INFLUENCE OF CHITOSAN RAW MATERIALS POWDER ON YIELD PERFORMANCE OF BRRI dhan75

DIPTA CHAKRABARTY

DEPARTMENT OF SOIL SCIENCE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

DECEMBER, 2020

INFLUENCE OF CHITOSAN RAW MATERIALS POWDER ON YIELD PERFORMANCE OF BRRI dhan75

By

DIPTA CHAKRABARTY

Reg. No.: 18-09149

A Thesis

Submitted to the Department of Soil Science Sher-e-Bangla Agricultural University, Dhaka, In partial fulfilment of the requirements For the degree of

MASTER OF SCIENCE (M.S.)
IN
SOIL SCIENCE

SEMESTER: JULY-DECEMBER, 2020

Approved By:

…………………………………………..

Prof. Dr. Mohammad Issak
Department of Soil Science
Faculty of Agriculture
Sher-e-Bangla Agricultural University
Dhaka
Supervisor

…………………………………………

Dr. Amena Sultana
Senior Scientific Officer
Agronomy Division
Bangladesh Rice Research Institute
Gazipur
Co-Supervisor

………………………………….

Prof. A.T.M. Shamsuddoha
Chairman
Examination Committee

Department of Soil Science
Sher-e-Bangla Agricultural University
Dhaka-1207

Prof. Dr. Mohammd Issak
Department of Soil Science
Faculty of Agriculture
Sher-e-Bangla Agricultural University
Mobile : 01716-238645
Email: mdissaksau07@yahoo.com
issak@sau.edu.bd

CERTIFICATE

This is to certify that thesis entitled, **"INFLUENCE OF CHITOSAN RAW MATERIALS POWDER ON YIELD PERFORMANCE OF BRRI dhan75"** 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 **DIPTA CHAKRABARTY**, Registration No. **18-09149,** 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, 2020
Place: Dhaka, Bangladesh

Prof. Dr. Mohammad Issak
Supervisor

Dedication

To my beloved parents.

Thanks for your endless affection, supports and sacrifices

ACKNOWLEDGEMENT

All praises to the Almighty God who enable me to complete a piece of research work and prepare this thesis for the degree of Master of Science (M.S.) in Soil Science.

I feel much pleasure to express my gratitude, sincere appreciation and heartfelt indebtedness to my reverend research supervisor, ***Prof. Dr. Mohammad Issak****, Department of Soil Science, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh, for his scholastic guidance, support, encouragement, valuable suggestions and constructive criticism throughout the study period.*

I also express my gratefulness to respected co-supervisor, ***Dr. Amena Sultana,*** *Senior Scientific Officer, Agronomy Division, Bangladesh Rice Research Institute, Gazipur, constant inspiration, valuable suggestions, cordial help, heartiest co-operation, providing all facilities and supports which were needed to completing the study.*

I would like to express my deepest respect and thanks to ***all my honourable teachers*** *of the Department of Soil Science, Sher-e-Bangla Agricultural University (SAU) for their valuable suggestions, instructions, cordial help and encouragement.*

I am thankful enough to all MS students of and July-Dec./2018 and Jan.-June./2019 semester, all officers and staffs of the Department of Soil Science, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 for their kind support and sincere co-operation during my study.

Finally, I express my deepest sense of gratitude to my beloved parents, brothers, sisters, other family members, relatives, well-wishers and friends for their inspiration, help and encouragement throughout the study.

Dhaka, Bangladesh **The Author**

December, 2020

INFLUENCE OF CHITOSAN RAW MATERIALS POWDER ON YIELD PERFORMANCE OF BRRI dhan75

ABSTRACT

A pot experiment was conducted under the net house at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period of July-November, 2020 to study on performance of a rice variety (BRRI dhan75) as influenced by chitosan raw materials. Fourteen (14) inches size plastic pots were used in the experiment having length (10.5 inches) and diameter (9.5 inches). The pots were filled with 10 kg SAU field moist soils having the texture silty clay loam soil. The experiment was laid in a Completely Randomized Design (CRD). The experiment was comprised of six (6) treatments i.e. T_1 = 0% chitosan raw materials, T_2 = 0.1% chitosan raw materials, T_3 = 0.2% chitosan raw materials, T_4 = 0.3% chitosan raw materials, T_5 = 0.4% chitosan raw materials and T_6 = 0.5% chitosan raw materials. 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). The treatment materials was applied in the seedbed before sowing the sprouted seeds. Seedling characters like 100 seedling fresh weight, 100 seedling oven dry weight, seedling height and seedling strength were significantly increased in all the treatments used in the experiment. The maximum seedling strength was found in the T_4 (3.9) where minimum seedling strength was observed in control treatment T_1 (2.7). The trend of the seedling strength was $T_4>T_5>T_6>T_2>T_3>T_1$. Biomass production was increased at the maximum tillering (MT) stage. The increasing tendency of the seedling characters had profound effect on early tiller production, higher number of tiller production, fresh and dry matter production at maximum tillering stage resulting higher yield. The maximum effective tiller/hill production was found in T_2 (15.8) whereas the minimum effective tiller/hill was observed in control T_1 (14.2). The highest grain yield (40.11 g/hill) was found in T_2 and the lowest grain yield was found in the control T_1 (34.33 g/hill). Taken together, the research findings indicated that chitosan raw materials significantly influenced the seedling strength and that was allow to influenced the maximum effective tiller production resulting higher grain yield. The results suggested that the chitosan raw materials could be an effective yield boosting tool for rice cultivation under Climate Smart Agriculture in Bangladesh.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF CONTENTS (Cont'd)

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

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
CRM	Chitosan raw materials
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 main cereal crop of the world and is a staple food for more than a half population of the world (Ahmad *et al*., 2020; Singh *et al*., 2019). The global demand of rice is increasing day by day. Current average world rice production is 676 million tons, while the global demand will rise to 852 million tons for the year 2035 (Khush, 2013). However, the productivity of rice needs to be increased from 10 to 12.5 t/ha to fulfill the requirement of 176 million tons more rice (Khush, 2013).

Among the three rice rowing 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). According to the latest estimation made by BBS, per capita rice consumption is about 166 kg/year. 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 growth rate of Bangladesh is two million per year, and if the population increases at this rate, the total population will reach 215.4 million by 2050, when 44.6 million tons of clean rice will be required (Kabir *et al*., 2015). The population of Bangladesh is growing by two million every year may increase by another 30 million over the next 20 years. 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). The average yield of rice is about 4.5 t/ha in Bangladesh whereas it is about 6-6.5 t/ha in Japan, Korea, China (BRRI, 2020). But it is not sufficient to meet the food demand of increasing population. So, increasing rice production in a sustainable manner is vital for ensuring food security for the increasing population in Bangladesh.

Frequent flash flood, heat waves in Boro season, excess irrigation input and longer life span are major issues to be addressed in Boro season. To get sustainable production and to lessen over dependency on Boro rice, we should keep focus on expanding T. Aman rice. In case of Aman rice, it covers the largest area of 5.56 (48.69% of total rice cultivation area) million hectares (Broadcast 0.23 + T. Local 0.84 + HYV 4.5 million ha) with a production of 14.20 million tons and the average yield is about 2.56 million t/ha during 2019-2020 (BBS, 2020).

BRRI dhan75 is a lodging resistant, slightly aromatic, high yielding variety which has been released by Bangladesh Rice Research Institute (BRRI) in 2016. It could be ideal rice variety for Bangladesh, because the life cycle is around 110 days, average height 101-110 cm and yield is around 4.5 t/ha (BRRI, 2020).

The extensive application of agrochemicals in farms is a severe crisis globally. Chemical fertilizers have resulted in numerous detrimental effects, such as erosion of soil fertility, biodiversity loss, nutrient and pesticide runoff, and it has taken a toll on the environment and human health (Boussemart *et al.,* 2013). Hence, to reduce the negative impacts of agriculture on the adjacent surroundings, it is vital to decrease the dependency on chemical products. In such a scenario, there arises an immense demand for effective and eco-friendly application of plant growth regulators in crop production.

Chitosan is one such product, which cationic amino polysaccharide is made up of N-acetyl D-glucosamine (GlcNAc) repeat blocks, joined by β-1, 4 glycosidic bonds (Rinaudo, 2006). The natural bio-control active ingredients, chitosan is found in the shells of crustaceans, such as lobsters, crabs and shrimps and many other organisms, including insects and fungi. It is one of the most abundant biodegradable materials in the world. The chitosan has strong effects on agriculture such as acting as the carbon source for microbes in the soil, accelerating of transformation the process of organic matter into inorganic matter and assisting the root system of plants to absorb more nutrients from the soil (Ibrahim *et al*., 2015). Application of chitosan can enhance plant growth seed germination, chlorophyll content, chloroplast ultra-structure, nitrogen fixation and nutrient uptake (Chibu *et al*., 2002; Boonlertnirun *et al*., 2008; Manjunatha *et al*., 2008). Several studies have shown the importance of chitosan on plant growth and development. In agriculture, chitosan is used primarily as a natural seed treatment and plant growth enhancer and as an ecologically friendly biopesticide substance that boosts the innate ability of plants to defend themselves against fungal infections (Linden *et al.*, 2000).

Limited information is available on the effect of organic growth promoting substance like chitosan raw materials on the growth and yield of rice in Bangladesh. A pot experiment was conducted to investigate yield performance of a T. Aman rice variety (BRRI dhan75) as influenced by the chitosan raw materials under the Agro Ecological Zone (AEZ-28) Modhupur Tract.

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

1. To examine effect of chitosan raw materials on the improvement of rice seedling quality.
2. To observe performance of BRRI dhan75 rice seedlings treated by chitosan raw materials.

CHAPTER II

REVIEW OF LITERATURE

An attempt was made in this section to collect and study the relevant information available in the country and abroad regarding the tillering pattern of BRRI dhan75 using chitosan raw materials in the seedbed to gather knowledge helpful in conducting the present research work and subsequently writing up the results and discussion.

2.1 Effect of chitosan on growth, yield parameter and yield

2.1.1 Seedling Fresh weight (g)

Phothi and Theerakarunwong (2017) conducted a study to know the effects of chitosan on physiology, photosynthesis and biomass of rice cultivar RD47. For combined effects of chitosan and ozone, rice was soaked and sprayed with chitosan 0.05% (W/V) under elevated ozone concentration at 40 ppb (Chi+EO340) and 70 ppb (Chi+EO370). Samples were analyzed weekly for tiller number per plants, leaf area, leaf chlorophyll, photosynthesis, shoot biomass, root biomass and total biomass. For the samples soaked and sprayed with chitosan under elevated ozone for 21 days, Chi+EO340 and Chi+EO370 significantly gathered more shoot biomass than EO340 and EO370, respectively ($p \leq 0.05$). In addition, chitosan could reduce the ozone negative effects and increased higher physiology and photosynthesis rate.

Issak and Sultana (2017) conducted an experiment at the research field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from December 2015 to January 2016. There were six treatments in the experiments i.e. T_1: seedbed applied CHT powder at 100 g/m^2, T_2: seedbed applied CHT powder at 200g/m^2, T_3: seedbed applied CHT powder at 300 g/m^2, T_4: seedbed applied CHT powder at 400 g/m^2, T_5: seedbed applied CHT powder at 500g/m^2 and T_6: seedbed applied CHT powder at 0 g/m^2. From the experiment result revealed that Fresh weight production of BRRI dhan29 rice seedlings were significantly increased with the chitosan powder treatments in the seedbed. The maximum fresh weight (29.14 g) production of 100 seedlings was found in the treatment T_4 having 400 g CHT powder/m^2 which was significantly different from all other treatments. The lowest fresh weight production (12.6 g) was found in the treatment T_6 (control) which was significantly different from all other treatments.

Guan *et al.* (2009) showed that application of oligo-chitosan also increased mineral uptake of maize and stimulated the growth of maize seedlings. Spraying oligochitosan with concentration of 60 mg/L. 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.

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

2.1.2 Seedling Oven Dry weight (g)

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-materials on yield maximization of BRRI dhan49 laid out in RCBD having four treatments with five replications.). The treatment combinations were as follows: T_1: Seedbed applied @ 0 g/m^2 + Main field applied @ 0 t/ha (Control); T_2: Seedbed applied @ 0 g/m^2 + Main field applied @ 0.5 t/ha; T_3: Seedbed applied @ 250 g/m^2 + Main field applied @ 0 t/ha; T_4: Seedbed applied @ 250 g/m^2 + Main field applied @ 0.5 t/ha. Average 25.88 mg dry matter of a treated single seedling was increased.

Issak and Sultana (2017) conducted an experiment at the research field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from December 2015 to January 2016. There were six treatments in the experiments i.e. T_1: seedbed applied CHT powder at 100 g/m^2,T_2: seedbed applied CHT powder at 200g/m^2, T_3: seedbed applied CHT powder at 300g/m^2, T_4: seedbed applied CHT powder at 400g/m^2, T_5: seedbed applied CHT powder at 500g/m^2 and T_6: seedbed applied CHT powder at 0 g/m^2. From the experiment result revealed that oven dry weight of BRRI dhan29 rice seedlings were significantly influenced due to the application of chitosan powder. The maximum oven dry weight (6.43 g) production of 100 seedlings was found in the treatment T_4 having 400 g powder/m^2 which was statistically different from all other treatments. The lowest oven dry weight production (3.5 g) was found in the treatment T_6 (control) which was significantly different from all other treatments.

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

2.1.3 Seedling height (cm)

Chitosan is well known for its role in stem elongation. The effect of chitosan on plant height was studied in various parts of the world by various workers on a variety of crops. It was observed in most cases that chitosan remarkably increases plant height of different crops.

Sultana *et al.* (2015) conducted a field experiment on rice plant. This experiment was carried out by using four different concentrations of oligomeric chitosan that is 0, 40, 80 and 100 ppm and four times foliar spray after germination. This experiment showed that plant height does not play any statistically significant differences between control and 40 ppm oligo-chitosan sprayed plants. But in case of 80 and 100 ppm oligo-chitosan sprayed rice plants show significant differences with compared to control.

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

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

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

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

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

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

Ouyang and Xu (2003) carried out an experiment with Chinese cabbage (Brassica campestris) cv. Dwarf hybrid No.1 and observed that when seed dressed with chitosan8 at the rate of 0.4-0.6 mg/g seed and leaf sprayed 20-40 micro g/L plant height and leaf area of Chinese cabbage was increased.

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

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

Sekh (2002) carried out an experiment to find out the effect of PGRs on rice and found that GABA @ 0.33 mg/L 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 ml/L, 0.33 ml/L and 0.66 ml/L aqueous solutions and revealed that the GABA at 0.33 ml/L produced the tallest shoot at 60 and 90 DAS. Shoot height was significantly higher over that produced in control.

2.1.4 No of tillers/hill

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-materials of on yield maximization of BRRI dhan49 laid out in RCBD having four treatments with five replications.). The treatment combinations were as follows: T_1: Seedbed applied @ 0 g/m^2 + Main field applied @ 0 t/ha (Control); T_2: Seedbed applied @ 0 g/m^2 + Main field applied @ 0.5 t/ha; T_3: Seedbed applied @ 250 g/m^2 + Main field applied @ 0 t/ha; T_4: Seedbed applied @ 250 g/m^2 + Main field applied @ 0.5 t/ha. In producing the total number of tillers/hill the treatments were found as T3>T4>T2>T1. It showed that the application of chitoan-raw-materials in soil increases the total tillers/hill.

Phothi and Theerakarunwong (2017) conducted an study to know the effects of chitosan on physiology, photosynthesis and biomass of rice cultivar RD47. For combined effects of chitosan and ozone, rice was soaked and sprayed with chitosan 0.05% (W/V) under elevated ozone concentration at 40 ppb (Chi+EO340) and 70 ppb (Chi+EO370).Samples were analyzed weekly for tiller number per plants, leaf area, leaf chlorophyll, photosynthesis, shoot biomass, root biomass and total biomass. For the samples soaked and sprayed with chitosan under elevated ozone for 21 days, Chi+EO340 and Chi+EO370 significantly performed more photosynthesis and more tiller number per plants than EO340 and EO370, respectively ($p \leq 0.05$). In addition, chitosan could reduce the ozone negative effects and increased higher physiology and photosynthesis rate.

Sultana *et al*. (2015) conducted a field experiment at the Atomic Energy Research Establishment (AERE) area in the year 2015. Each experimental plot size was 2.5×2.5m^2. Four different concentrations were used in this experiment that is 0, 40, 80 and 100 ppm oligomeric chitosan and four times foliar spray after germination (on day 3, 17, 55 and 70 at field stages) were carried out. In the control treatment only water was sprayed. Plant height, number of effective tiller per plant, panicle length, total grains per panicle, 1000-grain weight and yield were recorded at harvesting time. Result revealed that seed soaking in oligochitosan before planting tends to stimulate plant height. Plant height does not show any statistically significant differences between control and 40 ppm oligochitosan sprayed plants. But for 80 and 100 ppm oligochitosan sprayed plants show significant differences with compared to control. From data it is observed that number of effective tillers per plant, panicle length, total grains per panicle and thousand grain weights also show significant differences between control plants and foliar sprayed chitosan plants. It is also found that with o-chitosan the yield of rice shows good result with compare to control. With 100 ppm o-chitosan the yield of rice in terms of t/ha is 8.3 whereas in control it is 6.0 t/ha. The increase of yield with chitosan in terms of control is 38%.

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

Limpanavech *et al.* (2008) carried out an experiment to observed that the effects on Dendrobium "Eiskul" floral production with six types of chitosan molecules, P-70, O-70, P-80, O-80, P-90, and O-90. Compared to the non-chitosan treated controls,9 chitosan O-80 induce early flowering at all concentrations tested, 1, 10, 50, and 100 mg/L and during the 68 weeks of the experimental periodic time it increase the accumulative inflorescence number.

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

Hoque (2002) conducted an experiment on germination of seed and growth of seedling by seed soaking of different wheat cultivars with 0.16 ml/L, 0.33 ml/L and

0.66 ml/L of CI-IAA, GABA and TNZ-303. Compared to the control number of tiller significantly increased at 0.33 ml/L of PGR.

Bhuvaneswari and Chandrasekharan *et al.*(2008) showed varying chitosan application methods did not affect tiller numbers per plant. The maximum tiller numbers obtained from treatment of seed soaking in chitosan solution before planting and soil application, however did not differ significantly 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.

2.1.5 Grain yield

Al-Tawaha *et al*. (2020) conducted an experiment to investigation the quality and productivity of barley by the fertilizer and chitosan application. Chitosan, in three different concentrations (0, 5, and 10 g L^{-1}), was randomly applied to all fertilized plots as subplot treatments. However, other parameters, namely the number of grains, number of spikes, and number of grains were also found to be influenced by the chitosan treatment. Significant variation (P<0.01) were also high between the lines in the presence and absence of chitosan application. The highest number of grain yield, number of spikes, and grains/spike were found by the foliar treatment of 10 g L^{-1}chitosan to barley plants at the tillering stage. Similarly, the grain quality, particularly with respect to protein and starch, was found to be enhanced significantly over control.

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-materials of on yield maximization of BRRI dhan49 laid out in RCBD having four treatments with five replications.). The treatment combinations were as follows: T_1: Seedbed applied @ 0 g/m^2 + Main field applied @ 0 t/ha (Control); T_2: Seedbed applied @ 0 g/m^2 + Main field applied @ 0.5 t/ha; T_3: Seedbed applied @ 250 g/m^2 + Main field applied @ 0 t/ha; T_4: Seedbed applied @ 250 g/m^2 + Main field applied @ 0.5 t/ha. Maximum grain yield (6.64 t/ha) was found in the treatment T_4 which was statistically identical with the grain yield (6.51 t/ha) of treatment T_3. 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-materials, had a profound effect on grain yield and yield traits of T. aman rice (BRRI dhan49).

Priyaadharshini *et al.* (2019) conducted an experiment to study the effect of chitosan nanoemulsion in pearl millet under water deficit condition. Foliar spray of 0.1% chitosan nanoemulsion along with control was done at flowering stage under moisture stress condition. Physiological traits on gas exchange parameters (photosynthetic rate, stomatal conductance, transpiration rate and leaf temperature), chlorophyll index, relative water content and yield attributes were recorded after foliar spraying of chitosan. The results showed that the treatment with chitosan causes reduction in stomatal conductance thereby limiting the photosynthesis, transpiration rate and raise in leaf temperature than unsprayed plants. The yield was also significantly increased in treated plants than control under drought condition. Hence, foliar spray of chitosan plays an important role in alleviating the harmful effects of water stress by improving the plant water status and yield.

Phothi and Theerakarunwong (2017) conducted a study to know the effects of chitosan on physiology, photosynthesis and biomass of rice cultivar RD47 under elevated ozone. Rice samples were grown at indoor climate controlled chambers, allowing the inlet air to pass through charcoal filters. For combined effects of chitosan and ozone, rice was soaked and sprayed with chitosan 0.05% (W/V) under elevated ozone concentration at 40 ppb (Chi+EO340) and 70 ppb (Chi+EO370). Control groups (CF) with no additional ozone were also studied. Samples were analyzed weekly for tiller number per plants, leaf area, leaf chlorophyll, photosynthesis, shoot biomass, root biomass and total biomass. The results obviously showed that ozone at the concentration of both 40 and 70 ppb caused negative effects on rice physiology, photosynthesis and biomass. The 70 ppb concentration, particularly, caused severe damage. Whilst soaking and spraying with chitosan could significantly reduce the harmful effects of ozone compared with the control group. For the samples soaked and sprayed with chitosan under elevated ozone for 21 days, Chi+EO340 and Chi+EO370 significantly performed more photosynthesis and contained more leaf chlorophyll than EO340 and EO370, respectively ($p \leq 0.05$). In addition, chitosan could reduce the ozone negative effects and increased higher physiology and photosynthesis rate.

Kananont *et al.* (2015) carried out an experiment with Fermented chitin waste (FCW) with three levels of FCW @ (0.25%, 0.50% and 1.0% (w/w)) along with CF = soil supplemented with chemical fertilizer and CMF = soil supplemented with chicken manure fertilizer. The results revealed that FCW @ 1% the grain yield differ significantly from 0.5% FCW, 0.25% FCW and the rest of the treatment.

Sultana *et al.* (2015) conducted a field experiment on rice plant. This experiment was carried out by using four different concentrations of oligomeric chitosan that is 0, 40, 80 and 100 ppm and four times foliar spray after germination. Results found that grain yield show significant differences in case of foliar sprayed chitosan plants and control plants.

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

Abdel-Mawgoud *et al.* (2010) conducted a pot experiment and they reported that application of chitosan at 2 mg/L improve yield components (number and weight) of strawberry plants.

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

Boonlertnirun *et al.* (2008) carried out an experiment with 4 treatments. The treatments were T_1- control (no chitosan application), T_2- seed soaking with chitosan solution, T_3 - seed soaking and soil application with chitosan solution and T_4 – seed soaking and foliar spraying with chitosan solution. The results revealed that chitosan15 application by seed soaking and then soil significantly increased yield over the other treatments of rice plants.

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

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

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

2.1.6 Straw yield

Phothi and Theerakarunwong (2017) conducted an study to know the effects of chitosan on physiology, photosynthesis and biomass of rice cultivar RD47. Rice samples were grown at indoor climate controlled chambers, allowing the inlet air to pass through charcoal filters. For combined effects of chitosan and ozone, rice was soaked and sprayed with chitosan 0.05% (W/V) under elevated ozone concentration at 40 ppb (Chi+EO340) and 70 ppb (Chi+EO370). Control groups (CF) with no additional ozone were also studied. Samples were analyzed weekly for tiller number per plants, leaf area, leaf chlorophyll, photosynthesis, shoot biomass, root biomass and total biomass. The results obviously showed that ozone at the concentration of both 40 and 70 ppb caused negative effects on rice physiology, photosynthesis and biomass. The 70 ppb concentration, particularly, caused severe damage. In addition, chitosan could reduce the ozone negative effects and increased higher physiology and photosynthesis rate.

Sultana *et al.* (2015) conducted a field experiment on rice plant. This experiment was carried out by using four different concentrations of oligomeric chitosan that is 0, 40, 80 and 100 ppm and four times foliar spray after germination. Finally it is observed that straw yield show significant differences between control plants and foliar sprayed chitosan plants and highest straw yield was observed under 100 ppm oligomeric chitosan and lowest straw yield was observed under 0 ppm oligomeric chitosan.

Kananont *et al.* (2015) carried out an experiment with Fermented chitin waste (FCW) with three levels of FCW @ (0.25%, 0.50% and 1.0% (w/w)) along with CF = soil supplemented with chemical fertilizer and CMF = soil supplemented with chicken manure fertilizer. The results revealed that FCW @ 1% the straw yield differ significantly from 0.5% FCW, 0.25% FCW and the rest of the treatment.

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

Sultana and Issak (2020) conducted an experiment at the research field of Sher-e-Bangla Agricultural University, Dhaka- 1207, Bangladesh, during 2015-2016, to investigate residual effect of raw material of chitosan (CHT) powder on chemical properties of rice growing soils. The experiment was laid out in randomized complete block design (RCBD) with four replications. T1= 0.5 t/ha, T2 = 1.0 t/ha, T3 = 2.0 t/ha, T 4.0 t/ha and T5 = 0 t/ha. The maximum value of the pH (7.01), organic carbon content (0.72%), and organic matter content (1.24%) in the post-harvest soils were found in the treatment T4 and lowest values were observed in the control treatment (T5). These results suggested that the residual effect of the raw material of CHT powder could play a significant role to improve the sustainable soil health.

Fermented chitin waste (FCW), a by-product obtained from chitinase production using chitin fermentation. Kananont *et al.* (2015) carried out an experiment with16 Fermented chitin waste (FCW) with three levels of FCW @ (0.25%, 0.50% and 1.0% (w/w)) along with CF = soil supplemented with chemical fertilizer and CMF = soil supplemented with chicken manure fertilizer. The results revealed that @ 1% FCW the pH differ significantly from 0.5% FCW, 0.25% FCW and the rest of the treatment. The pH ranges from 5.01 to 5.93 among the treatment. @ 1% FCW the highest pH was obtained (5.93) and lowest pH was obtained (5.01) with CF = soil supplemented with chemical fertilizer.

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

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

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.

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

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted under the net house at Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from July to November, 2020. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout of the experiment design, intercultural operations, data recording and their analyses.

3.1 Experimental site

The research work was carried out at Sher-e-Bangla Agricultural University, Dhaka under the net house. The soil of the experimental plots belonged to the Agro Ecological Zone, Madhupur Tract (AEZ-28). For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

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 soil characteristics were silty clay loam in texture with pH value 5.6. The pots were above flood level and sufficient sunshine was available during the experimental period. The physical and chemical characteristics of the experimental soil have been presented in Appendix- II.

3.3 Climate

This area characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif-II season (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 L.*) variety BRRI dhan75 was used as planting material. This is most popular varieties due to high yielding potentials and suitable for planted at mid-June to mid-July. The life span of this variety is at 110-117 days. Grain yield of BRRI dhan75 is 4.5-5.5 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 dhan75 was 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 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 were cleaned and irrigated properly. Sprouted seeds were sown in the wet soil on 19 July, 2020. Weeds were removed and irrigation was given in the pots where seeds were sown when necessary.

3.8 Application of Chitosan raw materials

Chitosan raw materials prepared from shrimp shell in the form of powder was applied in seedbed pot 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 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. And finally put into experimental pots. The first ploughing was done 6th August and the final land preparation was done 8th August, 2020. After final land preparation, 10 kg soil for each pot was taken. Plastic pots were then divided into unit plots following the design of experiment.

3.10 Treatments of the experiment

T_1 = 0% chitosan raw materials,

T_2 = 0.1% chitosan raw materials,

T_3 = 0.2% chitosan raw materials,

T_4 = 0.3% chitosan raw materials,

T_5 = 0.4% chitosan raw materials and

T_6 = 0.5% chitosan raw materials.

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 Completely Randomized Design (CRD). 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 is presented in Appendix III.

3.12 Fertilizer application

All the fertilizers including $1/3^{rd}$ dose of urea were added to the soil during final land preparation on 8 August, 2020. Urea was applied equally in three splits. The second split (1/3rd of total amount of N) was applied on 30th August, 2020 and the third split (1/3rd of total amount of N) on 19th September, 2020 at maximum tillering stage.

3.13 Transplanting of seedling

Twenty one days old seedlings were uprooted carefully from the seedbed pot and transplanted in the experimental pots on 10 August, 2020. Single seedling was transplanted in each hill.

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

After transplanting 5-6 cm water was maintained in each pot through irrigation during the growth period. Frequency of irrigation water was reduced after panicle emergence and grain filling stage. The field was kept dried 7 days before harvesting.

3.14.2 Weeding

The crop was infested with some weeds during the early stage of crop establishment. Three hand weeding were done to reduce crop competition with weed. First weeding was done at 20 days after transplanting followed by second weeding at 15 days after first weeding. Third weeding was done 15 days after second weeding.

3.14.3 Protection against insect and pest

There were some incidence in insects specially rice stem borer, grasshopper, rice bug etc. which were controlled by spraying Diazinon 50 EC. Crop was protected from birds and rats during the grain filling period. Rat was controlled by using field trap and poisonous bait. The net house was kept under strong surveillance, especially during morning and afternoon to control birds.

3.15 Harvest and Threshing

The crop was harvested depending upon the maturity of plant. Harvesting was done by serrated edged sickles manually from each pot. Maturity of crop was determined when 80% of the grains became matured. The harvested crops from each pot were bundled, properly tagged and then brought to the threshing floor for recording grain and straw yield. Threshing was done plot wise by pedal thresher. The grains were cleaned and sun dried to a moisture content of 12%. Straw was also sun dried properly. Finally grain and straw yields per pot were determined and expressed in gram (g).

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

Operations	Working Dates
Application of chitosan raw materials in seedbed	19 July, 2020
First ploughing	6 August, 2020
Transplanting pot preparation	8 August, 2020
Application of fertilizers ($1/3^{rd}$ 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) No of tillers/hill at 20 DAT
5) No of tillers/hill at 30 DAT
6) No of tillers/hill at 40 DAT
7) No of tillers/hill at 50 DAT
8) Fresh weight production of tiller/6 hills at MT stage
9) Effective tiller
10) Grain yield (g)
11) Straw yield (g)

3.17 Procedure of data collection:

3.17.1 Seedling height (cm)

The heights of 21 days old seedlings were measured with a meter scale from the ground level to tip of seedlings and the mean heights were expressed in cm.

3.17.2 Seedling Fresh weight (g)

Fresh seedlings of 21 days old were collected and then weighed by using a digital electric balance.

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.

3.17.4 Number of tillers/hill at 20 DAT

Number of tillers/hill were carefully counted at 20 DAT from each pot and averaged.

3.17.5 Number of tillers/hill at 30 DAT

Number of tillers/hill were carefully counted at 30 DAT from each pot and averaged.

3.17.6 Number of tillers/hill at 40 DAT

Number of tillers/hill were carefully counted at 40 DAT from each pot and averaged.

3.17.7 Number of tillers/hill at 50 DAT

Number of tillers/hill were carefully counted at 50 DAT from each pot and averaged.

3.17.8 Fresh weight of tiller/6 hills at MT stage

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

3.17.9 Effective tiller

The tiller which beared panicle, was considered as effective tiller. Number of effective tiller/hill were carefully counted at harvest from each pot and averaged. Number of effective tiller/hill were carefully counted at harvest from each pot and averaged.

3.17.10 Grain yield (g)

Harvested bundles of rice plants from each pot were threshed and winnowed separately. After winnowing the grain was sun dried pot wise upto 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)

After separating the grains, straw obtained from each pot were sun dried and weighed carefully by digital electrical balance and finally expressed as gram (g).

3.18 Analysis of data

The data were collected on different parameters and were statistically analyzed by graphical presentation by means of standard deviation and standard error of mean.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises of the presentation and discussion of the results obtained due to application of different rate of chitosan raw materials on growth and yield of BRRI dhan75. The results of the present investigation have been presented, discussed and compared with the results of the researchers.

4.1 Seedling fresh weight (g)

Seedling fresh weight production of BRRI dhan75 showed significant variation with the application of chitosan raw materials in seedbed. The results revealed that production of maximum 100 seedling fresh weight (29.7 g) was observed in T_5 treatment. Whereas minimum 100 seedling fresh weight (13.9 g) was observed in T_1 (control) treatment (Fig 1, A). 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 materials in the seedbed and this might be due its supplementation of different plant nutrients and plant growth regulators (PGR). Chitosan raw materials 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).

4.2 Seedling oven dry weight (g)

Significant variation was found in seedling oven dry weight production among the treatments used in the experiment. The experimental results revealed that production of maximum 100 seedling oven dry weight (11.2 g) was observed in T_5 treatment. Whereas minimum production of 100 seedling oven dry weight (5.4 g) was observed in T_1 (control) treatment (Fig 1, A). Increasing trend of the seedlings dry weight production was observed among the treatments. The dry matter production was increased almost in a dose dependent manner. 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. The results might be due to the alteration of soil pH, OC & N level with application of using chitosan raw materials in seedbed (Rahman *et al*., 2015; Sultana *et al.,* 2020).

4.3 Seedling height (cm)

Seedling height of BRRI dhan75 showed significant variation with the application of chitosan raw materials in all the treatments used in the experiment. The experimental results revealed that maximum seedling height (31.11 cm) was observed in T_5 treatment and followed by T_6 (30.86 cm), T_4 (27.18 cm), T_3 (25.81 cm), T_2 (23.64 cm). Whereas minimum seedling height (20 cm) was observed in T_1 (control) treatment (Fig 1, B). Seedling height was increased almost in a dose dependent manner. Present findings were supported with the similar findings of Rahman *et al.*, (2015); Ahmed *et al*., (2020) and Sultana *et al*., (2020).

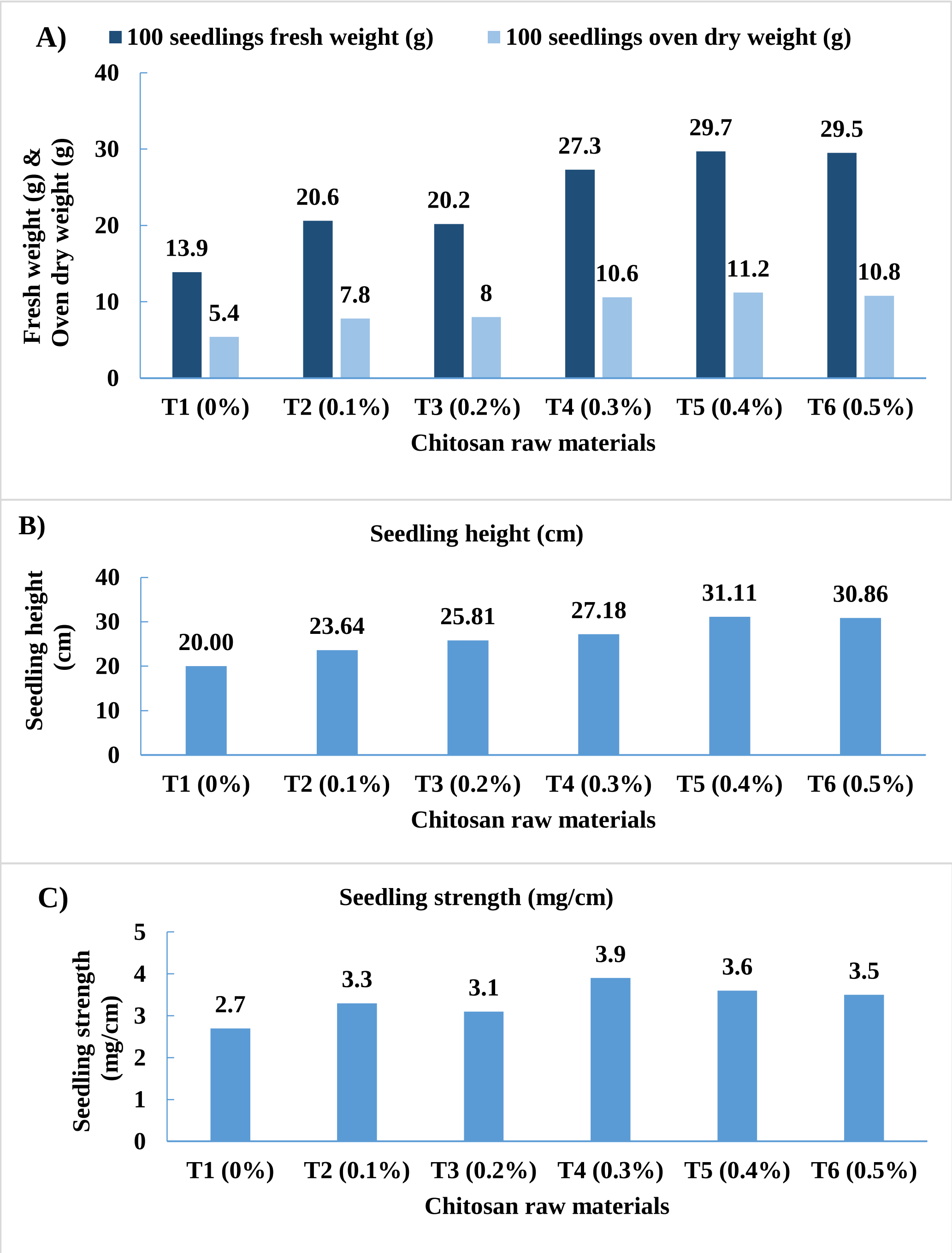


Fig 1. Effect of chitosan raw materials on the production of fresh weight, oven dry weight, seedling height and seedling strength of BRRI dhan75; A) 100 seedling fresh and oven dry weight; B) seedling height and C) seedling strength

4.4 Seedling strength (mg/cm)

Seedling strength of BRRI dhan75 showed significant variation with the application of chitosan raw materials in all the treatments used in the experiment. The results revealed that maximum seedling strength (3.9 mg/cm) was observed in T_4 (0.3%) treatment (Fig 1, B). Whereas minimum seedling strength (2.7 mg/cm) was observed in T_1 (control) treatment. Chitosan raw materials have positive role on seedling strength modification (Ahmed *et al.*, 2020; Issak and Amena, 2017).

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

Tiller production capacity of chitosan raw materials treated seedlings was significantly improved. Seedling strength strongly improved the average tiller production capacity of BRRI dhan75 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/hill (6.52) was observed in T_5 treatment which was statistically similar with T_6 (6.15) treatment and followed by T_4 (6.06), T_3 (6.02) and T_2 (5.5) (Fig 2 A). Whereas minimum tiller number/hill (4.48) was observed in T_1 (control) treatment. All the treatments produced higher tillering number/hill than the control treatment at 20 DAT.

At 30 DAT tiller production showed significant differences with the effects of chitosan raw materials on seedling strength. The results showed that maximum tiller number/hill (16.51) was observed in T_4 treatment which was statistically similar with T_3 (16.4) treatment and followed by T_2 (15.18), T_6 (14.7) and T_5 (14.56) (Fig 2 B).

Whereas minimum tiller number/hill (12.31) was observed in T_1 (control) treatment. All the treatments produced higher tillering number/hill than the control treatment at 30 DAT.

Similar to the above two results, at 40 DAT tiller number/hill showed significant variation among the treatments used in the experiment. The results showed that maximum tiller number/hill (21.12) was observed in T_2 treatment which was statistically similar with T_3 (20.88) and T_4 (20.2) and was followed by treatments T_5 (18.14) and T_6 (18.14) (Fig 2 C). Whereas minimum tiller number/hill (17.86) 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/hill than the control treatment.

At 50 DAT tiller number/hill also showed significant variation among the treatments. The results showed that production of maximum tiller number/hill (21.83) was observed in T_3 treatment which was statistically identical with T_2 (21.74) and T_4 (20.98) treatments (Fig 2 D). Whereas production of minimum tiller number/hill (18.1) was observed in T_1 (control) treatment but statistically identical with T_5 (18.14) and T_6 (18.36) treatments. At 50 DAT all the treatments produced higher tiller number/hill than the control treatment.

Improved seedling strength, boosting with chitosan raw materials in the seedbed, play influential role on early tiller production and significantly higher number of tiller production/hill in the T_2, T_3 & 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 materials in the seedbed at different rates exhibited the production of higher tiller number/hill in all the tillering stages as compared with the control treatment. The growth-promoting effect of chitosan raw materials 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).

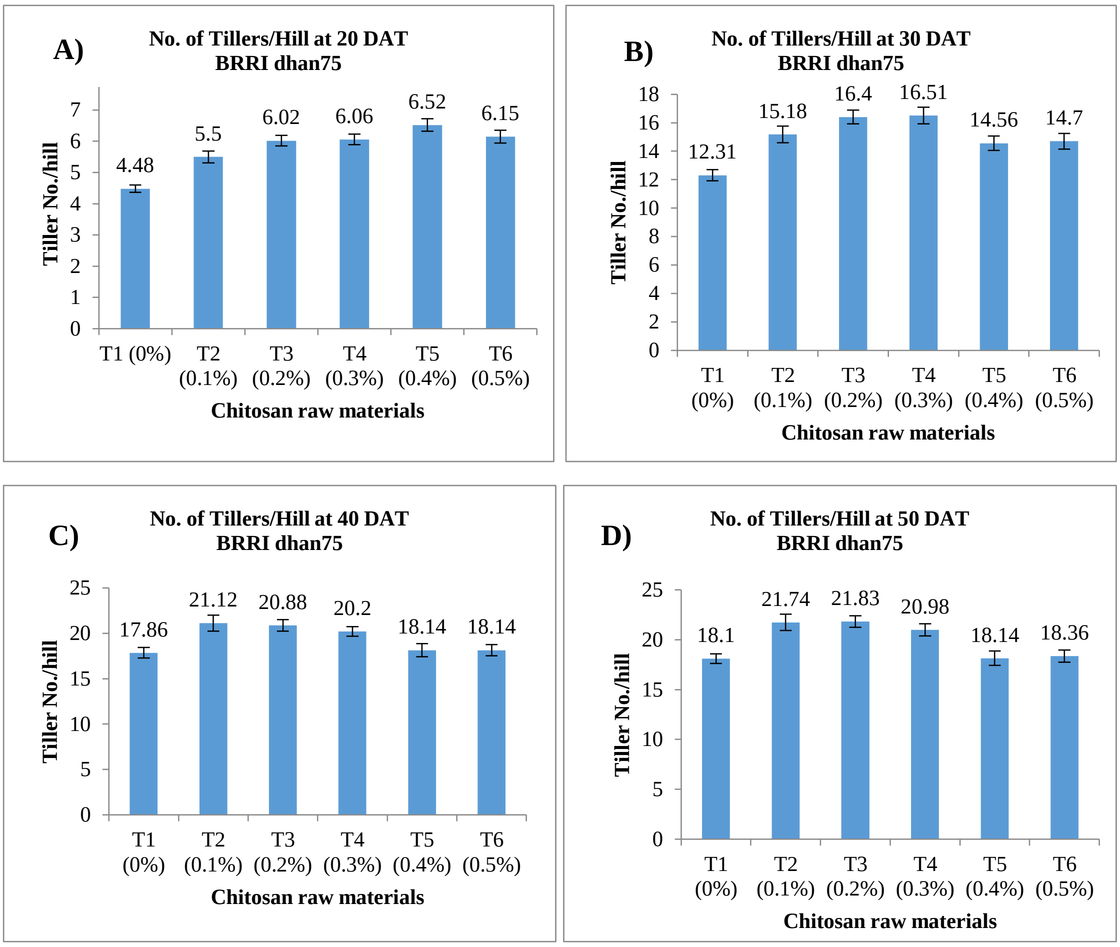


Figure 2: Effect of chitosan raw materials influenced seedling strength on average tiller production capacity of rice at 20, 30, 40 and 50 DAT

4.6 Effect of chitosan raw materials influenced seedling strength on total tiller production of BRRI dhan75 at 20 DAT

Chitosan raw materials significantly influenced total tiller production of rice at 20 DAT as applied in the seedbed before sowing. The results revealed that maximum total tiller number (313/48 hills) was observed in T_5 treatment (Fig. 3, A). Whereas minimum total tiller number (220/48 hills) was observed in T_1 (control) treatment. The total tiller production was higher in all the treatments than the control treatment. The total tiller production capacity of the treated seedlings were increased in a dose dependent manner up to T_5 treatments. The trend of the tiller production was $T_5>T_6>T_4>T_3>T_2>T_1$ respectively. At 20 DAT, production of tiller per hill was found higher in all the treatments over control. The maximum tiller number per hill (6.52) was found in T_2 treatment and followed by T_6 (6.15), T_4 (6.06), T_3 (5.90), T_2 (5.50) (Fig. 3, B). The results indicated that early tiller production per hill was influenced by the seedbed application of chitosan raw materials. At 20 DAT, percent tiller production was higher in all the treatments over control. The maximum percentage (45.54%) of more tiller production was found in T_5 treatment and followed by T_6 (37.28%), T_4 (35.27%), T_3 (34.38%), T_2 (22.77%) (Fig. 3, C). The results indicated that early tiller production was influenced in the seedling treated with chitosan raw materials and it could be a good sign for yield boosting of BRRI dhan75.

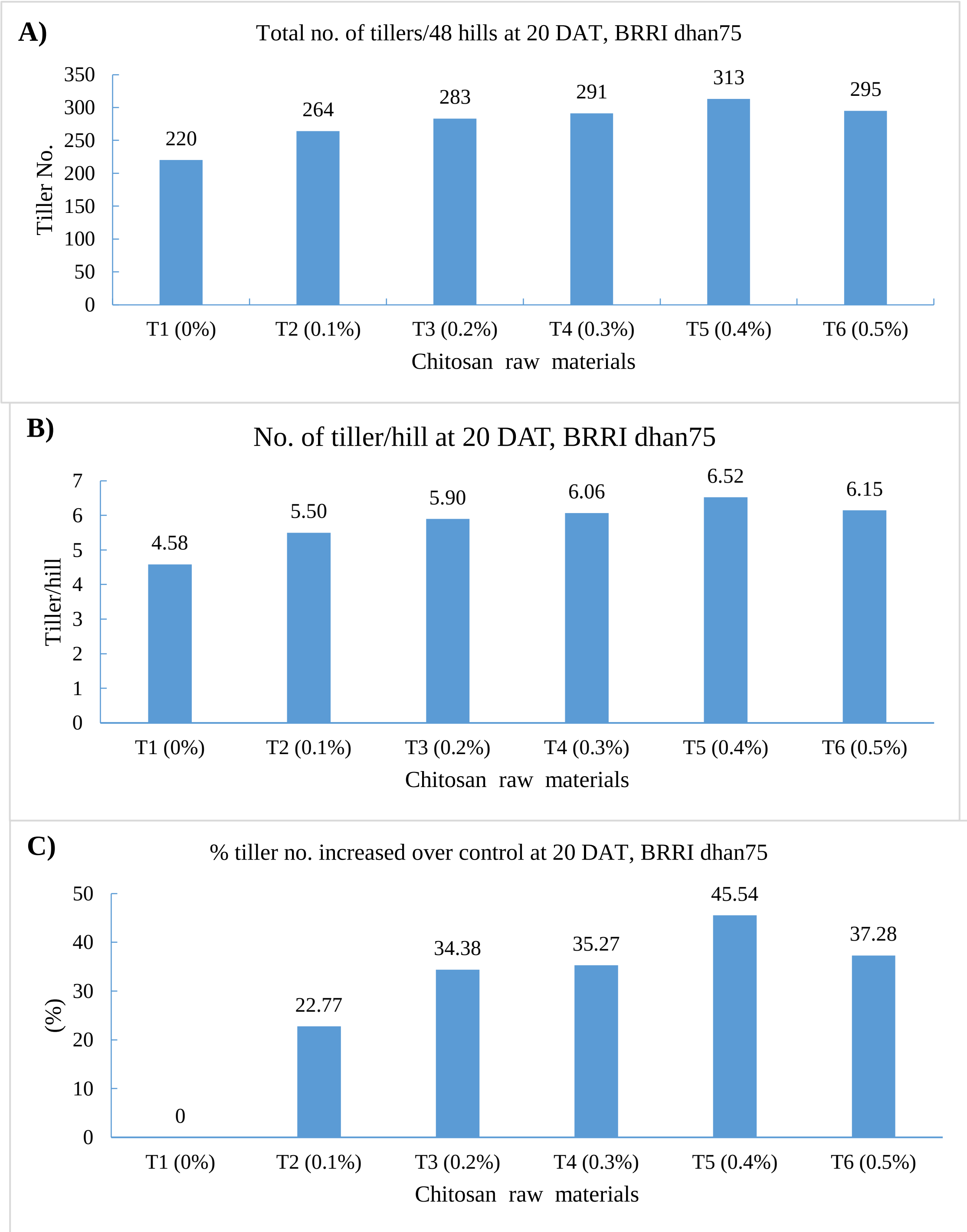


Figure 3: Effect of chitosan raw materials influenced seedling strength on total tiller production of BRRI dhan75 at 20 DAT

4.7 Effect of chitosan raw materials influenced seedling strength on total tiller production of rice at 30 DAT

Chitosan raw materials significantly influenced total tiller production of rice at 30 DAT as applied in the seedbed before sowing. The results revealed that maximum total tiller number (787/48 hills) was observed in T_3 treatment (Fig. 4, A). Whereas minimum total tiller number (591/48 hills) was observed in T_1 (control) treatment. The total tiller production was higher in all the treatments than the control treatment. The total tiller production capacity of the treated seedlings were increased in a dose dependent manner up to T_4 treatments. The trend of the tiller production was $T_3>T_4>T_2>T_6>T_5>T_1$ respectively. At 30 DAT, production of tiller per hill was found higher in all the treatments over control. The maximum tiller number per hill (16.40) was found in T_3 treatment and followed by T_4 (16.31), T_2 (15.50), T_6 (14.71), T_5 (14.56) (Fig. 4, B). Whereas minimum tiller per hill production (12.31) was observed in T_1 (control) treatment. The results indicated that early tiller production per hill was influenced by the seedbed application of chitosan raw materials. At 30 DAT, higher percent tiller production was found in all the treatments over control. The maximum higher percentage (34.12%) of more tiller production was found in T_4 treatment and followed by T_3 (33.23%), T_2 (23.31%), T_6 (19.42%), T_5 (18.28%) (Fig. 4, C). The results indicated that early tiller production was influenced by the seedbed application of chitosan raw materials.

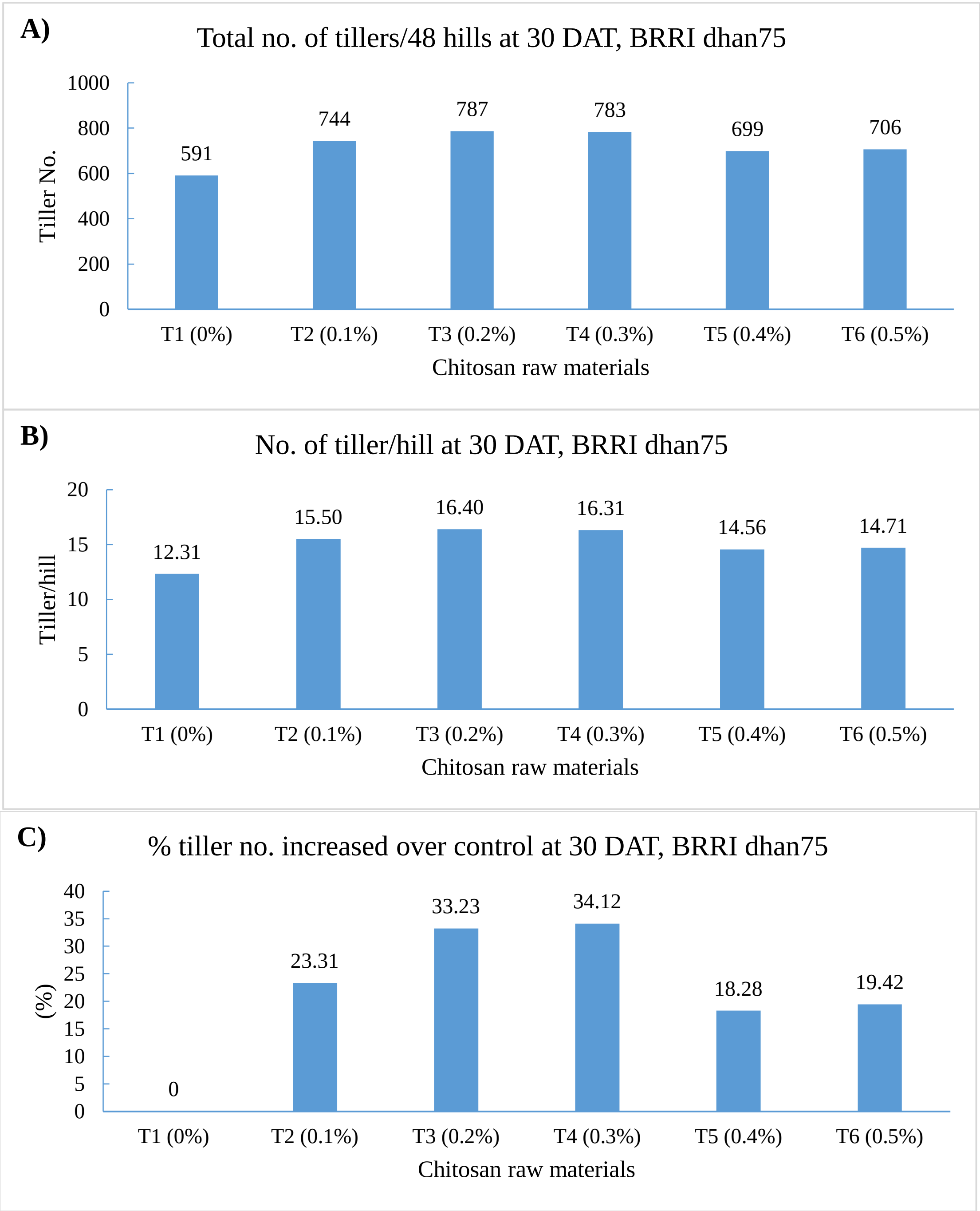


Figure 4: Effect of chitosan raw materials influenced seedling strength on total tiller production of BRRI dhan75 at 30 DAT

4.8 Effect of chitosan raw materials influenced seedling strength on total tiller production of rice at 40 DAT

Chitosan raw materials significantly influenced the total tiller production of rice at 40 DAT as applied in the seedbed before sowing. The results revealed that maximum total tiller production (887/42 hills) was observed in T_2 treatment and followed by T_3 (877/42 hills), T_4 (848/42 hills), T_5 (762/42 hills) and T_6 (762/42 hills) (Fig. 5, A). Whereas minimum total tiller production (750/42 hills) was observed in T_1 (control) treatment. Tiller production was higher in all the treatments than the control treatment. At 40 DAT, The maximum production of tiller per hill (21.12) was observed in T_2 treatment and followed by T_3 (20.88), T_4 (20.19), T_5 (18.14) and T_6 (18.14) (Fig. 5, B). Whereas minimum tiller per hill production (17.86) was observed in T_1 (control) treatment. At 40 DAT, higher percent of total tiller production was found in all the treatments over control. The maximum percentage (18.26%) of more tiller production was found in T_2 treatment and followed by T_3 (16.93%), T_4 (13.09%), T_5 (1.6%), T_6 (1.6%) (Fig. 5, C). The results indicated that early tiller production was influenced by the seedbed application of chitosan raw materials.

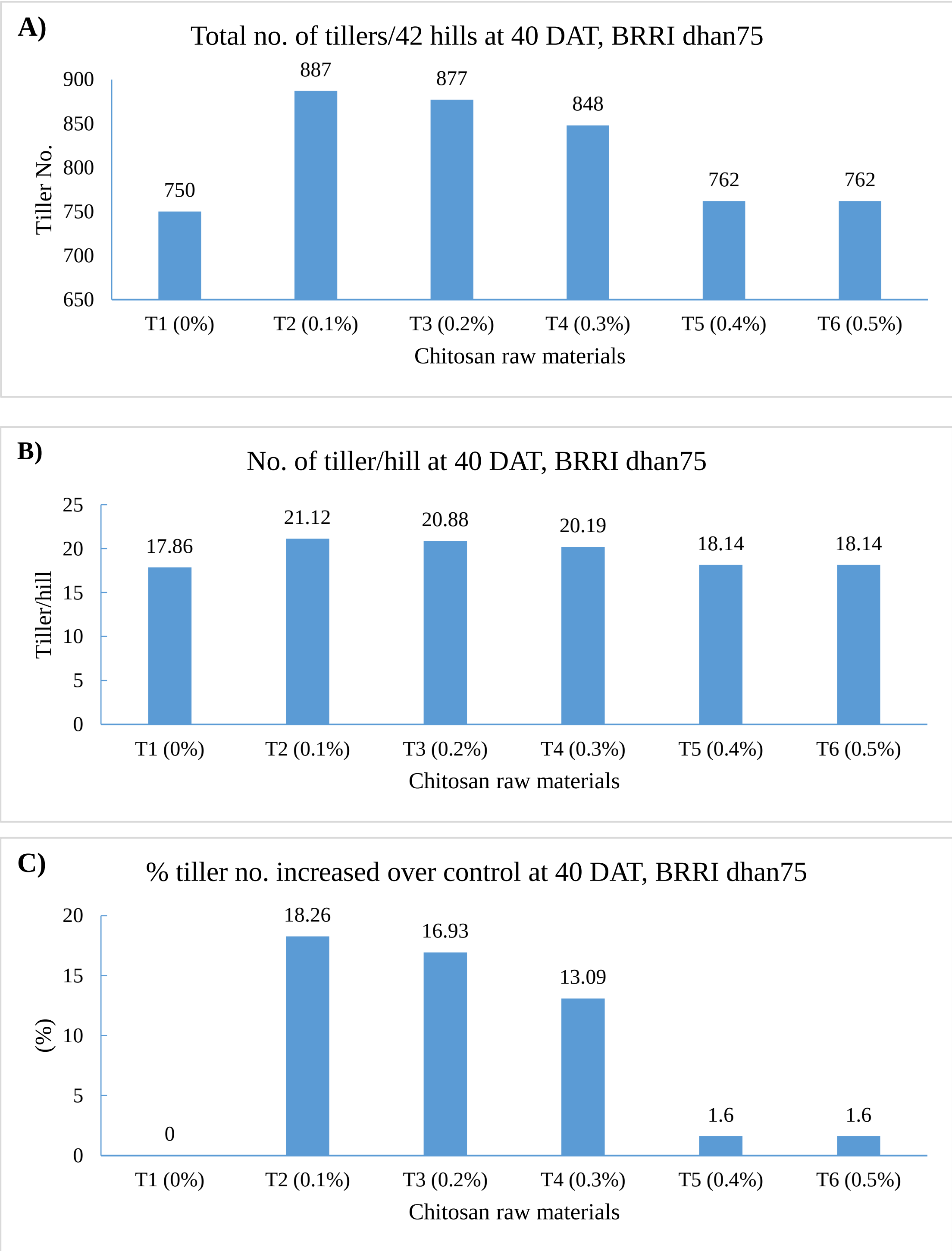


Figure 5: Effect of chitosan raw materials influenced seedling strength on total tiller production of BRRI dhan75 at 40 DAT

4.9 Effect of chitosan raw materials influenced seedling strength on total tiller production of BRRI dhan75 at 50 DAT

Chitosan raw materials significantly influenced tiller production of rice at 50 DAT as applied in the seedbed before sowing. The results revealed that maximum total tiller number (913/42 hills) was observed in T_2 treatment and followed by T_3 (895/42 hills), T_4 (881/42 hills), T_6 (771/42 hills) and T_5 (762/42 hills) (Fig. 6, A). Whereas minimum total tiller number (760/42 hills) was observed in T_1 treatment. The total tiller production was higher in all the treatments than the control treatment. At 50 DAT, production of tiller per hill was found higher in all the treatments over control. The maximum tiller per hill (21.74) was observed in T_2 treatment and followed by T_3 (21.31), T_4 (20.98), T_6 (18.36) and T_5 (18.14) (Fig. 6, B). Whereas minimum total tiller number (18.10) was observed in T_1 (control) treatment. At 50 DAT, higher percent tiller production was found in all the treatments over control. The maximum percentage (20.14%) of more tiller production was found in T_2 treatment and followed by T_3 (17.18%), T_4 (13.21%), T_6 (1.46%) and T_5 (0.21%) (Fig. 6, C). The results indicated that early tiller production was influenced by the seedbed application of chitosan raw materials.

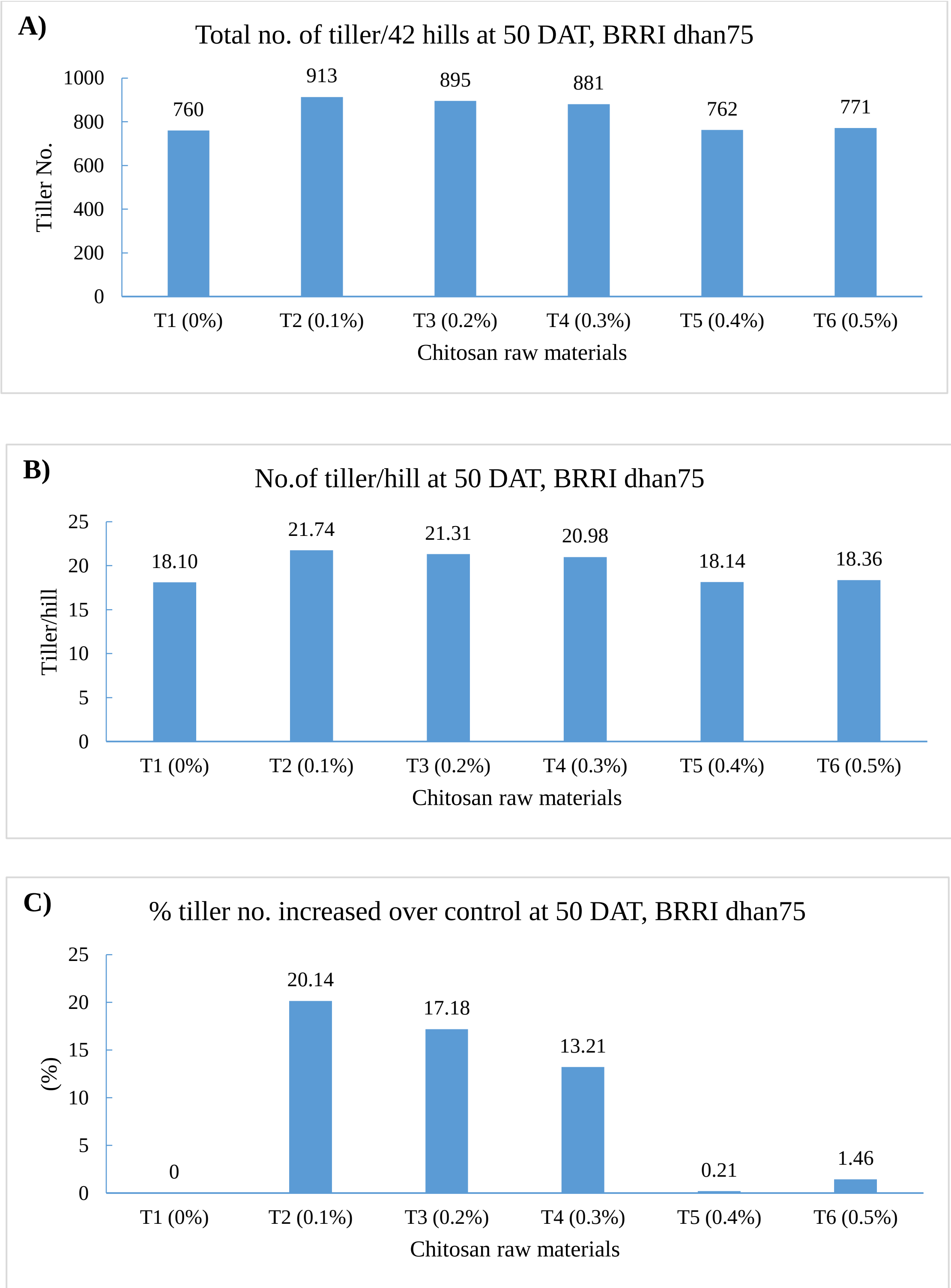


Figure 6. Effect of chitosan raw materials influenced seedling strength on total tiller production of BRRI dhan75 at 50 DAT

4.10 Effect of chitosan raw materials influenced seedling strength on fresh weight production of BRRI dhan75 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 CRM application in the seedbed. The results revealed that maximum fresh weight production (468/6 hills) was observed in T_6 treatment at MT stage and followed by T_3 (432/6 hills), T_4 (395/6 hills), T_2 (393/6 hills) and T_5 (390/6 hills) (Fig. 7, A). Whereas minimum fresh weight production (355/6 hills) 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 hill (78 g) was found in T_6 and minimum average fresh weight production was observed in T_1 (59.2 g) treatment (Fig. 7, 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 (31.8%) and followed by T_3 (21.6%), T_4 (11.7%), T_2 (10.5%) and T_5 (10.3%) treatments (Fig. 7, 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 CRM application in seedbed.

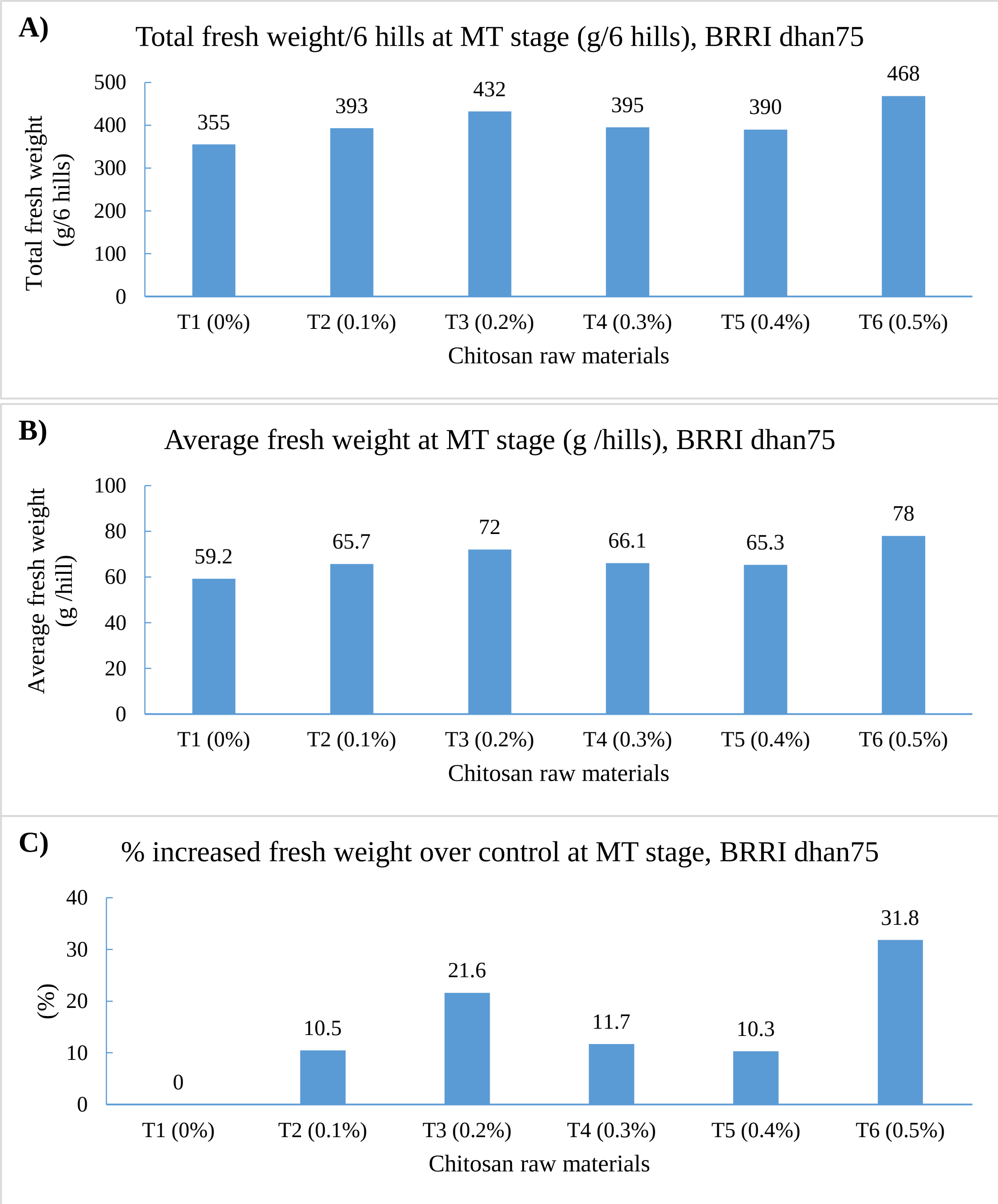


Figure 7. Effect of chitosan raw materials influenced seedling strength on fresh weight production of BRRI dhan75 at maximum tillering stage

4.11 Total tiller/hill and effective tiller/hill at harvest

Total tiller/hill and effective tiller/hill at harvest were showed significant differences among the treatments. All the treatments produced higher effective tiller/hill than the control. Only T_2 treatment showed significant differences with the control but not others treatments. The results revealed that average maximum effective tiller/hill (15.8) was produced in T_2 treatment followed by T_3 (15.3), T_4 (15.2), T_5 (14.8), T_6 (14.3) (Fig. 8). Maximum 11.2% higher tiller production was found in T_2 treatment. The results indicated that it could be the vital indicator for yield maximization of BRRI dhan75.

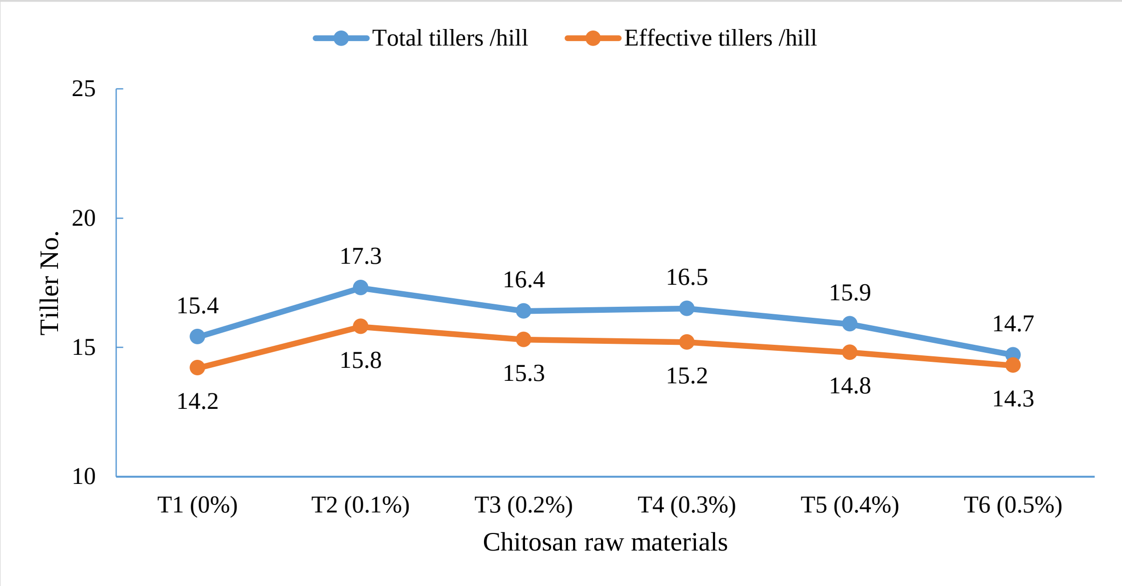


Figure 8. Effect of chitosan raw materials influenced seedling strength on total tiller/hill and effective tiller/hill at harvest

4.12 Grain yield (g/hill)

A significant variation was observed on BRRI dhan75 grain yield with the treatments. The results revealed that maximum grain yield (40.11 g/hill) was observed in T_2 treatment which was statistically similar with the T_3 (38.27 g/hill) treatment (Fig. 9, A). The minimum grain yield (34.33 g/hill) was observed in T_1 treatment which was statistically similar with T_6 (35.16 g/hill), T_4 (35.49 g/hill) and T_5 (35.68 g/hill) treatment. All the treatments produced higher grain yield than control treatment. But only T_2 and T_3 had significant differences over control treatment. Maximum higher grain yield (16.84%) was produced in T_2 treatment followed by T_3 (11.47%), T_5 (3.93%), T_4 (3.38%) and T_6 (2.42%) (Fig. 9, B). This result is supported with the results of Al-Tawaha *et al*. (2020), Priyaadharshini *et al.* (2019) and Al-Tawaha *et al.* (2018).

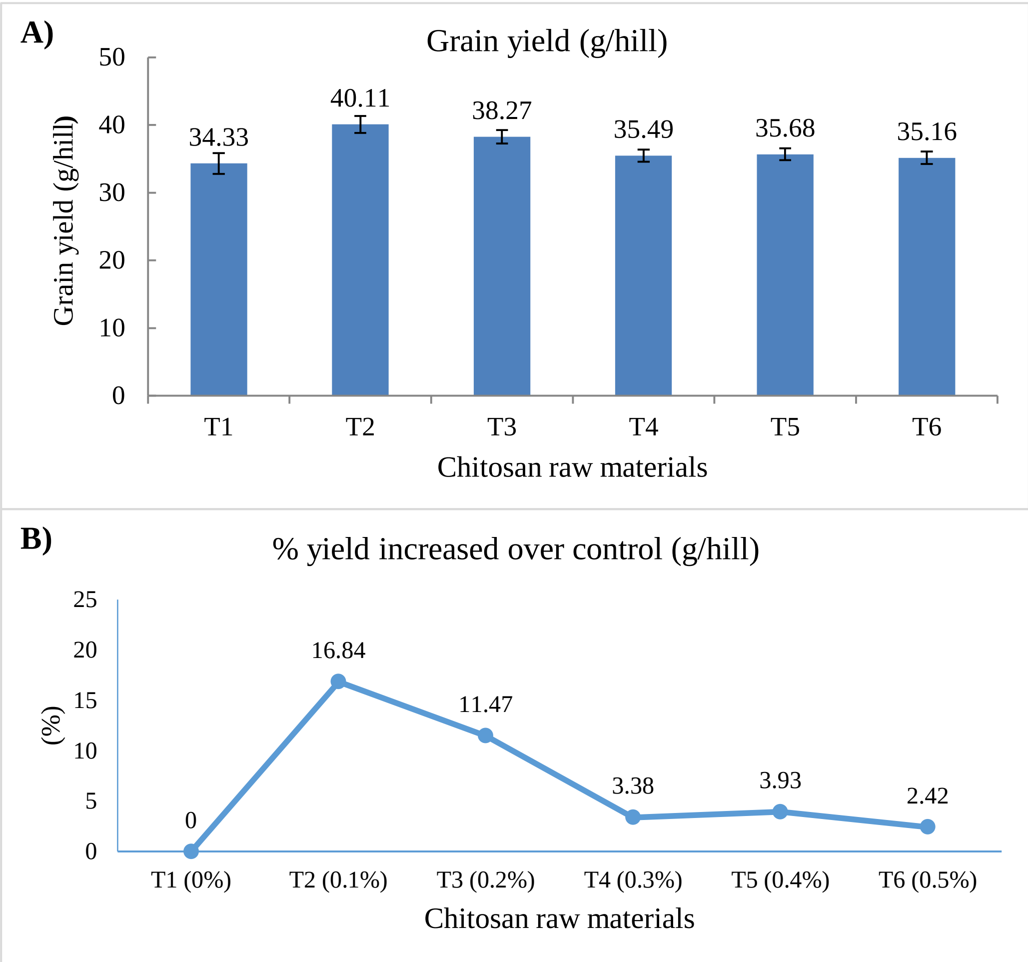


Figure 9. Effect of chitosan raw materials influenced seedling strength on grain yield of BRRI dhan75. (A) grain yield (g/hill) and (B) % yield increased over control (g/hill)

4.13 Straw yield (g/hill)

Due to application of chitosan raw materials significant variation was observed on the straw yield production of BRRI dhan75. The results showed that the maximum straw yield (43.8 g/hill) was observed in T_2 treatment (Fig. 10). Whereas minimum straw yield (34.5 g/hill) was observed in T_6 treatment which was statistically similar with T_5 (35.3 g/hill), T_1 (37.8 g/hill), T_3 (38.5 g/hill) and T_4 (39.2 g/hill) treatments.

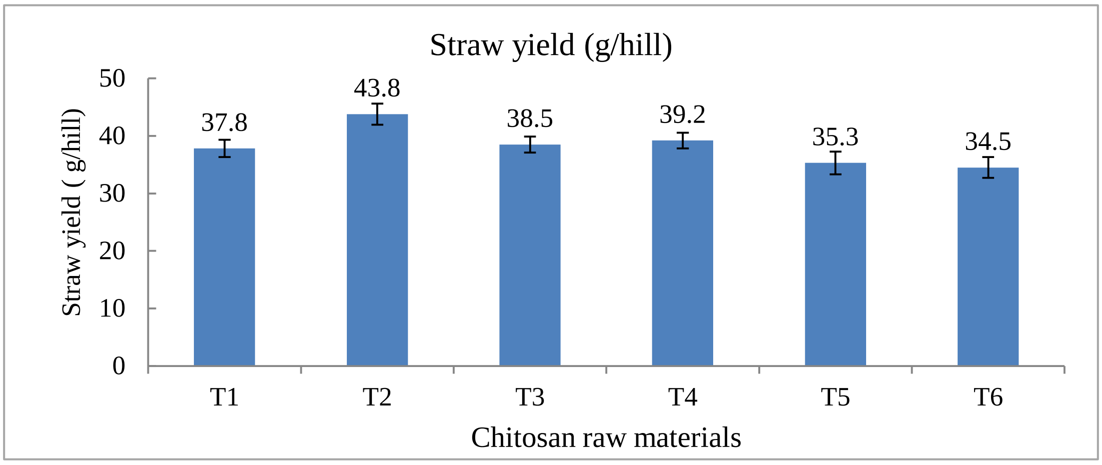


Figure 10. Effect of chitosan raw materials influenced seedling strength on on straw yield (g/hill) of BRRI dhan75

CHAPTER V

SUMMARY AND CONCLUSION

A pot experiment was conducted under the net house at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period of July-November, 2020 to study the performance of a rice variety (BRRI dhan75) as influenced by chitosan raw materials. 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 field moist soils of SAU having the soil texture silty clay loam. The experiment was laid in a Completely Randomized Design (CRD). The experiment was comprised of six (6) treatments i.e. T_1 = 0% chitosan raw materials, T_2 = 0.1% chitosan raw materials, T_3 = 0.2% chitosan raw materials, T_4 = 0.3% chitosan raw materials, T_5 = 0.4% chitosan raw materials and T_6 = 0.5% chitosan raw materials. 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). The treatment materials was applied in the seedbed before sowing the sprouted seeds. Different parameters i.e. 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 were recorded and compared among treatments. Significant differences were observed among the treatments used in the experiment due to the application of chitosan raw materials in the seedbed.

The production of maximum 100 seedling fresh weight (29.7 g) was observed in T_5 treatment, whereas minimum 100 seedling fresh weight (13.9 g) was observed in T_1 (control) treatment. The production of maximum 100 seedling oven dry weight (11.2 g) was observed in T_5 treatment whereas minimum production of 100 seedling oven dry weight (5.4 g) was observed in T_1 (control) treatment. The maximum seedling height (31.11 cm) was observed in T_5 treatment, whereas minimum seedling height (20 cm) was observed in T_1 (control) treatment. The maximum seedling strength was found in the T_4 (3.9) where minimum seedling strength was observed in control treatment T_1 (2.7).

At 20 DAT, production of maximum tiller number/hill (6.52) was observed in T_5 treatment, whereas minimum tiller number/hill (4.48) was observed in T_1(control) treatment. At 30 DAT, production of maximum tiller number/hill (16.51) was observed in T_4 treatment, whereas minimum tiller number/hill (12.31) was observed in T_1(control) treatment. At 40 DAT, production of maximum tiller number/hill (21.12) was observed in T_2 treatment, whereas minimum tiller number/hill (17.86) was observed in T_1 (control) treatment. At 50 DAT, production of maximum tiller number/hill (21.83) was observed in T_3 treatment, whereas production of minimum tiller number/hill (18.1) was observed in T_1 (control) treatment. The maximum percentage (45.54%) of more tiller production was found in T_5 treatment at 20 DAT. The maximum higher percentage (34.12%) of more tiller production was found in T_4 treatment at 30 DAT. The maximum percentage (18.26%) of more tiller production was found in T_2 treatment at 40 DAT. And finally at 50 DAT, the maximum percentage (20.14%) of more tiller production was found in T_2 treatment. Production of maximum fresh weight (468/6 hills) was observed in T_6 treatment at MT stage, whereas minimum fresh weight production (355/6 hills) was observed in T_1 (control) treatment. The maximum average fresh weight production per hill (78 g) was found in T_6 and minimum average fresh weight production was observed in T_1 (59.2 g) treatment at MT stage. The maximum effective tiller/hill production was found in T_2 (15.8) whereas the minimum effective tiller/hill was observed in control T_1 (14.2). The highest grain yield (40.11 g/hill) was found in T_2 and the lowest grain yield was found in the control T_1 (34.33 g/hill). The maximum straw yield (43.8 g/hill) was observed in T_2 treatment whereas minimum straw yield (34.5 g/hill) was observed in T_6 treatment.

Taken above results together, the research findings indicated that chitosan raw materials significantly influenced the seedling strength and that was allow to influenced maximum effective tiller production remitting higher grain yield. The treatment T_2 having 0.1% chitosan raw materials applied in the seedbed had maximum effective tiller (15.8) and so had maximum grain yield (40.11 g/hill).

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

REFERENCES

Abdel-Mawgoud, A.M.R., Tantawy, A.S., El-Nemr, M.A. and Sassine, Y.N. (2010). Growth and yield responses of strawberry plants to chitosan application. *European J. Sci. Res.* **39**(1): 170-177.

Ahmad, H.M., Shahid, M.I., Ali, Q., Awais, N., Ayyub, M., Ikram, A., Faisal, M., Ali, A. and Palwasha, A. (2020). Efficacy of different fungicides against rice blast under field condition in rice crop. *J. of Glbl. Inn. Agri. Soc. Sci.* **8**(1): 15– 18.

Ahmed, F., Issak, M. and Sultana, A. **(**2020). Effect of chitosan-raw-materials on grain yield and agronomic traits of transplanted aman rice (BRRI dhan49).*Eco-friendly Agril. J.* **13(**10**):** 38-46.

Alam, M.S., Baki, M.A., Sultana, M.S., Ali, K.J. and Islam, M.S. (2012). Effect of variety, spacing and number of seedlings per hill on the yield potentials of transplant aman rice. *Int. J. Agron. Agric. Res*. **2**(12): 10-15.

Al-Tawaha, A.R., Turk, M. A., Al-Tawaha, A.R.M., Alu'datt, M.H., Wedyan, M., Al-Ramamneh, E.A.D.M. and Hoang, A.T. (2018). Using chitosan to improve growth of maize cultivars under salinity conditions. *Bulg J. Agric. Sci.* **24**(3): 437-442.

Al-Tawaha, A.R.M., Jahan, N., Odat, N., Al-Ramamneh, E.A., Al-Tawaha, R., Abu-Zaitoon, M., Fandi, K., Alhawatema, M., Rauf, A., Wedyan, M., Shariati, M.A., Qaisi, A.M., Tawaha, K., Turk, M. and Khanum, S. (2020). Growth, yield and biochemical responses in barley to DAP and chitosan application under water stress. *J. Ecol. Eng.* **21**(6): 86–93.

Baruah, K.K. (1990). Effect of growth regulator and yield of rainfed wheat. *Indian J. Ecol.* **17**: 2.

Baruah, K.K., Gogoi, B., Borah, L., Gogoi, M. and Boruah, R. (2012). Plant morpho physiological and anatomical factors associated with nitrous oxide flux from wheat (*Triticum aestivum*). *J. Plant Res*. **125**: 507–516.

BBS (Bangladesh Bureau of Statistics). (2020). The Yearbook of Agricultural Statistics of Bangladesh. Bangladesh Bureae of Statistic, Statistics Division, Ministry of Planning, Government of. Peoples Republic of Bangladesh. Dhaka, Bangladesh. p. 53.

Berber, J., Sood, A., Sharma, K.N. and Rana, D.S. (2012). Integrated nutrient management in rice-wheat system. *J. Indian Soc. Soil Sci*. **40**: 742-747.

Berger, S. and Santos, C. (2013). Plant soil characteristics affected by biofertilizer from rocks and organic matter inoculated with diazotrophic bacteria and fungi that produce chitosan. *J. Soil Sci.* **66:** 100-107.

Bhuvaneswari, R. and Chandrasekharan, M.V. (2008). Influence of organic manures in conjunction with sulphur on yield and nutrient uptake by rice. *J. Plant Sci.* **19**(2): 543-545.

Boonlertnirun, S., Boonlertnirun, K. and Sooksathan, I. (2005). Effect of chitosan application on growth and yield of rice (*Oryza sativa*) var. Suphunburi 1. Bangkok, Thailand: Kasetsart Univ. Proc. 43rd-Kasetsart Univ. Annual Conf., Thailand, 1-4 February, 2005, Subject: Plants. Pp. 37-43.

Boonlertnirun, S., Boonlertnirun, K. and Sooksathan, I. (2006). Effects of molecularweight of chitosan on yield potential of rice cultivar SuphanBuri 1. Bangkok, Thailand: Kasetsart Univ. *Kasetsart J. Natural Sci.* **40**(4): 854-861.

Boonlertnirun, S., Boonlertnirun, K., Meechoui, S. and Sooksathan, I. (2007). Drought recovery and grain yield potential of rice after chitosan application. Bangkok, Thailand: Kasetsart Univ. *Kasetsart J. Natural Sci.* **41**(1): 1-6.

Boonlertnirun, S., Boonraung, C. and Suvanasara, R. (2008). Application of chitosan in rice production. *J. Metals, Materials Minerals*. **18**(2): 47-52.

Boussemart, J.P., Leleu, H. and Ojo, O. (2013). The spread of pesticide practices among cost-efficient farmers. *Env.Modeling & Assessment*. **18**(5): 523-532.

BRRI (Bangladesh Rice Research Institute). (2020) Adhunik Dhaner Chash. Joydevpur, Dhaka-1701. p. 1.

Chibu, H. and Shibayama, H. (2001). Effects of chitosan applications on the growth of several crops, in: T. Uragami, K. Kurita, T. Fukamizo (Eds.), chitin and chitosan in Life Science, Yamaguchi. pp. 235-239.

Chibu, H., Shibayama, H. and Arima, S. (2002). Effects of chitosan application on the shoot growth of rice and soybean. *Japanese J. of crop sci*. **71**(2): 206-211.

Dzung, N.A., Khanh, V.T.P. and Dzung, T.T. (2011). Research on impact of chitosan oligomers on biophysical characteristics, growth, development and drought resistance of coffee. *Carbohydr. Polym*. **84**: 751-755.

Ghoname, A.A., El-Nemr, M.A., Abdel-Mawgoud, A.M.R. and El-Tohamy, W. A. (2010). Enhancement of sweet pepper crop growth and production by application of biological, organic and nutritional Solutions. *Res. J. Agric. Biol. Sci*. **6**(3): 349-355.

Guan, Y., Hu, J., Wang, X. and Shao, C. (2009). Seed priming with chitosan improves maize germination and seedling growth in relation to physiological changes under low temperature stress. *J. Zhejiang Univ. Sci.* **10**(6): 427-433.

Harada, J., Arima, S., Shibayama, H. and Kabashima, R. (1995). Effect of chitosan application on growth and seed yield of soybean. Marine & Highland Bioscience Center Report **2:** 15- 19.

Hong, S. P., Kim, J. T., Kim, S. S. and Hwang, J. K. (1998). Effect of chitosan on the yield enhancement and quality of indica rice. *J. chitin chitosan*. **3**: 176-183.

Hoque, M. (2002). Effect of CI-IAA, GABA and TNL-3003 on growth, yield and yield contributing characters of wheat.MS Thesis, Dept. of Crop Botany, Bangladesh Agricultural University, Mymensingh.

Ibrahim, E.A. and Ramadan, W.A. (2015). Effect of zinc foliar spray alone and combined with humic acid or/and chitosan on growth, nutrient elements content and yield of dry bean (*Phaseolus vulgaris* L.) plants sown at different dates. *Sci. Hortic*. **184**: 101-105.

Islam, M.M. (2007). Effect of foliar application of GABA and Myobi on growth and yield in wheat. MS Thesis, Dep. Crop Bot., Bangladesh Agric. Univ., Mymensingh.

Issak, M. and Sultana, A. (2017). Role of chitosan powder on the production of quality rice seedlings of BRRI dhan29. *Res. Agric. Livest. Fish.* **4**(3): 141-149.

Jiang, P. (2010). Summaries of Country Reports on Radiation Processing and Application of chitosan. Annex 4 and Part A. p. 1 (Workshop on application of electron accelerator radiation processing of natural polymer, 1-5 Mar, (2010); FNCA).

Kabir M.S., Salam M.U., Chowdhury A., Rahman N.M.F., Iftekharuddaula K.M., Rahman M.S., Rashid M.H., Dipti, S.S., Islam, A., Latif M.A., Islam A.K.M.S., Hossain, M.M., Nessa, B., Ansari, T.H., Ali, M.A. and Biswas, J.K. (2015). Rice Vision for Bangladesh: 2050 and Beyond. *Bangladesh Rice. J.* **19**: 1-18.

Kananont, N., Pichyangkura, R., Kositsup, B., Wiriyakitnateekul, W. and Chadchawan, S. (2015). Improving the rice performance by fermented chitin waste. *Intl. J. Agric. Biol*. **3**: 221-223.

Khush, G.S. (2013). Strategies for increasing the yield potential of cereals: case of rice as an example. *Plant Breeding*, **132**(5): 433-436.

Li, B., Liu, B., Shan, C., Ibrahim, M., Lou, Y., Wang, Y., Xie, G., LiH, Y. and SUN, G. (2013). Antibacterial activity of two chitosan solutions and their effect on rice bacterial leaf blight and leaf streak. *Pest. Man. Sci.* **34**(12): 2291-2298

Limpanavech P., Chaiyasuta S., Vongpromek R., Pichyangkura R., Khunwasi C., Chadchawan S., Lotrakul P., Bunjongrat R., Chaidee A. and Bangyeekhun T. (2008). Chitosan effects on floral production, gene expression, and anatomical changes in the Dendrobiumorchid. *Sci. Hortic.* **116**(1): 65-72.

Linden, J., Stoner, R., Knutson, K. and Hughes, G.C. (2000). Organic Disease Control Elicitors. Agro-Food Ind. Hi-Te. p. 12-15.

Lu, J., Zhang, C., Hou, G., Zhang, J., Wan, C., Shen, G., Zhang, J., Zhou, H., Zhu, Y. and Hou, T. (2002). The biological effects of chitosan on rice growth. *Acta Agric. Shanghai*. **18**(4): 31-34.

Ma, G.P., Yang, D.Z., Kennedy, J.F. and Nie, J. (2013). Synthesize and characterization oforganic-soluble acylated chitosan. *Carbohydr.Polym.* **75**(3): 390-4.

Mahamud, J.A., Haque, M.M. and Hasanuzzaman, M. (2013). Growth, dry matter production and yield performance of T aman rice varities influenced by seedling densities per hill. *Int. J. Sust. Agric.* **5**(1): 16-24.

Manjunatha, G., Roopa, K.S., Prashanth, G.N. and Shekar, H. (2008). Chitosan enhances disease resistance in pearl millet against downy mildew caused by *Sclerospora graminicola* and defence- related enzyme activation. *Pest Mngmt. Sci.* **64**(12): 1250-1257.

Mondal, M.M.A., Malek M.A., Puteh A.B., Ismail M.R., Ashrafuzzaman M., Naher L. (2012). Effect of foliar application of chitosan on growth and yield in okra. *Aust. J. Crop*. **6**: 918-921.

Nguyen, A.D., Phuong, K.V.T. and Dzung, T. T. (2013). Research on impact of chitosan oligomers on biophysical characteristics, growth, development and drought resistance of coffee. *J. Plant Physiol*, **84**(2): 751–755.

Nguyen, A.D., Phuong, K.V.T. and Dzung, T.T. (2011). Research on impact of chitosan oligomers on biophysical characteristics, growth, development and drought resistance of coffee. *J. Plant Physiol*. **84**(2): 751–755.

Ohta, K., Asao, T. and Hosokl, T. (2001). Effect of chitosan treatments on seedling growth,chitinase activity and flower quality in *Eustomagrandiflorum*(Raf) Shinn. KairyouWakamurasaki. *J. Hort. Sci. Biot.* **76**: 612-614.

Ouyang, S. and Langlai, X. (2003). Effect of chitosan on nutrient quality and some agronomic characteristic of non-heading chinese cabbage. *J. Plant Physiol.* **39**(1): 21-24.

Phothi, R. and Theerakarunwong, C.D. (2017).Effect of chitosan on physiology, photosynthesis and biomass of rice (*OryzasativaL.*) under elevated ozone. *Australian. J. C. S.* **11**(05): 624-630.

Priyaadharshini, M., Sritharan, N., Senthil, A. and Marimuthu, S. (2019). Physiological studies on effect of chitosan nanoemulsion in pearl millet under drought condition. *J. Pharmacog. Phytochemis.* **8**(3): 3304-3307.

Rahman, M.A. (2015). Performance of modified chitosan treated tomato (*Lycopersicon esculentum*) seedlings on the growth and yield of tomato. MS thesis, Dep. Soil Sci., SAU, Dhaka-1207.

Reddy, M.V.B., Angers, P., Castaigne, F. and Arul, J. (2000). Effect of growth regulators on yield and yield attributes in tomato *(Lycopersicon esculentum).Adv. Pl. Sci*. **10**(2): 29-3.

Rinaudo, M. (2006). Chitin and chitosan: properties and applications. *Progress in polymer sci.* **31**(7): 603-632.

Rodiguez, L. and Gao, X.H. (2002). Enzymic preparation of water-soluble chitosan and their defence mechanism activity in different crops. *Int. J. Biol. Macromol.* **31**: 111-117.

Sekh, M.H.R. (2002). Effect of C1-IAA, TNZ-303 and GABA on seed germination and seedling growth of different varieties of aman rice. MS Thesis, Dep. Crop Bot., Bangladesh Agric.Univ., Mymensingh, Bangladesh.

Singh, H.S., Kaushik, S.S., Chauhan, M.S. and Negi, R.S. (2019). Efficacy of different fungicides against rice blast caused by *Pyricularia oryzae* (Cav.) under field condition in satna district of madhya pradesh. *Intl. J. Cunrt. Micro. App. Sci.* **8**(06): 63–69.

Sultana, A., Munshi, M.H., Kamruzzaman, M., Bari, A.F. and Issak, M. (2020). Residual effect of raw material of chitosan powder on chemical properties of soil under rice-rice cropping system. *Research in Agri. Livestock Fisheries*, **7**(1): 33-42.

Sultana, S. (2010). Summaries of Country Reports on Radiation Processing and Application of Chitosan. Annex 4 and Part A. p. 1 (Workshop on application of electron accelerator-radiation processing of natural polymer, 1-5 Mar, (2010).

Sultana, S., Dafader, N.C., Khatun, F., Rahman M. and Alam, J. (2015). Foliar application of oligochitosan improves morphological character and yield in rice. *J. Nuclear Sci. app.* **24**: (1-2).

Supachitra, C., Nontalee, C. and Sittiruk, R. (2011). Chitosan effects on rice (*Oryza sativa* L.) seedling growth and protein expression. *J. Plant Physiol.* **6**(10): 21-27.

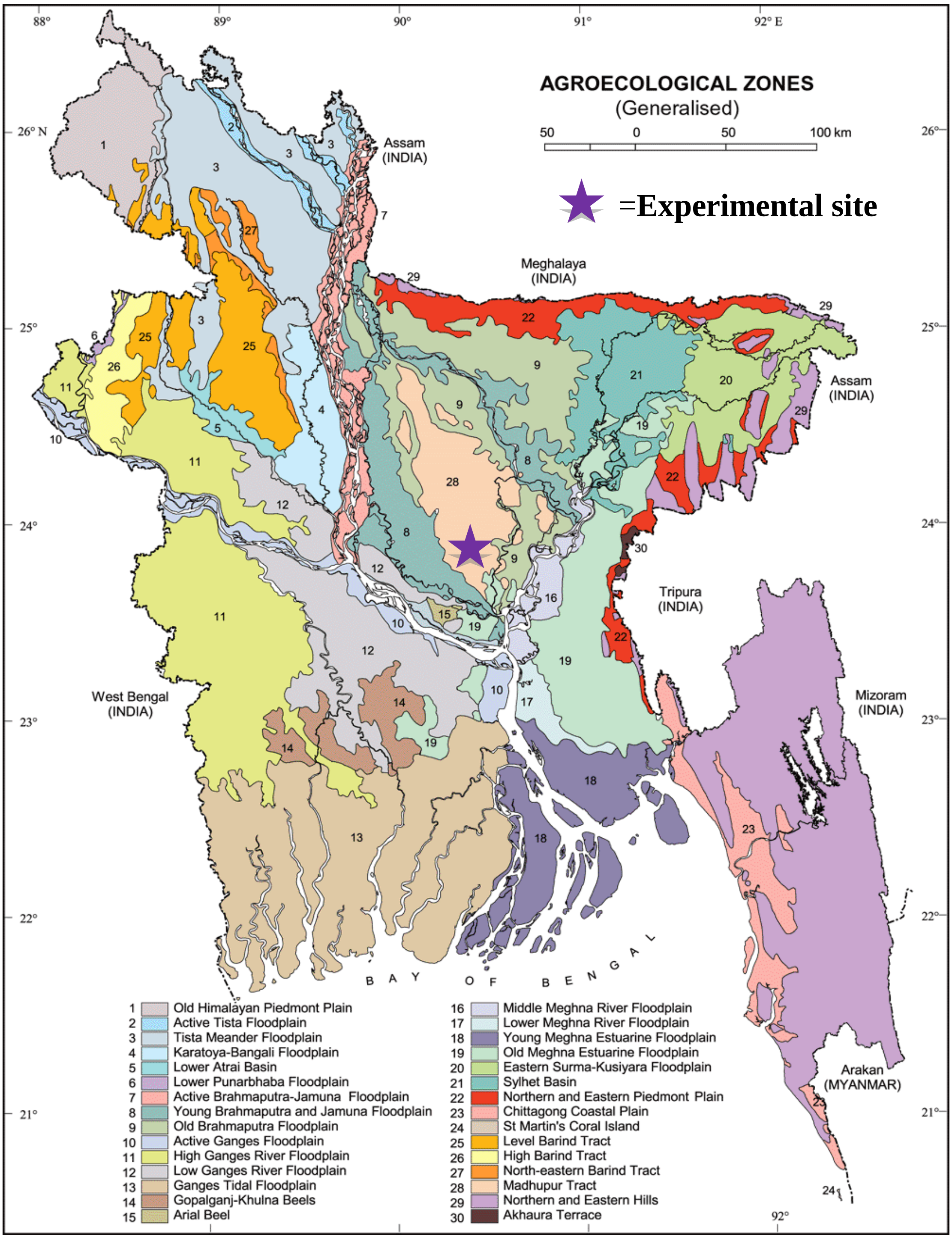
Tsugita, M.S., Bertram, R.E. and Ride, J.P. (1993) Chitin oligosaccharides elicit lignification in wounded Rice leaves.-Physiol. mol. Plant Pathol. **34**: 3-12.

Van, H.A., Van, I.J., Klunder, H., Mertens, E., Halloran, A.M.G. and Vantomme, P. (2013). Edible insects - Future prospects for food and feed security. FAO Forestry Paper 171.

Wang, W., Jian, L.U., Qing, Y., Xiao, K. and Hui, L. (2011). Effects of organic manure along with N, P, K fertilizer application on grain yield, quality, nutrient uptake and utilization of Rice. *Chinese J. of Rice Sci..* **25**(6): 645-653.

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 (%)	0.77
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

APPENDIX III: Layout of the experiment

T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6

T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	T_2	T_3	T_4	T_5	T_6
T_1	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

T_1 = 0% chitosan raw materials, T_2 = 0.1% chitosan raw materials, T_3 = 0.2% chitosan raw materials, T_4 = 0.3% chitosan raw materials, T_5 = 0.4% chitosan raw materials and T_6 = 0.5% chitosan raw materials.

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

Year	Month	Air temperature (^{0}C)		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)