the control. Only the T_2 treatment differed from the control in a significant way, while the other treatments did not. The T_2 treatment produced the highest average maximum effective tillers/pot (15.7), followed by the T_3 (15.3), T_4 (15.1), T_5 (14.7), and T_6 (14.3) treatments (Fig. 10). According to the findings, it could be a significant marker for BRRI hybrid dhan4 yield maximization.

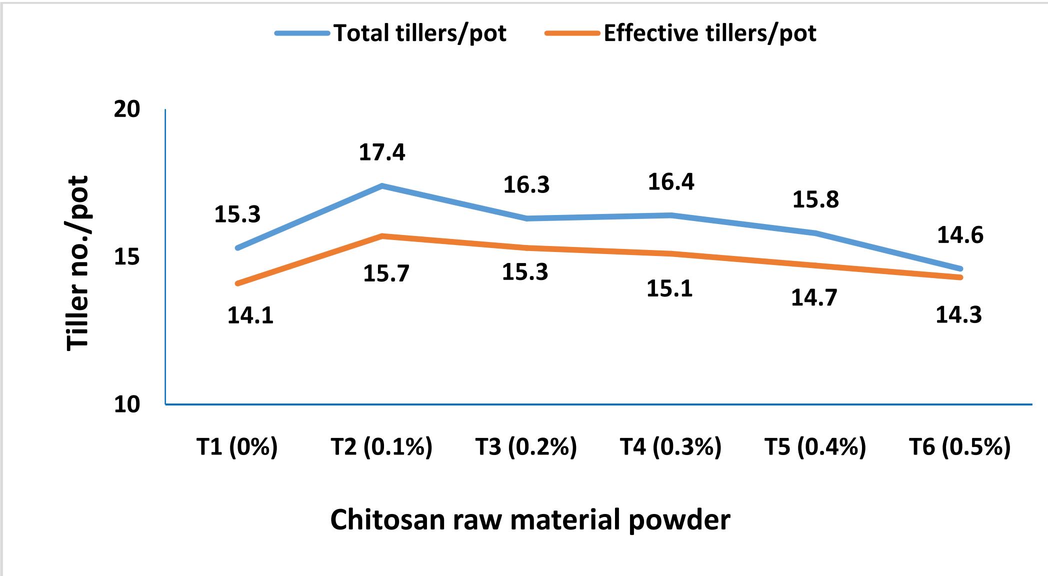

Figure 10. Effect of chitosan raw material powder influenced seedling strength on total tillers/pot and effective tillers/pot at harvest

4.8 Grain yield (g/pot)

A significant variation was observed on BRRI hybrid dhan4 on grain yield with the treatments. The results revealed that maximum grain yield (40.25g/pot) was observed in T_2 treatment which was statistically similar with the T_3 (38.82g/pot), treatment (Fig. 11, A). The minimum grain yield (34.46 g/pot) was observed in T_1 treatment which was statistically similar with T_6 (35.15 g/pot), T_4 (35.54 g/pot) and T_5 (36.16 g/pot) treatments. All the treatments produced higher grain yield than control treatment. But only T_2 and T_3 had significant differences over control treatment. This result is supported with the results of Al-Tawaha *et al*. (2020), Priyaadharshini *et al.* (2019) and Al-Tawaha *et al.* (2018). . Maximum higher grain yield (17.82%) was produced in T_2 treatment followed by T_3 (13.64%), T_5 (4.93%), T_4 (3.13%) and T_6 (2.81%) (Fig. 11, B).

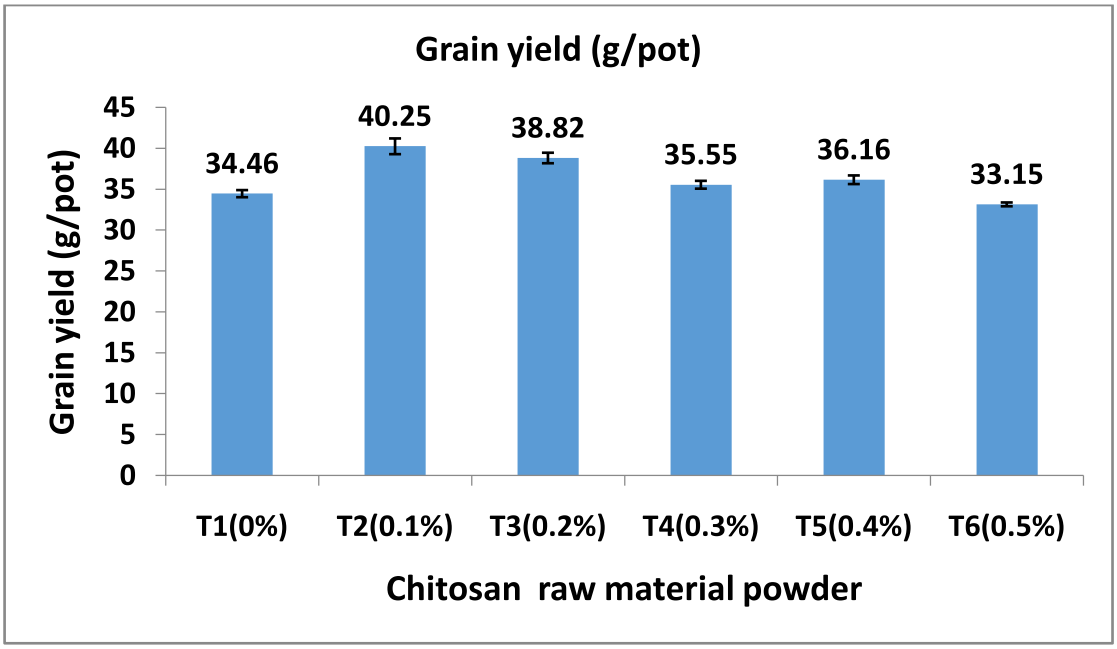

Fig 11. (A) Effect of chitosan raw material powder on the yield of BRRI Hybrid dhan4 on grain yield (g/pot)

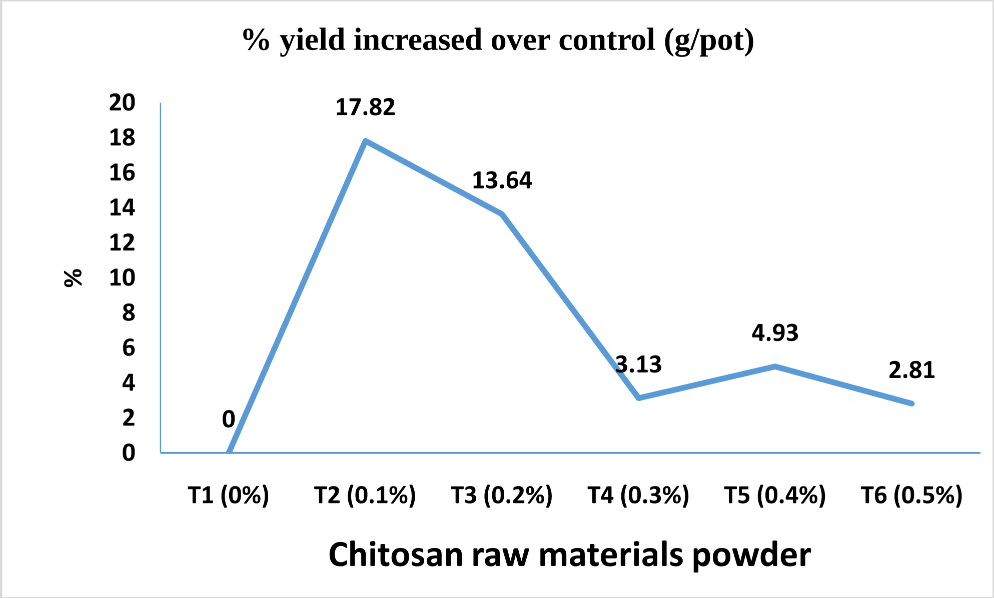

Fig 11.(B) Effect of chitosan raw material powder on the production of BRRI Hybrid dhan4 on % yield increased over control (g/pot)

4.9 Straw yield (g/pot)

In case of BRRI hybrid dhan4 result showed that the maximum straw yield (42.9 g/pot) was observed in T_2 treatment (Fig 11). Whereas the minimum straw yield (34.6 g/pot) was observed in T_6 treatment which was statistically similar with T_5 , T_1 and T_3 treatments. As the amount of chitosan application in soil increases straw yield also increases. These results were supported by Sultana *et al*.(2015), conducting 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. And finally it was observed that straw yield of rice show significant differences between control plants and seedbed applied chitosan plants.

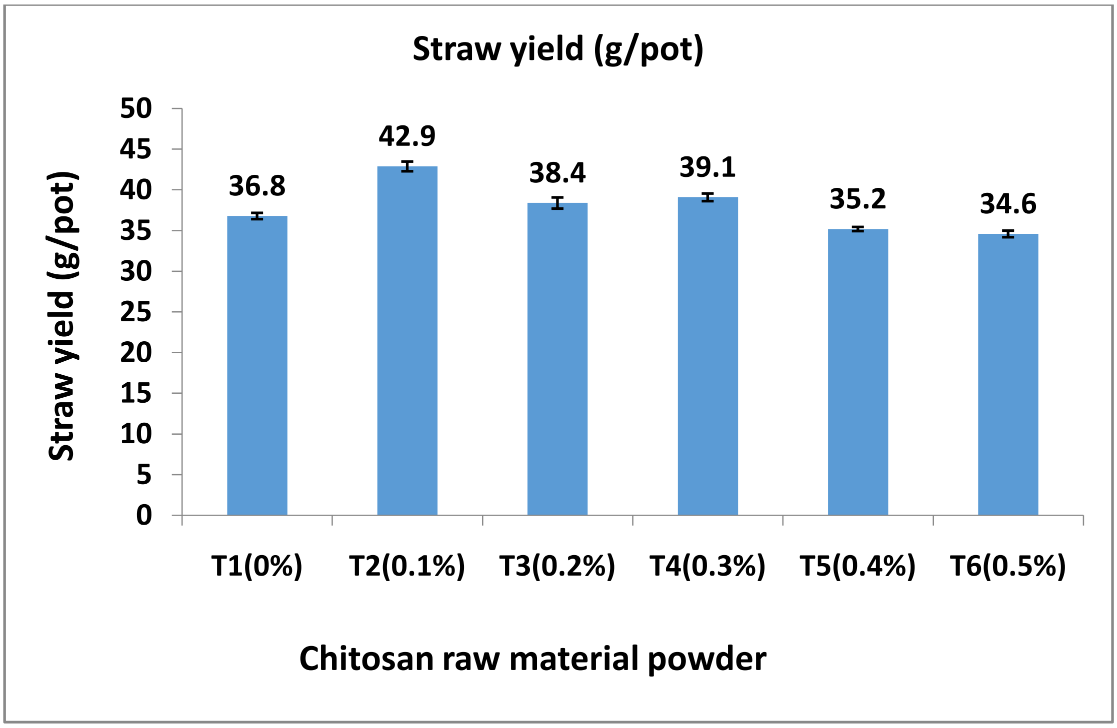

Fig 12. Effect of chitosan raw material powder on the production of BRRI Hybrid dhan4 on straw yield (g/pot)

CHAPTER V

SUMMARY AND CONCLUSION

During the months of July to November 2020, a pot experiment was done under the net house at Sher-e-Bangla Agricultural University in Dhaka, Bangladesh, to investigate the performance of a rice variety (BRRI hybrid dhan4) as influenced by chitosan raw material powder. Fourteen (14) inches size pots were used in the experiment, having length (10.5 inches) and diameter (9.5 inches).The pots were filled with 10 kg of moist field soil with a silty clay loam texture. The experiment was set up in a Randomized Complete Block Design (RCBD). The experiment was comprised of six (6) treatments i.e. T_1 = 0% chitosan raw material powder, T_2 = 0.1% chitosan raw material powder, T_3 = 0.2% chitosan raw material powder,T_4 = 0.3% chitosan raw material powder,T_5 = 0.4% chitosan raw material powder and T_6 = 0.5% chitosan raw material powder. There were forty eight (48) replications used in the experiment and the total number of experimental pots were two hundred eighty eight (6 x 48=288). Before spreading the sprouted seeds, the treatment material were applied to the seedbed. Different parameters were recorded and compared among treatments, including 100 seedling fresh weight; 100 seedling oven dry weight; seedling height and seedling strength; total tiller number at 20 DAT, 30 DAT, 40 DAT, 50 DAT; fresh weight production at MT stage; effective tiller number; grain yield and straw yield. Significant differences were observed among the treatments used in the experiment due to the application of chitosan raw material powder in the seedbed.

The production of maximum seedlings height at 21 days (15.55 cm) was observed in T_5 treatment, whereas minimum seedling height at 21 days (12.5cm) was observed in T_1 (control) treatment. T_5 treatment produced the highest 100 seedling fresh weight at 21 days (15.45 g), whereas T_1 (control) treatment produced the lowest 100 seedling fresh weight at 21 days (13.68 g). T_5 treatment produced maximum 100 seedling oven dry weight at 21 days (7.73 g), while T_1 (control) treatment produced minimum 100 seedling oven dry weight at 21 days (5.25 g). The T_5 (4.97 mg/cm) treatment had the highest seedling strength at 21 days, while the control treatment T_1 had the lowest seedling strength at 21 days (4.2 mg/cm). At 20 DAT, T_5 treatment produced the highest tiller number/pot (6.54), while T_1 treatment produced the lowest tiller number/pot (4.91). T_4 treatment produced the highest tiller number/pot (17.25) at 30 DAT, while T_1 treatment produced the lowest tiller number/pot (14.71). At 40 DAT, production of maximum tiller number/pot (21.12) was observed in T_2 treatment, whereas minimum tiller number/pot (17.91) was observed in T_1 (control) treatment. At 50 DAT, T_3 treatment showed maximum number of effective tillers per pot (22.36), while T_1 (control) treatment produced minimum number of effective tillers per pot (19.85). Production of maximum fresh weight (462 g/6 pot) was observed in T_6 treatment at MT stage, whereas minimum fresh weight production (348g/6 pots) was observed in T_1 (control) treatment. The maximum average fresh weight production per pot (77 g) was found in T_6 and minimum average fresh weight production was observed in T_1 (58 g) treatment at MT stage. The maximum effective tiller/pot production was found in T_2 (15.8) whereas the minimum effective tiller/pot was observed in control T_1 (14.2).Treatment T_2 produced the highest grain yield (40.25 g/pot), while T_1 produced the lowest grain yield (34.46 g/pot). The T_2

treatment obtained the highest straw yield (42.9 g/pot), while the T_6 treatment produced the lowest straw yield (34.6 g/pot).

Taken together, the research findings showed that chitosan raw material powder had a significant impact on seedling strength, which in turn influenced maximum effective tiller production, resulting in increased grain yield. Treatment T_2, which used 0.1 0% chitosan raw material powder in the seedbed, had the maximum effective tiller (15.7) and maximum grain yield production (40.25 g/pot).

However, more research on chitosan raw material application under these treatment variables in different Agro-ecological zones of Bangladesh should be done in order to obtain a specific conclusion and recommendation for sustainable rice production.

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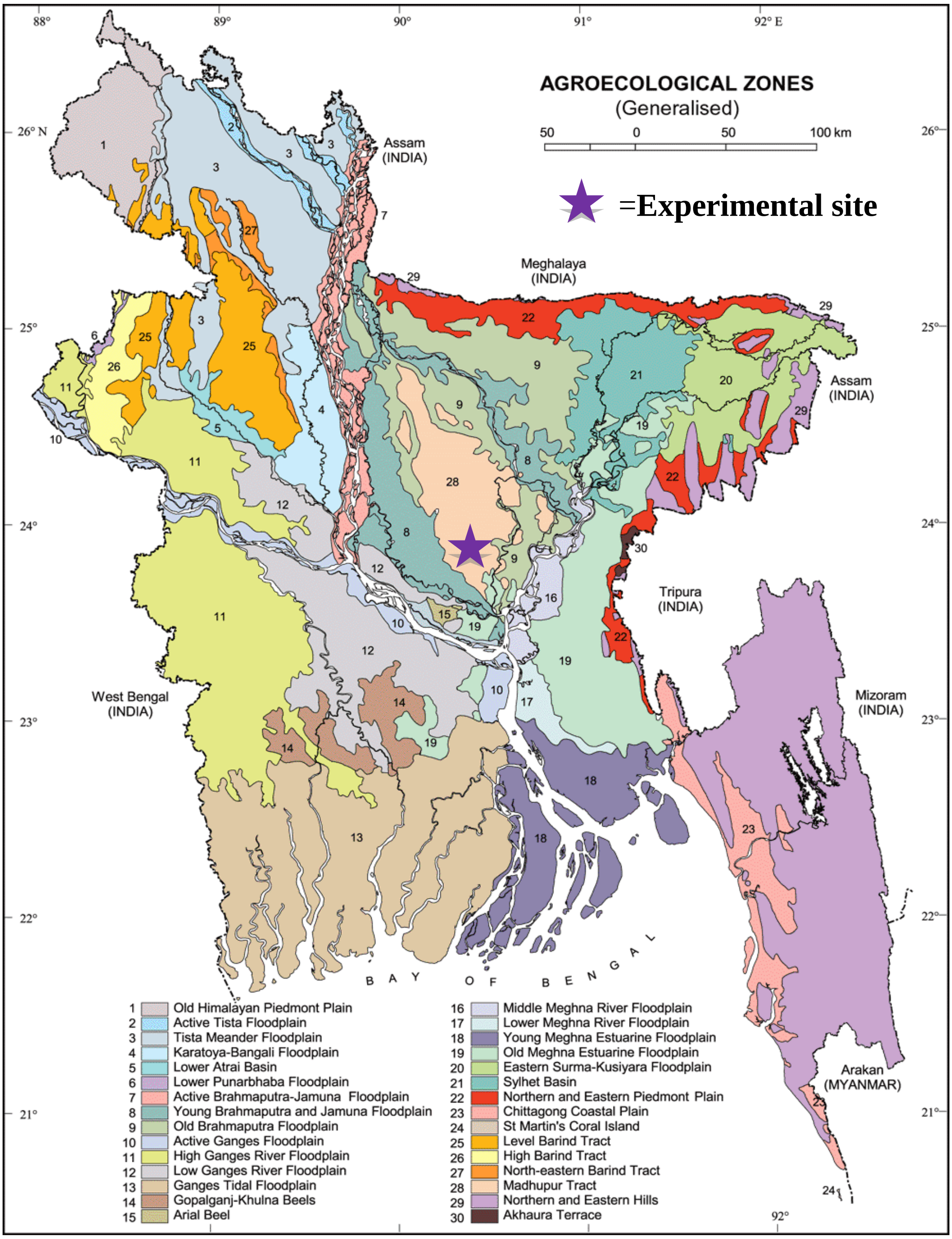
APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Characteristics of soil, used in the experiment

The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	20
Silt	51
Clay	29
Textural class	Silty clay loam
Chemical characteristics	
Soil characteristics	**Value**
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

APPENDIX III: Layout of the experiment

T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**

T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
T1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**

LEGEND

Each treatment had 48 pots and total pots in the experimental field were 48×6=288

T1 = 0% chitosan raw material, T_2 = 0.1% chitosan raw material, T_3 = 0.2% chitosan raw material, T_4 = 0.3% chitosan raw material, T_5 = 0.4% chitosan raw material and T_6 = 0.5% chitosan raw material.

Appendix IV. Monthly meteorological information during the period from July to November, 2020.

Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2020	July	32.6°C	26.8°C	81%	114mm
	August	32.6°C	25.5°C	80%	106mm
	September	32.4°C	25.7°C	80%.	86mm
	October	31.2°C	23.9°C	76%.	52mm
	November	29.2°C	20.5°C	38	9mm

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