IMPROVEMENT OF LATE SOWING BORO (BRRI dhan88) SEEDLING CHARACTERS AND YIELD BY USING CHITOSAN RAW MATERIAL POWDER

MD. MAMUN HOSSAIN

DEPARTMENT OF SOIL SCIENCE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

June, 2021

IMPROVEMENT OF LATE SOWING BORO (BRRI dhan88) SEEDLING CHARACTERS AND YIELD BY USING CHITOSAN RAW MATERIAL POWDER

BY

MD. MAMUN HOSSAIN

REGISTRATION NO: 14-06188

A Thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (M.S.)

IN

SOIL SCIENCE

SEMESTER: JANUARY- JUNE, 2021

Approved by:

……..……………………………………

Mst. Afrose Jahan
Professor
Department of Soil Science
Sher-e-Bangla Agricultural University
Supervisor

……..……………………………………..

Dr. Mohammad Issak
Professor
Department of Soil Science
Sher-e-Bangla Agricultural University
Co-supervisor

……..…………………………….

A. T. M. Shamsuddoha
Professor & Chairman
Department of Soil Science
Examination Committee
Sher-e-Bangla Agricultural University, Dhaka-1207

মৃত্তিকা বিজ্ঞান বিভাগ
শেরেবাংলা কৃষি বিশ্ববিদ্যালয়, ঢাকা।

মোছাঃ আফরোজ জাহান
অধ্যাপক
মৃত্তিকা বিজ্ঞান বিভাগ
শেরেবাংলা কৃষি বিশ্ববিদ্যালয়
শেরেবাংলা নগর, ঢাকা-১২০৭
Mobile: 01911232482
Email: jahansau@yahoo.com

CERTIFICATE

*This is to certify that thesis entitled, "**IMPROVEMENT OF LATE SOWING BORO (BRRI dhan88) SEEDLING CHARACTERS AND YIELD BY USING CHITOSAN RAW MATERIAL POWDER**" submitted to the Department of Soil science, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE (M.S.) in SOIL SCIENCE**, embodies the result of a piece of bona-fide research work carried out by **MD. MAMUN HOSSAIN**, **Registration no .14-06188** 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 duly been acknowledge

……………………………………………

Date: june,2021

Place: Dhaka, Bangladesh

Mst. Afrose Jahan
Professor
Department of Soil Science
Sher-e-Bangla Agricultural University
Supervisor

Dedicated To

My Beloved Parents

And Respected

Teachers

Whose Prayers,

Efforts And

Wishes Are an

Inspiration

ACKNOWLEDGEMENTS

All praises to the Almighty Allah, the great, the gracious, merciful and supreme ruler of the universe who enables me to complete this present piece of work for the degree of Master of Science (M.S.) in the Department of Soil Science.

The author would like to express his deepest sense of gratitude, respect to her research supervisor, ***Prof. Mst. Afrose Jahan****, Department of Soil Science, Sher- e-Bangla Agricultural University, for her kind and scholastic guidance, untiring effort, valuable suggestions, inspiration, extending generous help and encouragement during the research work and guidance in preparation of manuscript of this thesis.*

The author sincerely expresses his deepest respect and boundless gratitude to his co-supervisor ***Prof. Dr. Mohammad Issak,*** *Department of Soil Science, for his helpful suggestion and valuable advice during the preparation of this manuscript.*

It is highly appreciating words for ***Prof. A. T. M. Shamsuddoha,*** *Chairman, Department of Soil Science, Sher-e-Bangla Agricultural University, for the facilities provided, in carrying out this work. The author also acknowledges with deep regards the help and cooperation received from his respected teachers and stuff of the Department of Soil Science, Sher-e-Bangla Agricultural University while carrying out this work.*

The author feels proud to express his sincere appreciation and gratitude to Ministry of Science and Technology, The People's Republic of Bangladesh for awarding me National Science and Technology (NST) fellowship.

At last but not the least, the author feels indebtedness to his beloved parents and brother whose sacrifice, inspiration, encouragement and continuous blessing paved the way to his higher education and reach at this stage. May Allah bless us all.

The Author

IMPROVEMENT OF LATE SOWING BORO (BRRI dhan88) SEEDLING CHARACTERS AND YIELD BY USING CHITOSAN RAW MATERIAL POWDER

ABSTRACT

A pot experiment was conducted under the net house of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh, during November 2019 to April 2020, to investigate the improvement of late sowing *Boro* seedling characters and yield by using chitosan raw material powder in seedbed soil. The experiment was consisted of two factors and following Completely Randomized Block Design (RCBD) with four replications. Factor A: Level of chitosan raw material powder(w/w) (06) *viz;* C_0 = 0%, C_1 = 0.1%, C_2 = 0.2%, C_3 = 0.3%, C_4 = 0.4% and C_5 = 0.5% and Factor B: Different seedling age (3) *viz;* S_1 = 40 days old seedling, S_2 = 45 days old seedling and S_3 = 50 days old seedling. Experimental results revealed that among different levels of chitosan raw material powder, seedling treated with C_3 (0.3 %) treatment perform well and recorded the maximum average seedling height (17.75 cm), fresh weight seedling^{-1} (531.67 mg), oven dry weight seedling^{-1} (96.67 mg), seedling strength (5.44 mg/cm) , effective tillers pot^{-1} (28.33), minimum days for first flowering (66.92), minimum days for 100 % flowering (72.58), lowest unfilled grains weight pot^{-1} (1.42 g), maximum 1000 grains weight (21.93 g), maximum grain yield pot^{-1} (63.25 g), maximum straw yield pot^{-1} (63.08 g), maximum biological yield pot^{-1} (126. 34 g) and harvest index (49.84 %). In case of different seedling age, the maximum effective tillers pot^{-1} (22.96), minimum days for first flowering (65.88), minimum days for 100% flowering (71.58), unfilled grains weight pot^{-1} (1.35 g), maximum 1000 seeds weight (21.15 g), grain yield pot^{-1} (60.88 g), straw yield pot^{-1} (62.58 g), biological yield pot^{-1} (126.34 g) and harvest index (49.14 %) were obtained in S_1 (40 days old seedling) treatment. In case of combined effect, recorded the maximum 1000 seeds weight (23.08 g), grain yield pot^{-1} (68.92 g), straw yield pot^{-1} (66.75 g) and biological yield pot^{-1} (135.67 g) were obtained in C_3S_1 treatment combination. Chitosan raw material powder strongly improved the seedling characters at low temperature conditions, yield and yield attributing characters of BRRI dhan88. Thus for cultivation of BRRI dhan88, it is suggested that optimum level (0.3%) of chitosan raw material powder could be applied in the seedbed soil along with transplanting young (40 days old) seedling perform well for obtaining higher grain yield.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

LIST OF FIGURES (Cont'd)

LIST OF APPENDICES

LIST OF PLATES

ABBREVIATIONS

Full form	Abbreviations	Full form	Abbreviations
Agriculture	Agric.	Liter	L
Agro-Ecological Zone	AEZ	Milliliter	mL
And others	et al.	Mill equivalents	Meqs
Applied	App.	Triple super phosphate	TSP
Asian Journal of Biotechnology and Genetic Engineering	AJBGE	Milligram(s)	Mg
Bangladesh Agricultural Research Institute	BARI	Millimeter	Mm
Bangladesh Bureau of Statistics	BBS	Mean sea level	MSL
Biology	Biol.	Metric ton	MT
Biotechnology	Biotech.	North	N
Botany	Bot.	Nutrition	Nutr.
Centimeter	Cm	Regulation	Regul.
Cultivar	Cv.	Research and Resource	Res.
Degree Celsius	°C	Review	Rev.
Department	Dept.	Science	Sci.
Development	Dev.	Society	Soc.
Dry Flowables	DF	Soil plant analysis development	SPAD
East	E	Soil Resource Development Institute	SRDI
Editors	Eds.	Technology	Technol.
Emulsifiable concentrate	EC	Tropical	Trop.
Entomology	Entomol.	Thailand	Thai.
Environments	Environ.	United Kingdom	U.K.
Food and Agriculture Organization	FAO	University	Univ.
Gram	G	United States of America	USA
Horticulture	Hort.	Wet table powder	WP
International	Intl.	Serial	Sl.
Journal	J.	Percentage	%
Kilogram	Kg	Number	No.
Least Significant Difference	LSD	Microgram	μ

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food crop and a primary food source for more than one-third of world's population (Sarkar *et al.,* 2017). Worldwide, rice provides 27% of dietary energy supply and 20% dietary protein (Kueneman, 2006). It constitutes 95% of the cereal consumed and supplies more than 80% of the calories and about 50% of the protein in the diet of the general people of Bangladesh (Yusuf, 1997). World's rice demand is projected to increase by 25% from 2001 to 2025 to keep pace with population growth (Maclean *et al.,* 2002), and therefore, meeting this ever increasing rice demand in a sustainable way with shrinking natural resources is a great challenge. In Bangladesh, majority of food grains comes from rice. Rice has tremendous influence on agrarian economy of the country. 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 planting 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).

There are three distinct growing seasons of rice in Bangladesh, according to changes in seasonal conditions such as *Aus, Aman* and *Boro*. More than half of the total production (55.50 %) is obtained in *Boro* season occurring in December–May, second largest production in *Aman* season (37.90 %) occurring in July-November and little contribution from *Aus* season (6.60 %) occurring in April-June (APCAS, 2016).

Among three growing seasons (Aus, Aman and Boro), *Boro* rice is the most important rice crops for Bangladesh with respect to its high yield and contribution to rice production. *Boro* cultivation area has declined to 4.75 million hectares in 2020, which was 4.9 million hectares in 2019. The country produced an all-time-high 20.03 million tons of *Boro* rice in 2019. The government expects to achieve 20.04 million tons of *Boro* production target, although acreage of this major crop fell to a three-year low in 2010 which was due to reason that many farmers, upset with low paddy and rice prices, switched to other crops like corn, vegetables and tobacco etc. (Express, 2021).

Recently, food security especially attaining self-sufficiency in rice production is a burning issue in Bangladesh. The average yield of rice is almost less than 50% of the world average rice grain yield. The national mean yield (2.60 t ha^{-1}) of rice in Bangladesh is lower than the potential national yield (5.40 t ha^{-1}) and world average yield (3.70 t ha^{-1}) (Pingali*et al.*, 1997). The lower yield of transplanted *Boro* rice has been attributed to several reasons. In such condition, increasing rice production can play a vital role. Therefore, attempts must be made to increase the yield per unit area by adopting modern rice cultivars, nutrient management practices and applying improved technology such age of seedling etc. (Rinaudo, 2006).

Chitosan is a natural polymer and one of the chitin derivatives when the degree of deacetylation of chitin reaches about 50% (Rinaudo, 2006). Chitosan is obtained after deacetylation of chitin in which its chemical structure composed of a linear polymer consisting of two subunits, D-glucosamine and N-Acetyl-D-glucosamine linked together by glycosidic bond (Hidangmayum *et al*., 2019).

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*).* The cationic nature of chitosan is somewhat unique because most of the polysaccharides are usually either neutral or negatively charged in an acidic condition. The unique property allows it to generate electrostatic complexes with other negatively charged synthetic or natural polymers (Rinaudo, 2006). Chitosan has been, therefore, investigated and developed as a plant bio-stimulant (Katiyar *et al*., 2015; Hidangmayum *et al*., 2019). In plants, chitosan elicits numerous defense 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). Previous studies revealed that chitosan has a potential to enhance plant growth as well as increase yield in many crops including apple, wheat, maize and rice (Yang *et al*., 2009; Lizárraga-Paulín *et al*., 2011; Zeng and Luo, 2012; Seang-Ngam *et al*., 2014). In agriculture, Chitosan is used primarily as a natural seed treatment and plant growth enhancer and as an ecologically friendly bio-pesticide substance that boosts the innate ability of plants to defend themselves against fungal infections and increasing grain yield (Linden *et al*., 2000).

Grain formation is the result of interaction of genetic, environmental and cultural management practices (Dhillon *et al*., 2018). Among the cultural factor, the seedling age at the time of transplanting is the most important factor deciding uniform stand, growth and yield of rice (Faghani *et al*., 2011). When seedlings stay for an extended period of time in the beds of nursery, primary tiller buds on the lower nodes of main culm become degenerated leading to reduced tillering potential (Mobasser, *et al*., 2007). It is reported that tillering potential in rice plant mainly depends on the age of seedling at transplanting (Ali *et al*., 2013 and Pasuquin *et al*., 2008). Transplanting older nursery seedlings besides reducing tiller production also results in early panicle initiation, uneven flowering, shortening vegetative phase and thereby reducing number of grains per panicle ((Jia *et al*., 2014). Pre-anthesis dry matter accumulation determines the sink capacity and final grain yield. Katsura *et al.* (2007) reported that lesser supply of photosynthetic assimilates from source to sink in the older seedlings due to reduced sink capacity. Seedling age at staggered transplanting is an important factor due to its tremendous influence on plant height, tiller production, panicle length, grains panicle^{-1} and other yield contributing characters (Islam and Ahmed, 1981).

By considering the above fact, the proposed research work was undertaken to achieve the following objectives:

Objectives:

i. To improve late sowing Boro seedling characters by using chitosan raw material powder in seedbed.
ii. To examine late sowing effects of chitosan raw material powder treated Boro seedlings on grain yield.

CHAPTER II

REVIEW OF LITERATURE

An attempt was made in this section to collect and study relevant information available regarding to impact of late planting with chitosan raw material powder treated seedlings on yield performance of BRRI dhan88, to gather knowledge helpful in conducting the present piece of work.

2.1Effect of chitosan

Seedling height

Ahmed *et al*. (2020) reported that seedling height was increased with the application of chitosan-raw-materials in the seedbed.

Issak and Sultana (2017) carried out an experiment to observed the role of chitosan powder on the production of quality rice seedlings of BRRI dhan29 and found that Boro rice seedlings production were improved by using the chitosan powder in the seedbed.

Ziani *et al.* (2010) reported that seeds treated with chitosan resulted in a better growth of the seedlings (e.g. longer and better developed radicle and greener hypocotyls) and lower chance of being infected by fungi in comparison with the untreated seeds. The observed growth improvement by chitosan could be also related to the incorporation of nutrients (nitrogen) from chitosan.

Boonlertnirun *et al.* (2008) conducted an experiment to investigate the effect of chitosan application in rice production and reported that, chitosan is an actual biopolymer which stimulates growth and increases yield of plants as well as induces the immune system of plants.

Ouyang and Langlai (2003) who studied the Chinese cabbage (*Brassica campestris*) cv. Dwarf hybrid No. 1, found that seed dressing with 0.4-0.6 mgg^{-1} seed and leaf spraying 20-40 micro gml^{-1} increased plant height and leaf area of Chinese cabbage.

Khan *et al.* (2002) reported that foliar application of oligomeric chitosan did not affect plant height of soybean.

Tsugita *et al.* (1993) carried out a study on Chitin oligosaccharides elicit lignification in wounded Rice leaves and found that chitosan promotes shoot and root growth.

Bolto *et al.* (2004) carried out and experiment on Ion exchange for the removal of natural organic matter and found that CHT (chitosan) can increase the microbial population and transforms organic nutrient into inorganic nutrient which is easily absorbed by the plant roots.

Seedling fresh weight

Ahmed *et al*. (2020) reported that seedling fresh weight was increased with the application of chitosan-raw-materials in the seedbed.

Issak and Sultana (2017) carried out an experiment to observed the role of chitosan powder on the production of quality rice seedlings of BRRI dhan29 was in the field of Sher-e-Bangla Agricultural University, Dhaka and found that 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 and the lowest fresh weight production (12.6 g) was found in the treatment T_6 (control) which was significantly different from all other treatments. These results indicate that fresh weight productions of BRRI dhan29 rice seedlings were influenced by the chitosan powder treatments and this might be due its supplementation of plant nutrients and growth regulators.

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

Saravanan *et al*. (1987) carried out an experiment to know the effect of combined application of bio-organic and chemical fertilizers on physical properties, nitrogen transformation and yield of rice in submerged soils and found that the organic manures viz. sludge and spray of CHT increases the efficiency of applied N.

Seedling dry weight

Ahmed *et al*. (2020) reported that seedling oven dry weight was increased with the application of chitosan-raw-materials in the seedbed.

Issak and Sultana (2017) reported that oven dry weight productions of BRRI dhan29 rice seedlings were influenced by the chitosan powder applications and this might be due its nutritional support to the seedlings, improvement of growth promoting hormonal activity and could improve the biological as well as physio-chemical properties of the seedbed soils.

Boonlertnirun *et al.* (2008) conducted an experiment to investigate the effect of chitosan application in rice production and found that application of chitosan stimulates the seedling dry matter weight significantly.

Martinez et *al.* (2007) carried out an experiment to study the Influence of seed treatment with chitosan on tomato (*Lycopersicum esculentum* L.) plant growth and reported that in general, the best response was obtained when seeds were treated with 1 mgL^{-1} chitosan during four hours, as this concentration stimulated significantly plant dry weight, although the other indicators were not modified.

Seedling strength

Ahmed *et al*. (2020) reported that seedling strength was increased with the application of chitosan-raw-materials in the seedbed.

Issak, M. and Sultana, A. (2017) carried out an experiment to observed the role of chitosan powder on the production of quality rice seedlings of BRRI dhan29 and reported that application of different level of chitosan influenced the seedling strength of rice plant and maximum seedling strength (5.79 mg/cm) was obtained in the T_5 treatment having CHT powder @ 500 g/m^2 whereas the minimum seedling strength (10.80 mg/cm) was obtained in the T_6 treatment (control).

Boonlertnirun *et al.* (2008) found that application of chitosan stimulates the seedling strength significantly.

Tillers hill^{-1}

Ahmed *et al.* (2013) carried out an experiment at the field laboratory, Department of Crop Botany, Bangladesh Agricultural University, Mymensingh during the period from November 2011 to April 2012 to investigate the effect of Chitosan on growth, yield contributing characters and yield of BRRI dhan29 and reported that the foliar application of Chitosan had significant effect on the production of tillers hill^{-1}in rice. The result revealed that Chitosan treated plants produced the higher number of tillers compare to control. The maximum number of tillers hill^{-1} (9.33, 13.67 and 16.67) was observed in 50 mg L^{-1} followed by 75 mg L^{-1}Chitosan (8.33, 12.33 and 15.33) at 30, 60 and 90 DAT, respectively. In contrast, the minimum number of tillers $hill^{-1}$ (7.33, 10.33 and 13.33, respectively) was found in control.

Effective tiller $hill^{-1}$

Ahmed *et al*. (2020) conducted a field experiment at the research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, to examine the effect of chitosan-raw-materials on yield maximization of BRRI dhan49. The chitosan-raw-materials were applied in different doses and methods (Seedbed and main field applied methods). 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. Experiment result revealed that, different level of chitosan significantly effects on effective tillers $hill^{-1}$ and the highest number of effective tiller $hill^{-1}$ (14) was obtained in the T_3 whereas the lowest number of effective tillers $hill^{-1}$ (11.67) was obtained in the T_1 (control) treatment. It was observed that the chitosan-raw-materials application in soil the increases the effective tillers $hill^{-1}$.

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

1000 grains weight

Behboudi *et al.* (2018) observed the maximum 1000-grain weight with the foliar treatment of chitosan in the well-watered plant also they noticed that the chitosan application in soil considerably improved the 1000-grain weight in plants under water stress than that of control**.**

Yadav and Christopher (2006) carried out an experiment to study the effect of organic manures and panchagavya spray yield attributes, yield and economics of rice (*Oryza sativa* L.) and reported that chitosan spray recorded the maximum 1000 seed weight (16.55 g) as compared to without chitosan spray (15.59 g) respectively.

Krivtsov *et al*. (1996) found that thousand-grain weight and spike weight of wheat plants increased in treatment with low concentrations of polymeric chitosan.

Grain yield

Behboudi *et al.* (2018) reported that chitosan uses significantly improved the number of grain per spike and grain yield as compared to that in control

Ahmed *et al.* (2013) carried out a study to investigate the effect of chitosan on growth and yield of rice cv. BRRI dhan29 observed significant effect of Chitosan on grain yield of rice. The result revealed that 50 mg L^{-1} of Chitosan treated plants produced the highest grain yield (7.05 t ha^{-1}) followed by 75 mg L^{-1} (6.77 t ha^{-1}) and 100 mg L^{-1} (6.14 t ha^{-1}) of Chitosan where 75 and 100 mg L^{-1} Chitosan were statistically same. On the other hand, the lowest grain yield (5.83 t ha^{-1}) was observed at control treatment.

Nguyen and Tran (2013) carried out an experiment to know the effect of application of chitosan solutions for rice production in Vietnam and reported that, the chitosan produced from shrimp shells using dilute acetic acid proved effective in controlling plants infection by microbial agents leading to higher yields. The field study 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) reported that application of chitosan at 2 mgL^{-1} improved yield components (number and weight) of strawberry chitosan application had a tendency to increase grain yield of rice plants over than unapplied seed.

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

Krivtsov *et al.* (1996) which revealed that wheat plants treated with polymeric or oligomeric chitosan increased spike weight and grain yield.

Straw yield

Sultana *et al.* (2015) conducted a field experiment to investigate the impact of foliar application of oligo chitosan improves morphological character and yield in rice. The experiment was done with randomized complete block with four replications. BINA Dhan-14 seeds were soaked with 100 ppm o-chitosan for 24 hours whereas the control seeds were soaked in distilled water. 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. Experiment result revealed that straw yield shows significant differences between control plants and foliar sprayed chitosan plants and highest straw yield (4.38 t/ha) was recorded under 100 ppm oligomeric chitosan and lowest straw yield (3.24 t/ha) was observed under 0 ppm oligomeric chitosan.

Kananont *et al.* (2015) carried out an experiment to improving the rice performance by fermented chitin West with Fermented chitin waste (FCW). The experiment consisted with three levels of FCW (Fermented chitin waste) @ (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 experiment results revealed that FCW @ 1% the straw yield differ significantly from 0.5% FCW, 0.25% FCW and the rest of the treatment.

Biological yield

Ahmed (2015) carried out an experiment to know the Performance of BRRI dhan49 as influenced by modified chitosan in the seedbed and in the main field and found that chitosan application showed non-significant effect to biological yield, but slightly influenced biological yield comparable to control treatment.

Harvest index

Chibu *et al.* (2000) carried out a study to observed the effects of chitosan application on growth and chitinase activity in several crops and reported that in Soybean harvest index was significant in chitosan application plants compare to control.

2.2 Effect of age of seedling

Seedling height

Krishna (2006) from Dharwad reported that 12 days old seedling performed better than 8, 16 and 25 days old seedlings in terms of yield and yield attributes, B: C ratio, seed quality along with shoot length, root length, seedling dry weight and vigor index.

Gani *et al.* (2002) reported that young seedlings (7 or 14 days old) performed better than 21 days old seedlings. The plants of young seedlings were taller and they produced longer and heavier roots, more number of effective tillers and biomass.

Tillers hill^{-1}

Krishna *et al.* (2009) conducted an experiment in Karnataka and revealed that the 12 days old seedling produced more number of tillers hill^{-1} at harvest. The 8 days old seedling flowered and matured about four to five days early compared to 5 days old seedlings. The treatment combination of 12 days old seedling with wider spacing recorded maximum seed yield per hectare. Significantly higher seed yield (3.27 t ha^{-1}) and less spikelet sterility (16.72 per cent) recorded by 12 days old seedlings.

Sridevi and Chellamuthu (2007) observed that the combination of single and young seedling per hill with square planting and cone-weeding gave highest tiller m^{-2} and grain yield than the normal seedling or multiple seedling with rectangular planting and hand weeding.

Uphoff (2002) also stated that transplanting of very young seedlings usually 8-10 days old and not more than 15 days will have better tillering and rooting and it was reduced if transplanting was done after the 4th phyllochron usually about 15 days after emergence.

Effective tiller hill^{-1}

Sultana *et al.* (2020) conducted a field experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensinghfrom July 2016 to December 2016 to find out the effect of seedlings age and different nitrogen (N) levels on the yield performance of transplant Aman rice (cv. Binadhan-15). The experiment comprised four ages of seedlings viz., 15, 20, 25, 30 days old and four levels of nitrogen viz., 0 , 55, 75 and 95 kg N ha^{-1}following randomized complete block design (RCBD) with three replications. The effect of age of seedling, nitrogen levels and their interactions were significant on growth, yield and yield contributing characters of transplant Aman rice. By using optimum seedling age at 15 DAT recorded the highest number of effective tillers plant^{-1}(8.29) at harvest respectively.

Ali *et al.* (2013) reported more effective tillers hill^{-1} (24.9) when seedlings of 15 days' age were transplanted while 30 days old seedlings gave minimum number of effective tillers (15.6).

Kavitha and Ganesh raja (2012) reported from Madurai that 14 days old seedling recorded significantly higher number of productive tillers (m^{-2}) over 18 and 22 days old seedlings under SRI.

Faghani *et al.* (2011) found the significant effect of seedlings age on tillering pattern, and concluded that the maximum tillers $hill^{-1}$ (16.3) were recorded by transplanting 25 days old seedlings while 35 days' seedlings gave minimum tillers $hill^{-1}$ (15.3).

Oteng and Anna (2003) from Ghana (South Africa) observed that 10-15 day sold seedlings produced more number of effective tillers than those of 15-20 days and 20-25 days old seedlings under SRI practices.

1000 seed weight

Pramanik and Bera (2013) carried out a study to observed the Effect of seedling age and nitrogen fertilizer on growth, chlorophyll content, yield and economics of hybrid rice (*Oryza sativa* L.) and noticed that maximum 1000 grains weight 23.62 g was obtained from the transplanting of 10 days old seedling.

Dahal and Khadka (2012) worked out of four aged of seedling group's viz.,8, 15, 22 and 29-days under SRI in Nepal. The results showed that 8-day-old seedlings produced significantly higher 1000-seed weight (21.10 g).

Sarwa *et al.* (2011) conducted a study to investigate the impact of nursery seeding density, nitrogen, and seedling age on yield and yield attributes of fine rice and reported that younger seedlings of 10 days and 20 days old registered comparable higher 1000 grains weight of 21.43 g and 18.78 g respectively and its significantly superior over 30 (15.54 g) and 40days (14.8 g) old seedlings.

Tari *et al.* (2007) stated that appropriate time of transplanting resulted in higher 1000 grain weight.

Singh and Singh (1998) revealed that yield attributes viz 1000-grain weight significantly increased with transplanting of younger seedlings as compared to older seedlings.

Grain yield

Virk *et al*. (2020) carried out an experiment to identify the suitable seedling age of fine rice cultivars in transplanted rice systems under AWD. Four seedling age treatments (20, 25, 30, and 35 days), and three fine rice cultivars (Chenab, Punjab, Kissan basmati) were arranged under randomized complete block design (RCBD). Two years (2017–2018) of studies demonstrated that overall younger seedlings (20 days old) increased rice growth phase (days taken to reach physiological maturity) after transplantation with less mortality rate, and quantified with higher water productivity. Younger seedlings (20 days old) produced 14.69% and 13.36% longer panicle, 19.36% and 18% more filled grains panicle^{-1}in both years (2017 and 2018) respectively as compared to the older seedlings (35 days old). Moreover, younger seedling (20 days) produced 22% and 22.92% kg ha^{-1} more yield in comparison to (35 days) older seedling in both years, respectively.

Reuben *et al.* (2016), the study treatments adopted were three representing 8, 12 and 15 days old seedlings. The rice variety tested was TXD306 Super SARO, which was recommended by the ministry of Agriculture in Tanzania (United Kingdom). The yield for the three treatments was also investigated at the end of the season. No significant, differences were observed in rice yield in all the three treatments though 12 days has a slight higher yield compared to other rice ages. The rice yield was 8.4, 8.5 and 8.1 tones ha^{-1} for 8, 12 and 15 days old transplanted seedlings respectively.

Patra and Haque (2011) reported from West Bengal, that the highest effective tillers hill^{-1} (29.73), panicle length (28.13 cm), panicle weight (2.30 g), 1000-grain weight (21.18 g), grains panicle^{-1} (170.51), grains panicle^{-1} (123.30) resulted in higher grain yield (7.11 t ha^{-1}) with seedling of 10 days' age old under SRI due to lower sterility of grains (27.68 per cent). Transplantation of 10-day old seedling gave 18.66 per cent and 24.99 per cent more grain yield than 18 and 6 days old seedlings, respectively and also seen that for every day 'delay in transplanting beyond the age of 10 days caused reduction in grain yield to the extent of 4.5 per cent ha^{-1}year^{-1}.

Krishna *et al.* (2009) conducted an experiment in Karnataka and revealed that the treatment combination of 12 days old seedling with wider spacing recorded maximum seed yield per hectare. Significantly higher seed yield (3.27 t ha^{-1}) and less spikelet sterility (16.72 per cent) recorded by 12 days old seedlings.

Menete *et al*. (2008) reported that higher older seedling resulted in lesser grain yield *i.e*.9.3, 8.6 and 7.8 t ha^{-1}as against 10, 20 and 30 days old seedlings, respectively.

In Bhutan, L hendup (2006) recorded maximum grain yield and other parameters with seedlings of 3-leaf stage with 30 cm x 30 cm spacing.

Porpavi *et al.* (2006) tested four rice varieties viz., ADT36, ADT43, ADT45 and ADT47 with using 14 and 25 days old seedlings under SRI. The performance of ADT43 and ADT47 with 14 days seedling under SRI found better than 25 days aged seedling. The crop duration reduced by 5 to 6 days under system of rice intensification with 14 days old seedlings as well.

Basu *et al.* (2003) opined that transplanting of 21-day old seedlings gave identical grain yield with direct sown crop and matured 8-10 days earlier.

Wlalo and Kunicki (2003) suggested that use of young transplants resulted in higher yield and better quality.

Hussain *et al.* (2003) obtained 7.7 t ha^{-1} grain yield with SRI (15 days old seedling) while it was 5.4 t ha^{-1} in conventional practice with 36 days old seedling.

Diechar *et al.* (2002) in Cambodia reported that 8-12 days old seedlings performed better and had significantly higher yield potential then those of 15-20 days and 20-25 days old seedlings under SRI.

Randriamiharisoa and Up off (2002) reported the results of factorial trials evaluating four system of rice intensification practices (SRI). SRI practices evaluated were young seedlings (8, 12, 16 and 20 days old), water management (aerated soils and saturated soil), plant density (1 and 3 seedlings $hill^{-1}$) and fertilization (compost v/s NPK @ 16-11-22 v/son fertilizer). They reported that SRI practices were having advantageous effects individually as well as combined. In fact, these trials showed a high degree of synergy among practices. However, the ‘young seedlings ‘was found tobe the most important practice in these trials, none could be discarded without some loss. With growing conditions controlled, using all SRI practices, young seedlings, one seedling $hill^{-1}$, aerated soil, and added compost gave yield increase of 140 to 245 per cent, compared to plot where only non-SRI practices -more mature seedlings, three seedling $hill^{-1}$, and saturated soil with NPK fertilizer used.

Thiyagarajan *et al.* (2002) reported that the modified system of rice intensification practices, 14 days old seedling should be transplanted in puddled field with the square planting of 25 × 25 cm, which had significant effect on grain yield of about 5059 kg/ha to 7612 kg ha^{-1}.

Straw yield

Panigrahi*et al.* (2014) conducted a field experiment during the kharif season of 2007 and 2008 at OUAT, Bhubaneswar on basmati rice varieties under system of rice intensification (SRI) that observed growth, yield and economics of basmati rice did not vary much between the crops planted with 10 and 15-day old seedlings.

Bagheri *et al.* (2011) noticed that the highest (635.8 g m^{-2}) straw yield was obtained from 20 days old seedlings over 30 and 40 days.

Rajesh and Thanunathan (2003) reported that the seedling age had significant difference on straw yield. Planting of 40 day old seedlings found to be optimum to get significantly higher (5.63 t ha^{-1}) straw yield compared to 30 (5.09 t ha^{-1}) and 50 (4.76 t ha^{-1}) days old seedlings.

Sharma and Ghosh (1998) stated that younger seedlings produced significantly higher straw (7.53 t ha^{-1}) yields as compared to older seedlings from their studies on hybrids rice.

Biological yield

Chakrabortty (2013) conducted a field experiment at the Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from December 2011 to May 2012 to study the growth and yield of Boro rice as affected by seedling age and planting geometry under System of Rice Intensification (SRI) and reported that seedling age varied biological yield of Boro rice and the maximum biological yield (9.84 t ha^{-1}) was recorded in 16 days old seedling and the minimum biological yield (8.73 t ha^{-1}) was found in 30 days old seedling.

Chandrapala *et al.* (2010) a field experiment conducted during the kharif season of 2007 and 2008 on sandy clay loam soil-having pH 7.65 at Hyderabad. That observed that the transplanting of 12-day old seedling of rice (cv. Rassi) under SRI at as pacing of 25×25 cm, was recorded significantly higher biological yield over 25 days seedling under conventional transplanting at 20×15 cm and direct sowing of sprouted rice under un-puddled condition.

Harvest index

Islam *et al.* (2021) carried out an experiment in the Agriculture Field Laboratory, Noakhali Science and Technology University (NSTU) to evaluate the effects of age of seedlings on the yield and growth performance of transplanted Aus. (T. Aus) rice variety from April 2019 to July 2019 and observed that the age of seedlings had significantly affected total tillers hill^{-1}, effective tillers hill^{-1}, panicle length in T. *Aus* rice variety. The highest harvest index (33.88%) was obtained from 22 days old seedlings. The lowest harvest index (30.467%) was obtained from 30 days old seedlings.

Sarkar *et al*. (2011) reported that the highest harvest index was obtained from 25 days old seedlings, while the lowest was found with 35 days old seedlings.

Pramanik and Bera (2013) reported that maximum harvest index of 45.19 and 47.00 was noticed from 10 days and 15 days old seedlings.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to investigate the improvement of late sowing *Boro* seedling characters by using chitosan raw material powder and their yield performance at different seedling age. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental period

The experiment was conducted during the period from November-2019 to April 2020 in *Boro* season.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted in the Agronomy field of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level (Anon., 2004).

3.2.2 Agro-Ecological Zone

The experimental site belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28 (Anon., 1988 a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1988 b). For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.2.3 Soil

The soil of the experimental field belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Soil pH ranges from 5.4–5.8(Anon., 1989). The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0–15 cm depths were collected from the

Sher-e-Bangla Agricultural University (SAU) Farm, field. The soil analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The morphological and physicochemical properties of the soil are presented in below table.

Table 1. Morphological characteristics of the experimental area

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University soil research field, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

Table 2. The initial physical and chemical characteristics of soil used in this experiment

Physical characteristics	
Constituents	Percent (%)
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Soil characteristics	Value
pH	5.8
Organic carbon (%)	0.5
Organic matter (%)	0.87
Total nitrogen (%)	0.04
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10

3.2.4 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Meteorological data related to the temperature, relative humidity and rainfall during the experiment period was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix-III.

3.3 Experimental materials

BRRI dhan88 and different level of chitosan raw material powder were used as experimental materials for this experiment. The important characteristics of these are mentioned below:

BRRI dhan88

Rice (*Oryza sativa*) variety BRRI dhan88 was used as planting material. BRRI developed this variety and released in 2018. It is the most popular & high yielding *Boro* variety suitable for planted at 15th Dec-30th December. This variety attains a height of 100 cm. The life cycle of this variety is 140-143 days. Grain yield is around 7 t ha^{-1} and 1000 grain weight is 20-22 g. The seeds of this variety were collected from Bangladesh Rice Research Institute (BRRI), Gazipur. Seeds contain 76% carbohydrate, 26.3% amylose and 9.8% protein.

3.4 Chitosan raw materials

The composition of chitosan raw material powder is given below

Table 3: Composition of the chitosan raw material powder which was used in the research work.

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

3.5 Seed collection and sprouting

BRRI dhan88 was collected from BRRI (Bangladesh Rice Research Institute), Joydebpur, Gazipur. Healthy and disease free seeds were selected, following standard technique. Seeds were immersed in water in a bucket for 24 hrs. These were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hrs. which were suitable for sowing in 72 hrs.

3.6 Experimental treatment

There were two factors in the experiment namely Chitosan raw material powder level and different age of seedling as mentioned below:

Factor A: Level of Chitosan raw material powder(w/w) (6) *viz;*

C_0= 0%

C_1= 0.1%

C_2= 0.2%

C_3= 0.3%

C_4= 0.4%

C_5= 0.5%

Factor B: Seedling age (3) *viz;*

S_1= 40 days old seedling,

S_2= 45 days old seedling and

S_3= 50 days old seedling.

3.7 Sowing and transplanting time

Generally, farmers prepared the seedbed and sows their seed in the seedbed during the month of October to November and transplant seedling in the main filed at the month of November to December. But in this experiment late sowing was done at 9 December 2019 and transplanting at 18, 23 and 28 January to observed the yield variations between optimum time and the late sowing chitosan raw material powder treated seedling.

3.8 Seed pot preparation and application of chitosan raw material powder

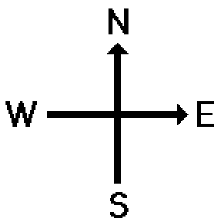
2-inch plastic pots were used for raising seedling. Field moist soil was collected from Sher-e-Bangla Agricultural University farm then mixed with different level of Chitosan raw material powder according with par treatment requirement. Then the pot was filled with 1 kg chitosan raw material treated soil. After that 100 seeds were sown in the pot for raising seedlings.

3.9 Experimental design

The experiment was laid out in Completely Randomized design (CRD) with 2 factor and four replications. Total 72 unit pots will be made for the experiment with 6 treatments. Each pot will be of required size. The layout of the experiment is given below

R_1	R_2	R_3	R_4
C_0S_1	C_5S_3	C_5S_3	C_4S_1
C_0S_2	C_5S_2	C_5S_2	C_4S_2
C_0S_3	C_5S_1	C_5S_1	C_4S_3
C_1S_1	C_4S_3	C_4S_3	C_5S_1
C_1S_2	C_4S_2	C_4S_2	C_5S_2
C_1S_3	C_4S_1	C_4S_1	C_5S_3
C_2S_1	C_3S_3	C_3S_3	C_0S_1
C_2S_2	C_3S_2	C_3S_2	C_0S_2
C_2S_3	C_3S_1	C_3S_1	C_0S_3
C_3S_1	C_0S_1	C_2S_3	C_1S_1
C_3S_2	C_0S_2	C_2S_2	C_1S_2
C_3S_3	C_0S_3	C_2S_1	C_1S_3
C_4S_1	C_1S_1	C_1S_3	C_3S_1
C_4S_2	C_1S_2	C_1S_2	C_3S_2
C_4S_3	C_1S_3	C_1S_1	C_3S_3
C_5S_1	C_2S_1	C_0S_1	C_2S_1
C_5S_2	C_2S_2	C_0S_2	C_2S_2
C_5S_3	C_2S_3	C_0S_3	C_2S_3

1m 1m 1m



LEGEND

Chitosan level *viz;*

C_0= 0% Chitosan,

C_1= 0.1% Chitosan,

C_2= 0.2% Chitosan,

C_3= 0.3%Chitosan,

C_4= 0.4% Chitosan and

C_5= 0.5% Chitosan

Different age of seedling *viz;*

S_1= 40 days old seedling,

S_2= 45 days old seedling and

S_3= 50 days old seedling.

Fig.1. Layout of the experiment

3.10 Detail of experimental preparation

3.10.1 Selection and preparation of the pot

Earthen pots of having 12 inches' diameter, 12 inches' height with a hole at the centre of the bottom were used. Silt soil was used in the experiment. The upper edge diameter of the pots was 30 cm (r= 15 cm). While filling with soil, the upper one inch of the pot was kept vacant so that irrigation can be provided using a hose pipe. As such the diameter of the upper soil surface was 15 inch (30 cm) and the area of the upper soil surface was (πr^2 = 3.14x 0.015x 0.015=0.07 m^2). The preparation of the pot was done in 16 January 2020.

3.10.2 Fertilizer management

The following doses of fertilizer were applied for cultivation of T. *Boro* rice (FRG, 2012).

Fertilizers	Quantity (kg/ha)	Fertilizer given pot^{-1} (g)
Urea	300	2.1
TSP	100	0.7
MP	120	0.84
Gypsum	60	0.42

Plant Macronutrients (*viz*. nitrogen, phosphorus, potash, sulfur) for rice were given through urea, triple super phosphate, muriate of potash, and gypsum, respectively. All of the fertilizers except urea were applied as basal dose at the time of filling pot with soil. Urea (300 kg ha^{-1}) was applied in equal three splits. The first dose of urea was applied at 12 days after transplanting (DAT). The second dose of urea was added as top dressing at 27 days after transplanting and third dose was applied at 42 days after transplanting recommended by BRRI.

3.10.3 Seedling transplanting in the pot

The seedling of rice was transplanted to the pot according to par treatment requirement. Seedling transplanting was done at 18, 23 & 28 January, 2020.Two seedlings were transplanted in each pot.

3.11 Intercultural operations

3.11.1 Application of irrigation water

Irrigation water was added to each pot according to the critical stage. It was given by using water pipe.

3.11.2 Weeding

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

3.11.3 Plant protection measures

The crop was attacked by yellow rice stem borer (*Scirpopagain certulas*) at the panicle initiation stage which was successfully controlled with Sumithion @ 1.5 L ha^{-1}. Yet to keep the crop growth in normal, Basudin was applied at tillering stage @ 17 kg ha^{-1} while Diazinon 60 EC @ 850 ml ha^{-1} were applied to control rice bug and leaf hopper. Application of insecticide was applied at 1 January 2020. Crop was protected from birds during the grain filling period by using net and covering the experimental site.

3.12 General observations of the experimental field

Regular observations were made to see the growth and visual different of the crops, due to application of different treatment were applied in the experimental pot. In general, the plant looked nice with normal green plants. Incidence of stem borer, green leaf hopper, leaf roller was observed during tillering stage and there was also some rice bug were present in the experimental pot. But any bacterial and fungal disease was not observed. The flowering was not uniform.

3.13 Crop sampling and data collection

Pot from each replication were randomly selected and marked with sample card. Different data were recorded from selected plants at various growth stage.

The rice plant was harvested depending upon the maturity of grains and harvesting was done manually from each plot. Maturity of crop was determined when 80–90% of the grains become golden yellow in colour. Harvesting date were 28.04.2020 and 1.05.2020. Harvesting was done in the morning to avoid shattering. Prior to harvesting, randomly selected plant from each replication pot were separately harvested for recording yield attributes and other data. The harvested plants were tied into bundles and carried to the threshing floor of the Soil Field Laboratory. Threshing was done by hand. The grains were cleaned and sun dried to moisture content of 12%. Straw was also sun dried properly. Finally grain and straw yields pot^{-1} were recorded.

3.15 Field operation

The different field operations performed during the course of present investigation are given below in chronological order in list form

Table 4. List of schedule of field operations done during the course of experimentation

Operations	Working Dates
Collection of field moist soil	7 December 2019
Different level of chitosan raw material powder was mixed with field moist soil	8 December 2019
Filling the pot with chitosan raw material powder mixed soil	8 December 2019
Seed sowing	9 December 2019
Collection and preparation of the main pot	16 January 2020
Application of fertilizers (1/3rd Urea, TSP, MoP, Gypsum)	16, 21 and 26 January 2020
Transplanting of seedlings	18, 23 and 28 January 2020
Intercultural Operations	**Working Dates**
1st Weeding	8 February 2020
2nd Weeding	18 February 2020
3rd Weeding	4 March 2020
1st split application of urea	30 January 2020
2nd split application of urea	15 February 2020
3rd split application of urea	1 March 2020
Insecticide application	15 February 2020
Harvesting and threshing	28 April and 1 May 2020

3.16 Data collection

The data were recorded on the following parameters

i. Average seedling height (cm)
ii. Fresh weight seedling^{-1} (g)
iii. Oven dry weight seedling^{-1} (g)
iv. Seedling strength (mg cm^{-1})
v. Number of tillers pot^{-1}
vi. Number of effective tillers pot^{-1}
vii. Days to first flowering
viii. Days to 100 % flowering
ix. Unfilled grain weight (g)
x. 1000 grain weight (g)
xi. Grain yield pot^{-1} (g)
xii. Straw yield pot^{-1} (g)
xiii. Biological yield pot^{-1} (g)
xiv. Harvest index

3.17 Procedure of data collection

i. Average seedling height (cm)

The height of 25 seedlings during transplanting were measured with a meter scale from the ground level to tip of seedlings and the mean heights were expressed in cm.

ii. Fresh weight seedling^{-1} (g)

Fresh weight of 25 seedlings were collected during transplanting time from each treatment and then weighted by using a digital electric balance and the mean weight were expressed in gram.

iii. Oven dry weight seedling^{-1} (mg)

Different treated 25 seedlings were collected from seedbed and then sun dried. The sun dried seedling again dried in oven and weighted by using a digital electric balance & their mean was expressed in mg

iv. Seedling strength (mg/cm)

Seedling strength was measured by using the following formula

Seedling strength= $\frac{\text{Oven dry weight per seedling}}{\text{Average seedling height}}$ mg/ cm

v. Number of tillers pot^{-1}

Number of tillers pot^{-1} were counted at 10 days' interval up to 60 DAT from pre-selected hills and finally averaged as their number pot^{-1}. Only those tillers having three or more leaves were considered for counting.

vi. Number of effective tillers pot^{-1}

The total number of effective tillers pot^{-1} were counted as the number of panicle bearing tillers per hill. Data on effective tiller per pot were recorded at harvesting time and average value was recorded.

vii. Days to first flowering

The date of flower blooming was recorded from the number of days of 1st the date of flower blooming after transplanting.

viii. Days to 100 % flowering

After completion of 100 % flowering data was recorded from the number of days of 100 % flowering after transplanting.

x. Unfilled grains weight (g)

Unfilled grain weight was measuring by using a digital electric balance and the mean weight were expressed in gram.

xi) 1000 grains weight (g)

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

xii. Grain yield pot^{-1} (g)

Grain yield from each pot were taken expressed as g pot^{-1} on about 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

xiii. Straw yield pot^{-1}(g)

Straw obtained from each pot were sun dried and weighted carefully and finally converted to g pot^{-1}

xiv) Biological yield pot^{-1}(g)

The summation of grain yield and above ground straw yield was the biological yield. Biological yield pot^{-1}(g) = (Grain yield pot^{-1}+ straw yield pot^{-1}) g.

xv) Harvest index (%)

Harvest index was calculated on dry weight basis with the help of following formula.

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

Here, Biological yield = Grain yield + straw yield

3.18 Chemical analysis of seed pot soil after seedling transplant

3.18.1 Particle size analysis

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

3.18.2 Soil pH

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

3.18.3 Organic C

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

3.18.4 Total nitroge

Total N content of soil were determined followed by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into micro jeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100:10:1), and 6 ml H_2SO_4 were added. The flasks were swirled and heated 2000C and added 3 ml H_2O_2 and then heating at 3600C was continued until the digest was clear and colorless. After cooling, the content was taken into 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination. Then 20 ml digest solution was transferred into the distillation flask, then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N-NaOH

solutions in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally, the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink. The amount of N was calculated using the following formula:

% N = (T-B) × N × 0.014 × 100/S. Where, T = Sample titration (ml) value of standard H_2SO_4, B = Blank titration (ml) value of standard H_2SO_4, N = Strength of H_2SO_4 and S = Sample weight in gram.

3.18.5 Available phosphorus

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

3.19 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program name MSTAT-C. The significance of the difference among the treatment means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

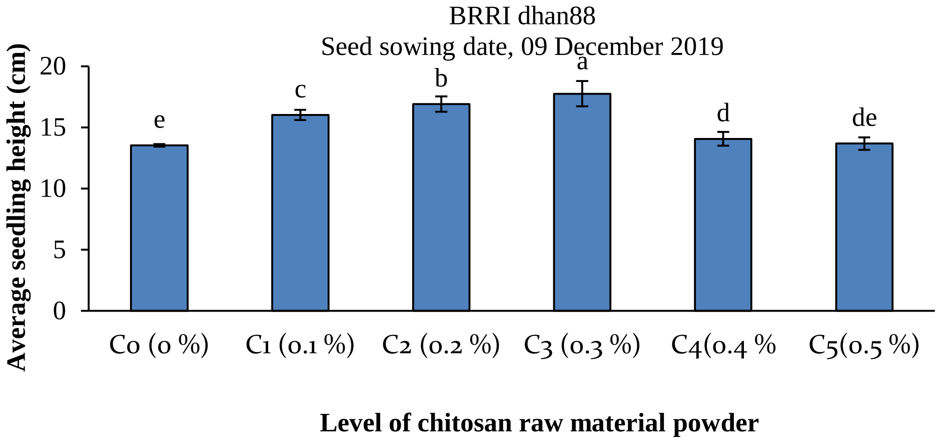
RESULTS AND DISCUSSION

Results obtained from the present study have been presented and discussed in this chapter with a view to study the improvement of late sowing *Boro* seedling characters and yield by using chitosan raw material powder in seedbed soil. The data are given in different tables and figures. The results have been discussed, and possible interpretations are given under the following headings.

4.1 Average seedling height (cm)

Effect of chitosan raw material powder on seedling height of BRRI dhan88

Seedling treated with different level of chitosan raw material powder significantly influenced average seedling height of BRRI dhan88 (Fig.2).Experimental result revealed that the maximum average seedling height (17.75 cm) was obtained in C_3 (0.3 % chitosan raw material powder) treatment whereas the minimum average seedling height (13.53 cm) was obtained in C_0 (0 % chitosan raw material powder) treatment, which was statistically similar with (13.67 cm) C_5 (0.5 % chitosan raw material powder) treatment. Seedling treated with chitosan raw material powder resulted in a better growth of the seedlings and lower chance of being infected by fungi in comparison with the untreated seedling. The observed growth improvement by chitosan raw material powder could also be related to the incorporation of nutrients from this powder. The result obtained from the present study was similar with the findings of Ahmed *et al*. (2020) and they reported that seedling height was increased with the application of chitosan-raw-materials in the seedbed. Issak and Sultana (2017) found that *Boro* rice seedlings production were improved by using the chitosan raw material powder in the seedbed. Boonlertnirun *et al.* (2008) also reported that, chitosan is a natural biopolymer which stimulates growth and increases yield of plants as well as induces the immune system of plants.



Here, Level of chitosan raw material powder, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5%.

Fig. 2. Effect of chitosan raw material powder level on average seedling height of BRRI dhan88. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

Effect of seedling age (40, 45 & 50 Days) on average seedling height of BRRI dhan88 as influenced by chitosan raw material powder

Different ages of seedling significantly effect on average seedling height of BRRI dhan88 (Fig. 3). Experimental result showed that, the maximum average seedling height (16.50 cm) was obtained in S_3 (50 days old seedling) treatment whereas the minimum average seedling height (14.07 cm) was obtained in S_1 (40 days old seedling) treatment. In general, the seedling height increased gradually with the advancement of time. Seedling stay in longer period in the seedbed increasing average seedling height due to reason that comparatively old seedling has mature root, uptake more nutrient from the seedbed which influence growth comparable to young seedlings.

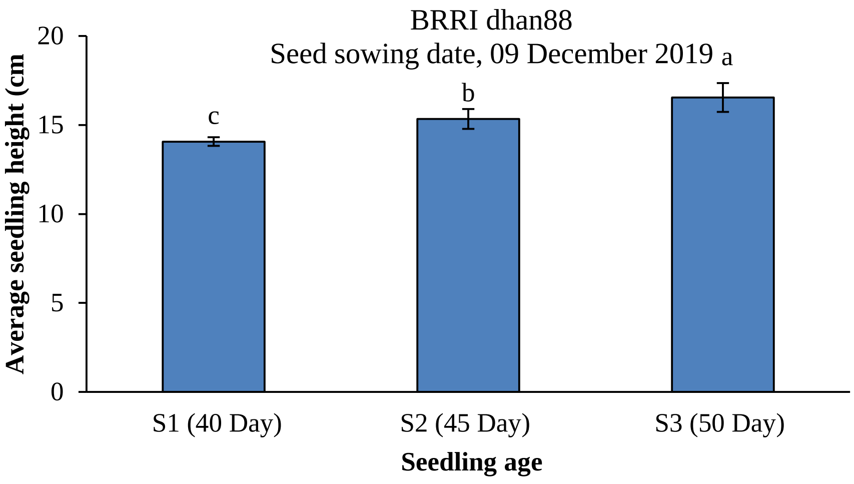
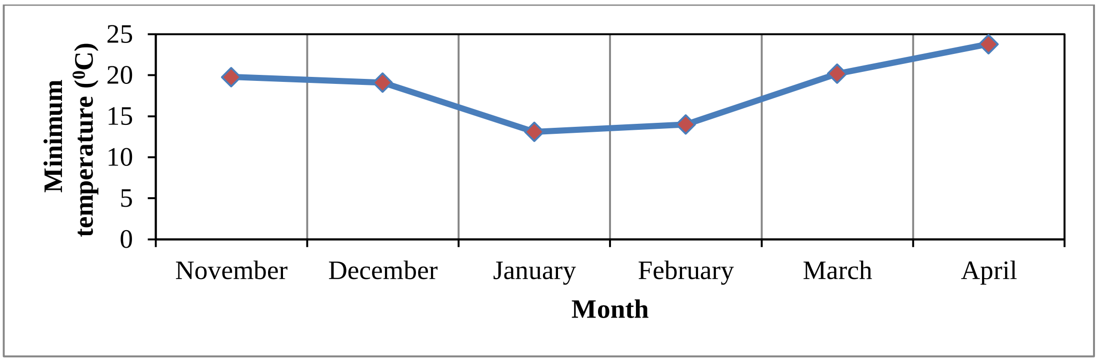


Fig. 3. Effect of seedling age on average seedling height of BRRI dhan88. Bars with different letters are significantly different at p ≤ 0.05 applying DMRT.

Plate 1. Morphological difference of rice seedlings at transplanting stage due to the application of chitosan raw material powder



Temperature fluctuation (Source Appendix II)

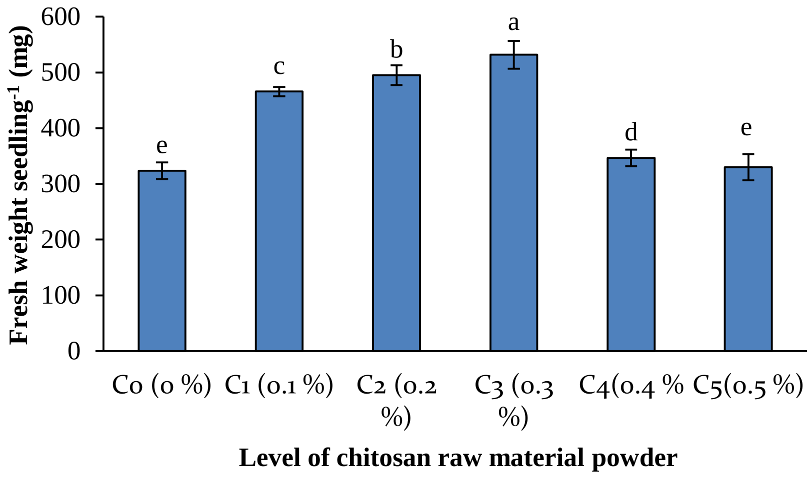
Combined effect of chitosan raw material powder and seedling age on average seedling height of BRRI dhan88

Seedling treated with different level of chitosan raw material powder along with different ages of seedling significantly effect on average seedling height of BRRI dhan88 (Table 5). Experimental result showed that, the maximum average seedling height (20.06 cm) was obtained in C_3S_3 treatment combination whereas the minimum seedling height (13.13) was obtained in C_0S_1 treatment combination, which was statistically similar with C_5S_1 (13.14 cm), C_4S_1 (13.37 cm), C_0S_2 (13.42 cm), C_5S_2 (13.60 cm) and C_4S_2 (13.63 cm) treatment combination.

4.2 Fresh weight seedling^{-1} (mg)

Effect of chitosan raw material powder on fresh weight seedling^{-1} of BRRI dhan88

Application of different level of chitosan raw material powder significantly effect on fresh weight seedling^{-1} of BRRI dhan88 (Fig. 4). Experimental result showed that, the maximum fresh weight seedling^{-1} (531.67 mg) was obtained in C_3 (0.3 % chitosan raw material powder) treatment, whereas the minimum fresh weight seedling^{-1}(323.58 mg) was obtained in C_0 (0.5 % chitosan raw material powder) treatment which was statistically similar with (330.00 mg) C_5 (0.5 % chitosan raw material powder) treatment. Optimum dose of chitosan raw material powder influences the nutrient uptake which improve the growth and development of the plant result in increasing fresh weight seedling^{-1} comparable to higher level of chitosan application. Ahmed *et al*. (2020) reported that seedling fresh weight was increased with the application of chitosan-raw-material powder in the seedbed. Issak and Sultana (2017) also reported that, fresh weight productions of BRRI dhan29 rice seedlings were influenced by the chitosan powder treatments and this might be due its supplementation of plant nutrients and growth regulators.



Here, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5% chitosan raw material powder

Fig. 4. Effect of chitosan raw material powder level on fresh weight seedling^{-1} of BRRI dhan88. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

Effect of seedling age on fresh weight seedling^{-1} of BRRI dhan88

Seedling age significantly effects on fresh weight seedling^{-1} of BRRI dhan88 (Fig. 5). Experimental result showed that, the maximum fresh weight seedling^{-1} (458.33 mg) was obtained in S_3 (50 days old seedling) treatment whereas the minimum fresh weight seedling^{-1} (368.04 mg) was obtained in S_1 (40 days old seedling) treatment. In this experiment, old seedling had higher fresh weight seedling^{-1} due to reason that, comparatively old seedling stays in longer period in the seedbed, developed root formation, uptake comparatively more water and nutrients which influence fresh weight comparatively young seedling.

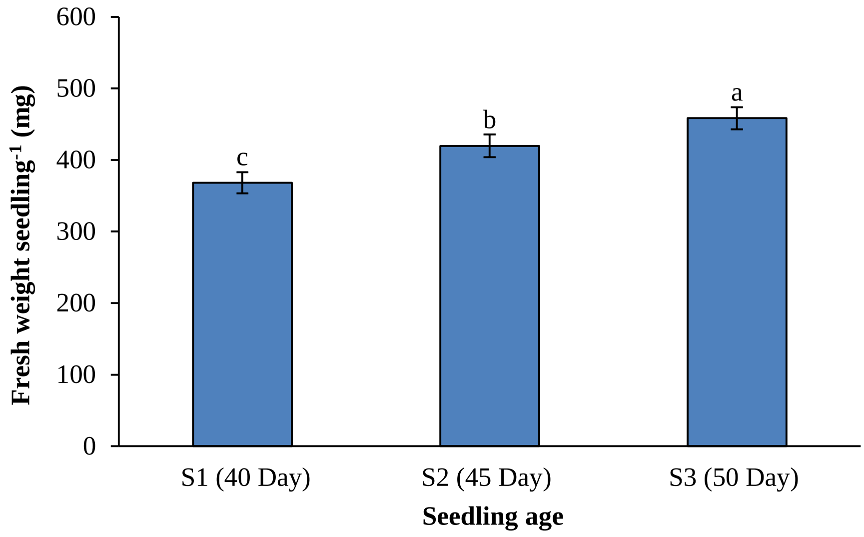


Fig. 5. Effect of seedling age on fresh weight seedling^{-1} of BRRI dhan88. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

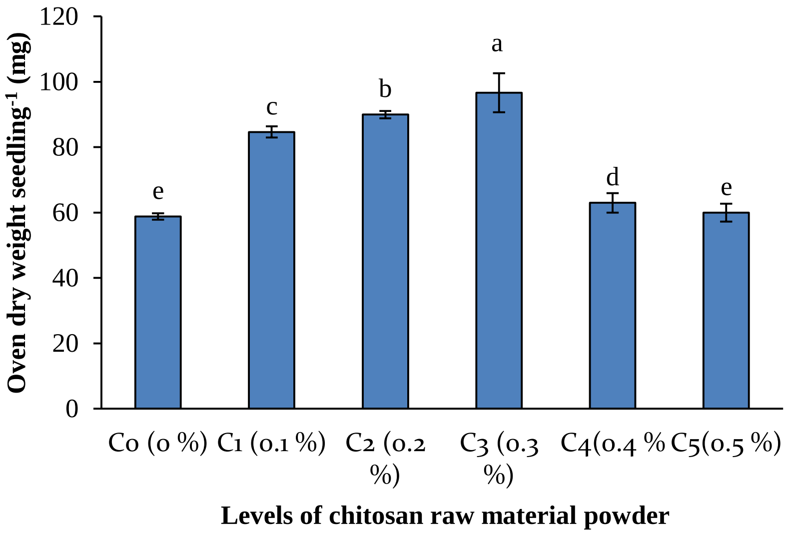
Combined effect of chitosan raw material powder and seedling age on fresh weight seedling^{-1} of BRRI dhan88

Seedling treated with different level of chitosan raw material powder along with different ages of seedling significantly effect on fresh weight seedling^{-1} of BRRI dhan88 (Table 5). Experimental result showed that, the maximum fresh weight seedling^{-1}(605.00 mg) was obtained in C_3S_3 treatment combination whereas the minimum fresh weight seedling^{-1}(299.75 mg) was obtained in C_0S_1 treatment combination, which was statistically similar with C_5S_1 (302.50cm) andC_4S_1 (313.50 cm) treatment combination.

4.3 Oven dry weight seedling^{-1} (mg)

Effect of chitosan raw material powder on oven dry weight seedling^{-1} of BRRI dhan88

Application of different level of chitosan raw material powder significantly effects on oven dry weight seedling^{-1} of BRRI dhan88 (Fig. 6). Experimental result showed that, the maximum oven dry weight seedling^{-1} (96.67 mg) was obtained in C_3 (0.3 % chitosan raw material powder) treatment, whereas the minimum oven dry weight seedling^{-1} (58.83 mg) was obtained in C_0 (0 % chitosan raw material powder) treatment which was statistically similar with (60.00 mg) C_5 (0.5 % chitosan raw material powder) treatment. Application of chitosan raw material powder influences the nutrient uptake capacity of plant which improve the growth and development of the plant. As a result, increasing dry weight seedling^{-1}comparable to control treatment were noticeable. Ahmed *et al.* (2020) reported that seedling oven dry weight was increased with the application of chitosan-raw-materials in the seedbed. Issak and Sultana (2017) also reported that oven dry weight productions of BRRI dhan29 rice seedlings were influenced by the chitosan powder applications and this might be due its nutritional support to the seedlings, improvement of growth promoting hormonal activity and could improve the biological as well as physio-chemical properties of the seedbed soils. Boonlertnirun *et al.* (2008) found that application of chitosan stimulates the seedling dry matter weight significantly.



Here, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5% chitosan raw material powder

Fig. 6. Effect of chitosan raw material powder level on oven dry weight seedling^{-1} of BRRI dhan88.Bars with different letters are significantly different at p ≤ 0.05 applying DMRT.

Effect of seedling age on oven dry weight seedling^{-1} of BRRI dhan88

Different ages of seedling significantly effect on oven dry weight seedling^{-1} of BRRI dhan88 (Fig. 7). Experimental result showed that, the maximum oven dry weight seedling^{-1} (83.33 mg) was obtained in S_3 (50 days old seedling) treatment whereas the minimum oven dry weight seedling^{-1} (66.92 mg) was obtained in S_1 (40 days old seedling) treatment. Seedling stay in longer period in the seeded increasing oven dry weight seedling^{-1} due to reason that comparatively old seedling has mature root, uptake more nutrient from the seedbed which influence growth comparable to young seedlings.

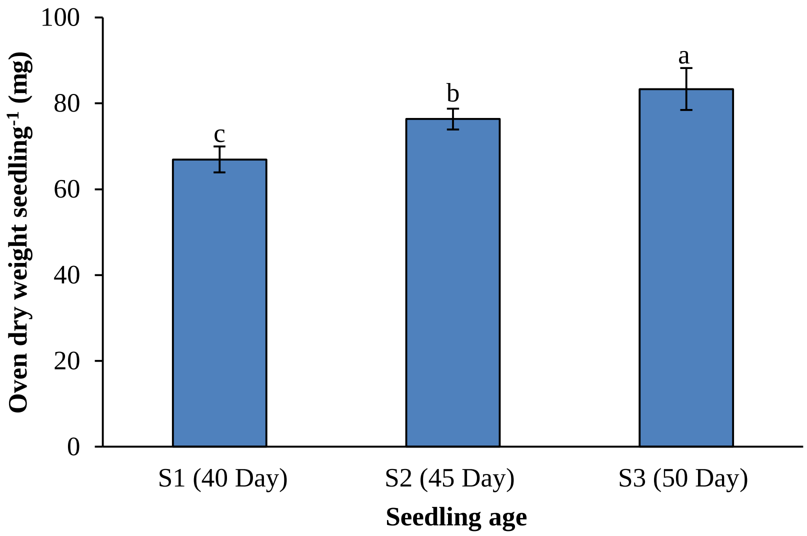


Fig.7. Effect of seedling age on oven dry weight seedling^{-1} of BRRI dhan88.Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

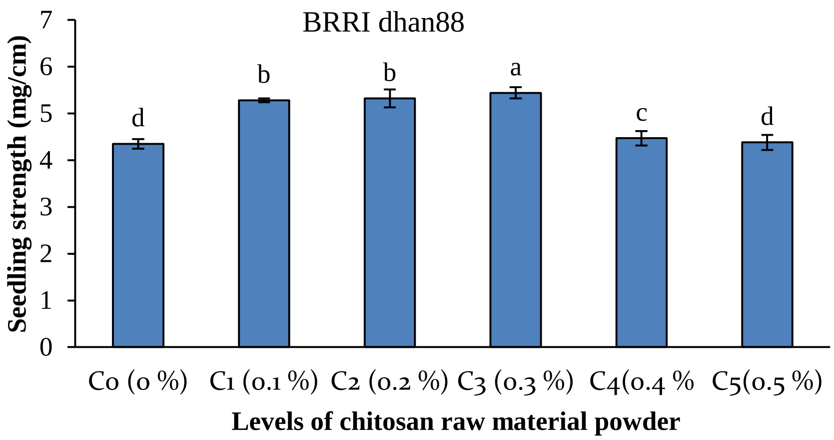
Combined effect of chitosan raw material powder and seedling age

Seedling treated with different level of chitosan along with different ages of seedling significantly effect on oven dry weight seedling^{-1}of BRRI dhan88 (Table 5). Experimental result showed that, the maximum oven dry weight seedling^{-1} (110.00 mg) was obtained in C_3S_3 treatment combination whereas the minimum oven dry weight seedling^{-1} (54.50 mg) was obtained in C_0S_1 treatment combination which was statistically similar with C_5S_1 (55 mg) and C_4S_1 (57 mg) treatment combination.

4.4 Seedling strength (mg/cm)

Effect of chitosan raw material powder on seedling strength of BRRI dhan88

Seedling treated with different level of chitosan raw material powder significantly effect on seedling strength (mgcm^{-1}) of BRRI dhan88 (Fig. 8). Experimental result showed that, maximum seedling strength (5.44 mgcm^{-1}) was obtained in C_3 (0.3 % chitosan) treatment, whereas the minimum seedling strength (4.35 mgcm^{-1}) was obtained in C_0 (0 % chitosan raw material powder) treatment which was statistically similar with (4.38 mgcm^{-1}) C_5 (0.5 % chitosan raw material powder) treatment. Ahmed *et al*. (2020) reported that seedling strength was increased with the application of chitosan-raw-materials in the seedbed. Boonlertnirun *et al.* (2008) found that application of chitosan stimulates the seedling strength significantly.



Here, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5% chitosan raw material powder

Fig. 8. Effect of chitosan raw material powder level on seedling strength of BRRI dhan88. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

Effect of seedling age on seedling strength of BRRI dhan88

Seedling age significantly effects on seedling strength of BRRI dhan88 (Fig. 9). Experimental result showed that, the maximum seedling strength (4.98 $mgcm^{-1}$) was obtained in S_3 (50 days old seedling) treatment whereas the minimum seedling strength (4.72 $mgcm^{-1}$) was obtained in S_1(40 days old seedling) treatment. Seedling stays in longer period in the seeded increasing seedling strength due to reason that comparatively older seedling has mature root, uptake more nutrient from the seedbed which influence height and dry matter accumulation to younger seedlings.

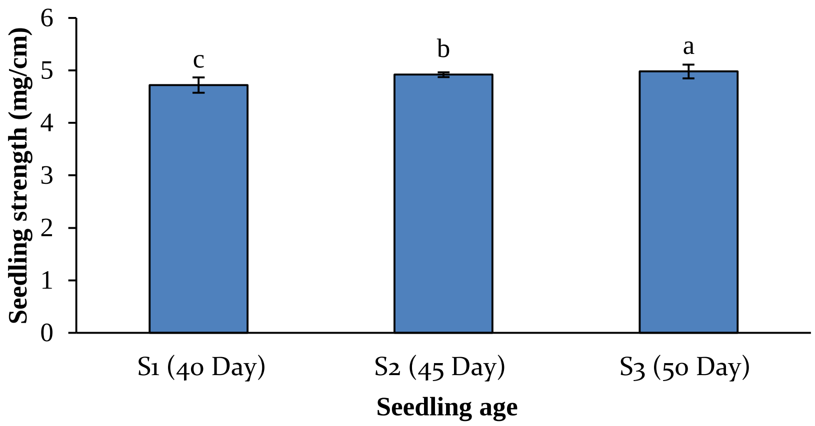
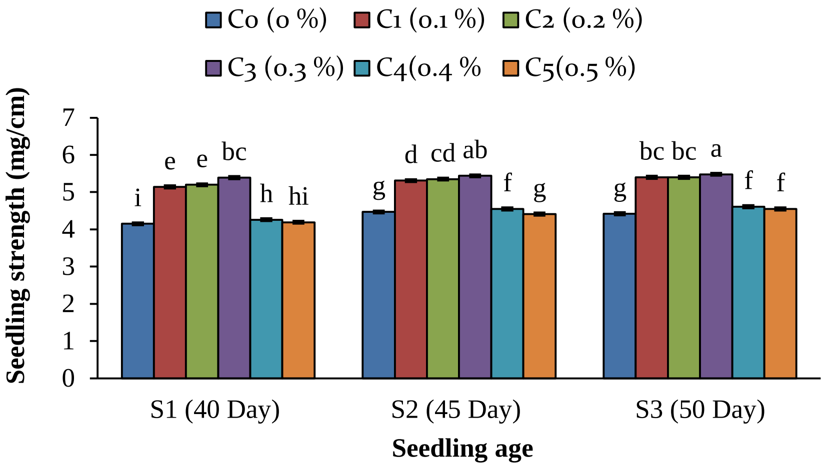


Fig. 9. Effect of seedling age on seedling strength of BRRI dhan88.Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

Combined effect of chitosan raw material powder and seedling age on seedling strength of *Boro* Rice

Combined effect of chitosan raw material powder and seedling age significantly effect on seedling strength of BRRI dhan88 (Fig. 10 &Table 5). Experimental result showed that, the maximum seedling strength (5.48 $mgcm^{-1}$) was obtained in C_3S_3 treatment combination which was statistically similar with C_3S_2 (5.44 $mgcm^{-1}$) treatment combination whereas the minimum seedling strength (4.15 mg/cm) was obtained in C_0S_1 treatment combination which was statistically similar with C_5S_1 (4.19 $mgcm^{-1}$) treatment combination.



Here, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5% chitosan raw material powder

Fig. 10. Effect of chitosan raw material powder level on seedling strength (mgcm^{-1}) of BRRI dhan88 at different seedling age. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

Table 5. Combined effect of chitosan raw material powder and seedling age on average seedling height, fresh weight, oven dry weight seedling^{-1} and seedling strength of BRRI dhan88

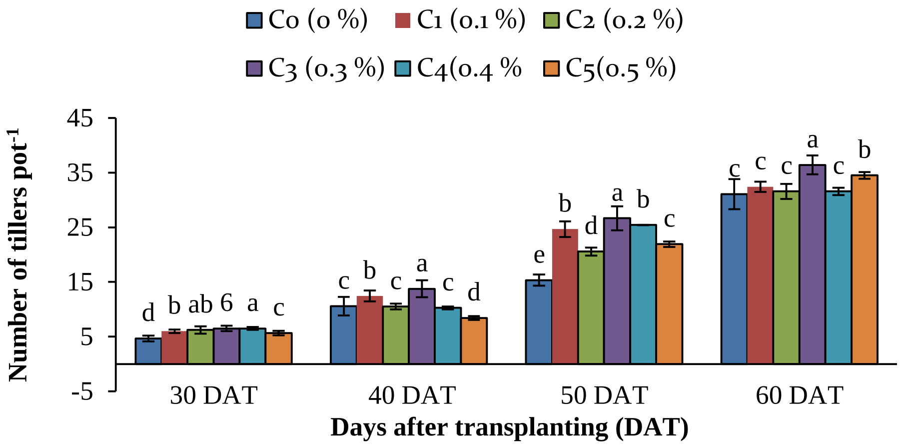
Treatment combinations	Average seedling height (cm)	Fresh weight seedling^{-1} (mg)	Oven dry weight seedling^{-1} (mg)	Seedling strength (mgcm^{-1})
C_0S_1	13.13 i	299.75 l	54.50 k	4.15 i
C_0S_2	13.42 hi	330.00 i-k	60.00 ij	4.47 g
C_0S_3	14.04 f-h	341.00 ij	62.00 hi	4.42 g
C_1S_1	14.60 d-f	412.50 fg	75.00 f	5.14 e
C_1S_2	16.38 c	478.50 cd	87.00 d	5.31 d
C_1S_3	17.04 c	506.00 c	92.00 c	5.40 bc
C_2S_1	15.00 de	429.00 ef	78.00 f	5.20 e
C_2S_2	17.00 c	500.50 c	91.00 c	5.35 cd
C_2S_3	18.70 b	555.50 b	101.00 b	5.40 bc
C_3S_1	15.20 d	451.00 de	82.00 e	5.39 bc
C_3S_2	18.00 b	539.00 b	98.00 b	5.44 ab
C_3S_3	20.06 a	605.00 a	110.00 a	5.48 a
C_4S_1	13.37 hi	313.50 j-l	57.00 jk	4.26 h
C_4S_2	13.63 g-i	341.00 ij	62.00 hi	4.55 f
C_4S_3	15.17 d	385.00 gh	70.00 g	4.61 f
C_5S_1	13.14 i	302.50 kl	55.00 k	4.19 hi
C_5S_2	13.60 g-i	330.00 i-k	60.00 ij	4.41 g
C_5S_3	14.29 e-g	357.50 hi	65.00 h	4.55 f
$LSD_{(0.05)}$	0.85	28.29	3.60	0.07
CV(%)	3.94	4.80	3.36	1.13

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability Here, S_1= 40 days old seedling, S_2= 45 days old seedling, S_3= 50 days old seedling, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5% chitosan raw material powder

4.5 Tiller Number pot^{-1}

Effect of chitosan raw material powder on tiller number pot^{-1} of BRRI dhan88

Different levels of chitosan raw material powder significantly effect on tiller number pot^{-1}at different days after transplanting of BRRI dhan88 (Fig. 11). Experimental result showed that, the maximum tiller number pot^{-1} (6.50, 13.75, 26.67 and 36.42) at 30, 40, 50 and 60 DAT were obtained in C_3 (0.3 % chitosan raw material powder) treatment which was statistically similar with (6.50) at C_4 treatment (0.4 % chitosan raw material powder) and (6.21) C_2 treatment (0.2 % chitosan raw material powder) at 30 DAT. Whereas the minimum tiller number pot^{-1} (4.67) at 30 DAT was obtained in C_0 (0 % chitosan raw material powder) treatment. At 40 DAT the minimum tiller number pot^{-1} (8.42) was obtained in C_5 (0.5 % chitosan raw material powder) treatment. At 50 and 60 DAT the minimum tiller number pot^{-1} (15.33 and 31.08) was obtained in C_0 (0 % chitosan raw material powder) treatment, which was statistically similar with (31.58) C_4 (0.4 % chitosan raw material powder), (31.58) C_2 (0.2 % chitosan) and (32.42) C_2 (0.2 % chitosan) treatment. The result obtained from the present study was similar with the findings of Ahmed *et al.* (2013) and they reported that Chitosan treated plants produced the higher number of tillers compare to control.

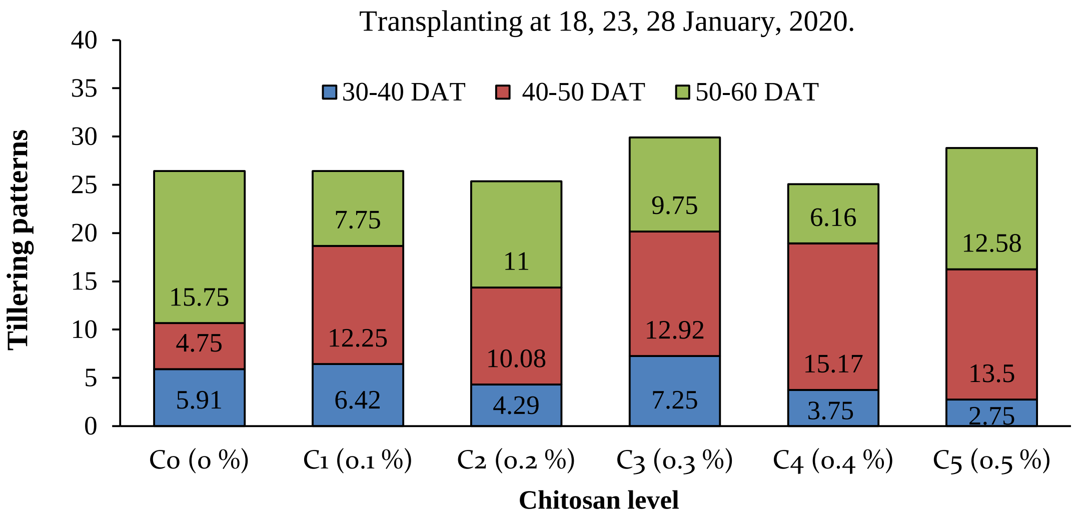


Here, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5% chitosan raw material powder

Fig. 11. Effect of chitosan raw material powder on tiller number pot^{-1} of BRRI dhan88 at different DAT. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

Effect of chitosan raw material powder on tillering patterns of BRRI dhan88 at different DAT

From the Fig. 12 it was observed that, application of different level of chitosan raw material powder influenced tillering patterns of BRRI dhan88. Application of chitosan raw material powder reducing the day requirement for maximum tillering occurrence comparatively to control treatment. In this experiment, result showed that application of different level of chitosan raw material powder influence maximum tillers occurrence and it was maximum at 40-50 DAT, whereas in control treatment it was 50-60 DAT. Chitosan enhances the ability of plants to uptake its required nutrients. It increases the ability of plants to accelerate its growth and germination, improve the quality of yield contributing characters comparable to control treatment.



Here, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5% chitosan raw material powder

Fig.12.Effect of chitosan raw material powder on tillering patterns of BRRI dhan88 at different DAT

Effect of seedling age on number of tillers pot^{-1} of BRRI dhan88 at different DAT

Seedling age significantly effects on tiller number hill^{-1} at different days after transplanting of BRRI dhan88 (Fig. 13). Experimental result showed that, the maximum number of tillers pot^{1} (6.67, 14.46, 26.83 and 37.63) at 30, 40, 50 and 60 DAT was obtained in S_1 (40 days old seedling) treatment whereas the minimum number of tillers hill^{-1} (4.96, 8.58, 19.58 and 28.63) at 30, 40, 50 and 60 DAT was obtained in S_3 (50 days old seedling) treatment. Overall younger seedlings produced higher numbers of tillers than older seedlings, which might be due to less root damage and minimum transplanting shock, as younger seedlings can more easily establish themselves after transplanting in the main field. It is possible to bring one week before the maximum tillering stage by application of chitosan raw material powder at optimum dose compare to control treatment. The result obtained from the present study was similar with the findings of Uphoff (2002a) and stated that transplanting of very young seedlings usually have better tillering and rooting which influences the tillernig number hill^{-1}.

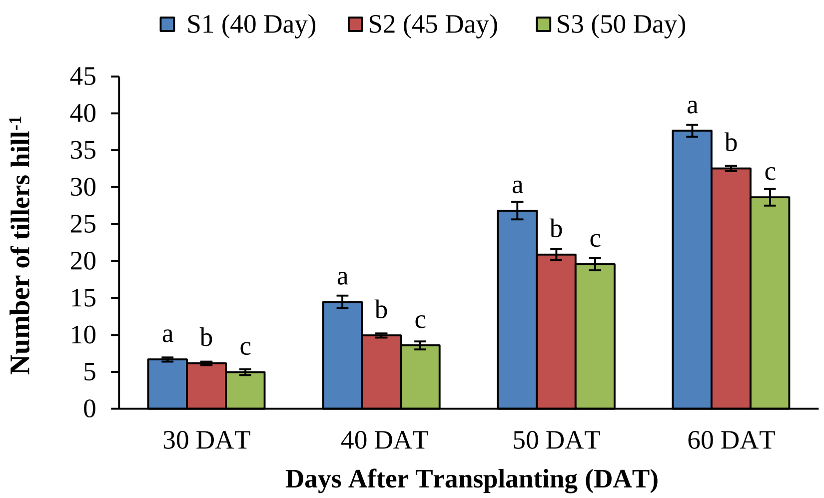
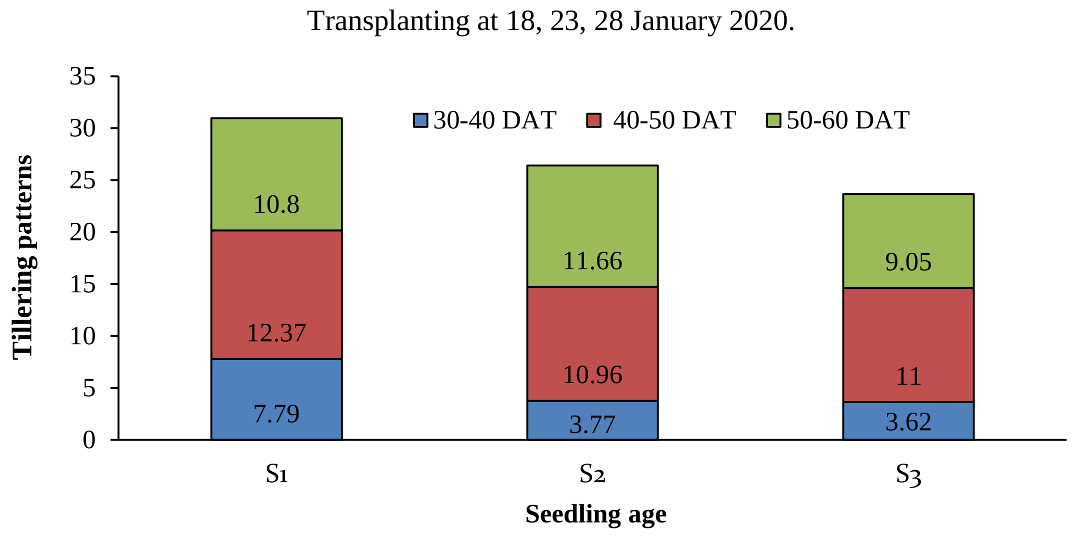


Fig. 13. Effect of seedling age on number of tillers pot^{-1}of BRRI dhan88 at different DAT. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

From the Fig. 14 it was observed that, different age of seedling influenced tillering patterns of BRRI dhan88. In this experiment, result showed that (S_1) 40 days old seedling needed less time for maximum tillers occurrence comparable to other different age seedling and it was maximum at 40-50 DAT, whereas increasing transplanting days may be decreasing tillering patterns and its was minimum in 45 days old seedling (S_2) needed more time for maximum tillering occurrence and its was at 50-60 DAT.



Here, S_1= 40 days old seedling, S_2= 45 days old seedling, S_3= 50 days old seedling.

Fig. 14. Effect of seedling age on tillering patterns of BRRI dhan88 at different DAT

Overall younger seedlings produced higher numbers of tillers than older seedlings, which might be due to less root damage and minimum transplanting shock, as younger seedlings can more easily establish themselves after transplanting in the main yield.

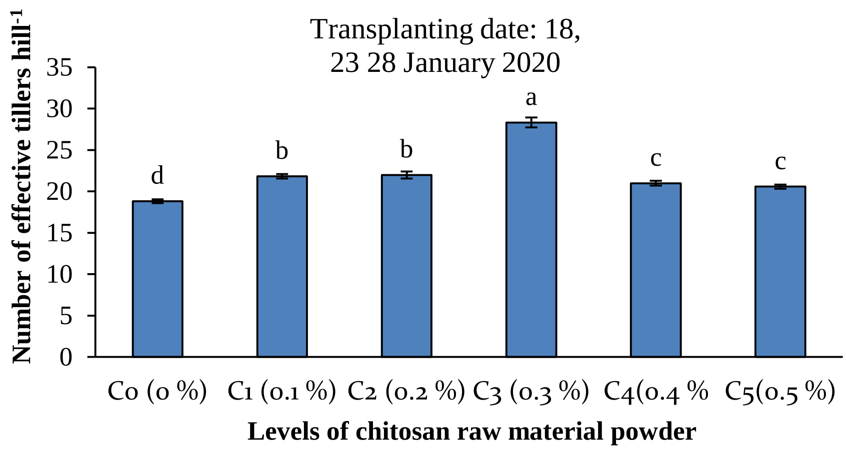
Combined effect of chitosan raw material powder and seedling age on tiller number pot^{-1} of BRRI dhan88

Combined effect of chitosan and seedling age significantly effect on number of tillers hill^{-1} of BRRI dhan88 at different days after transplanting (Table 6). Experiment result revealed that, the maximum tiller number hill^{-1} (8.25, 20.25, 36.50 and 43.25) at 30, 40, 50 and 60 DAT was obtained in C_3S_1 treatment combination, which was statistically similar with C_2S_2 (8.13) treatment combination at 30 DAT and with C_0S_1 (40.50) treatment combination at 60 DAT. Whereas the minimum tiller number hill^{-1} (2.50, 6.25, 12.00 and 20.75) at 30, 40, 50 and 60 DAT was obtained in C_0S_3 treatment combination.

4.6 Number of effective tillers pot^{-1}

Effect of chitosan raw material powder on number of effective tillers pot^{-1} of BRRI dhan88

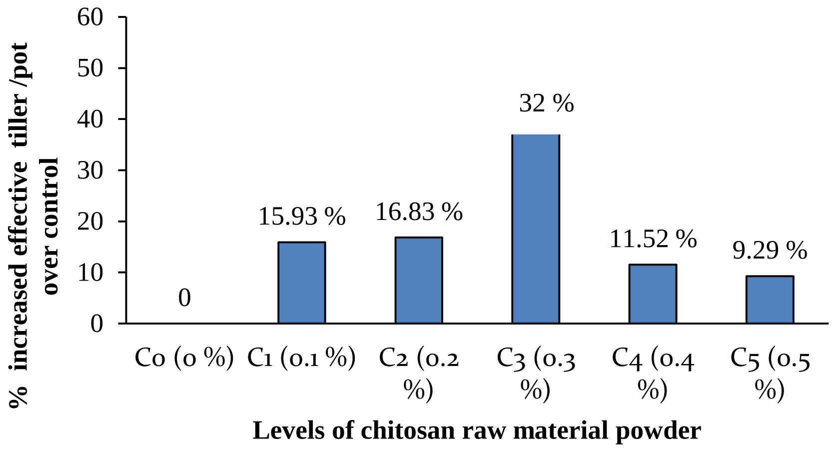
Seedling treated with different level of chitosan raw material powder significantly effect on effective tillers pot^{-1} of BRRI dhan88 (Fig. 15). Experimental result showed that, maximum effective tillers hill^{-1} (28.33) was obtained in C_3 (0.3 % chitosan raw material powder) treatment, whereas the minimum effective tillers hill^{-1} (18.83) was obtained in C_0 (0 % chitosan raw material powder) treatment. Ahmed *et al*. (2020) reported that different level of chitosan significantly effects on effective tillershill^{-1} and the highest number of effective tillershill^{-1} (14) was obtained in the T_3 (Seedbed applied @ 250 g/m^2 + Main field applied @ 0 t/ha) treatment whereas the lowest number of effective tillershill^{-1} (11.67) was obtained in the T_1 control treatment. It was observed that the application of chitosan-raw-material powder in soil increased the effective tillershill^{-1}. Boonlertnirun *et al.* (2012) also showed that application methods of chitosan significantly affected tiller number per plant.



Here, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5% chitosan raw material powder

Fig. 15. Effect of chitosan raw material powder on number of effective tiller pot^{-1} BRRI dhan88. Barswith different letters are significantly different at $p \leq 0.05$ applying DMRT.

From the Fig.16 it was noticed that, application of chitosan raw material powder increased the effective tiller number percentage over control treatment. Chitosan application in the seedbed influenced the seedling growth which ultimately helped proper root and shoot development of the seedlings as it consumed more nutrients. As a result, effective tiller number increased comparable to control treatment. Maximum effective tiller number percentage (32 %) was found in C3 (0.3% chitosan raw material powder) treatment.



Here, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5% chitosan raw material powder

Fig. 16. Effect of chitosan raw material powder on effective tillers number increasing percentage over control of BRRI dhan88.

Effect of seedling age on number of effective tillers pot^{-1} of BRRI dhan88

Seedling age significantly effect on effective tillers pot^{-1} of BRRI dhan88 (Fig. 17). Experimental result showed that, the maximum effective tillers pot^{-1} (22.96) was obtained in S_1 (40 days old seedling) treatment whereas the minimum effective tillers pot^{-1} (21.33) was obtained in S_3 (50 days old seedling) treatment. The difference of effective tiller pot^{-1} might be due to longer growing period of the crop for better development of parts to allocate greater accumulation of photosynthesis in early planted crop which may result in the better development of growth. Sultana*et al.* (2020) reported that the effect of age of seedling, nitrogen levels and their interactions were significant on growth, yield and yield contributing characters of transplant Aman rice. By using optimum seedling age at 15 DAT recorded the highest number of effective tillers plant^{-1} (8.29) at harvest respectively. Ali *et al.* (2013) also reported that more effective tillershill^{-1} (24.9) when seedlings of 15 days' age were transplanted while 30 days old seedlings gave minimum number of effective tillers (15.6).

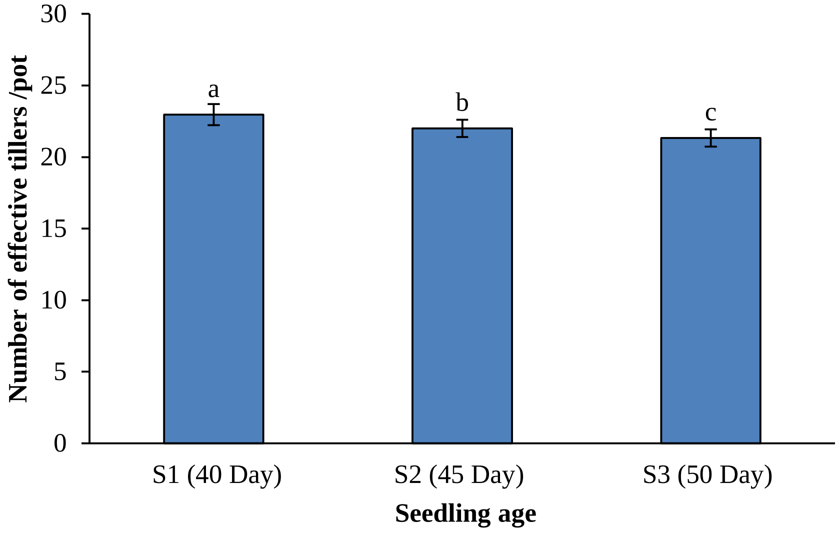


Fig 17. Effect of seedling age on number of effective tillers pot^{-1} of BRRI dhan88. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

Combined effect of chitosan raw material powder and seedling age on number of effective tillers pot^{-1} of BRRI dhan88

Combined effect of chitosan raw material powder and seedling age significantly effect on effective tillers pot^{1} of BRRI dhan88 (Table 6). Experimental result revealed that, the maximum effective tillers pot^{-1} (30.25) was obtained in C_3S_1 treatment combination. Whereas the minimum tiller number pot^{-1} (17.75) was obtained in C_0S_3 treatment combination.

Table 6. Combined effect of chitosan raw material and seedling age on number of tillers pot^{-1} at different DAT and number of effective tillers pot^{-1} of BRRI dhan88

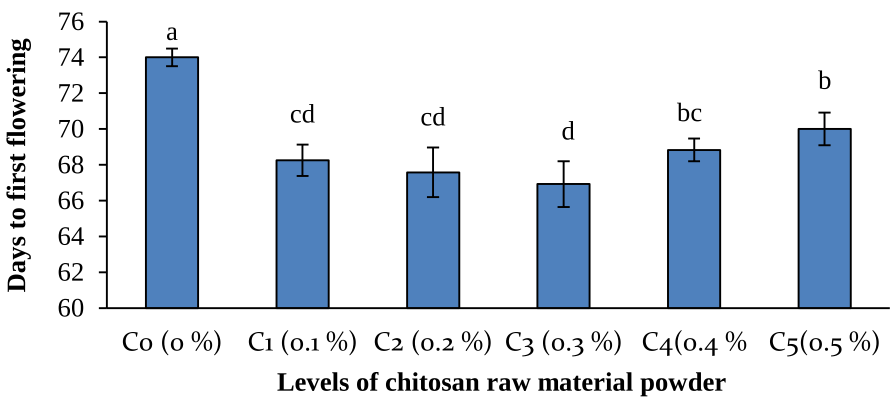
Treatment combinations	Number of tillers pot^{-1}				Effective tillers pot^{-1}
	30 DAT	40 DAT	50 DAT	60 DAT	
C_0S_1	6.75cd	17.00b	20.00hi	30.00 gh	19.50f
C_0S_2	4.75ef	8.50g	14.00k	25.50 h	19.25f
C_0S_3	2.50h	6.25h	12.00l	20.75 i	17.75g
C_1S_1	6.50d	16.75b	31.25b	36.75bc	21.25de
C_1S_2	7.00b-d	8.75fg	22.25ef	30.75f-h	22.00cd
C_1S_3	4.50f	11.75d	20.50g-i	29.75gh	22.25cd
C_2S_1	7.25bc	12.75c	24.00d	34.50b-d	23.00c
C_2S_2	8.13a	10.25e	19.25ij	30.00gh	21.50de
C_2S_3	3.25g	8.50g	18.50j	30.25gh	21.50de
C_3S_1	8.25a	20.25a	36.50a	43.25a	30.25a
C_3S_2	6.50d	12.75c	22.50e	35.00b-d	27.75b
C_3S_3	4.75ef	8.25g	21.00f-h	31.00e-h	27.00b
C_4S_1	7.00b-d	11.50d	25.25cd	33.50d-f	22.00cd
C_4S_2	5.25e	9.50ef	25.50c	32.75d-g	21.25de
C_4S_3	7.25bc	9.75e	25.50c	28.50h	19.75f
C_5S_1	4.25f	8.50g	24.00d	37.25b	21.75cd
C_5S_2	5.25e	9.75e	21.75 e-g	32.75 d-g	20.25ef
C_5S_3	7.50b	7.00h	20.00hi	33.50 d-f	19.75f
$LSD_{(0.05)}$	0.55	0.86	1.38	3.16	1.27
CV(%)	6.51	5.56	4.33	6.76	4.04

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability Here, S_1= 40 days old seedling, S_2= 45 days old seedling, S_3= 50 days old seedling, C_0= 0% Chitosan, C_1= 0.1% Chitosan, C_2= 0.2% Chitosan, C_3= 0.3% Chitosan, C_4= 0.4% Chitosan and C_5= 0.5% Chitosan

4.7 Days to first flowering

Effect of chitosan raw material powder on days to first flowering of *Boro* Rice

Different level of chitosan raw material powder treated seedlings significantly effect on first flowering day of BRRI dhan88 (Fig. 18). Experimental result showed that, the maximum days for first flowering (74.00) was obtained in C_0 (0 % chitosan raw material powder) treatment, whereas the minimum days for first flowering (66.92) was obtained in C_3 (0.3 %chitosan raw material powder) treatment, which was statistically similar with (68.25) C_1 (0.1 % chitosan raw material powder) and (67.58) C_2(0.2 % chitosan raw material powder) treatment. Different level of chitosan influenced florigen gene expression which ultimately impact on early flowering comparable to control treatment. In plants, flowering time is elaborately controlled by various environment factors. Rice has two florigens molecules Hd3a and Rice Flowering Locus T1 (RFT1), that are induced flowering. In rice (*Oryza sativa*), early heading date 1 (Ehd1) is a major inducer of florigen gene expression. Ehd1 (EH Domain Containing 1) is a Protein Coding gene. Several transcription factors activate or repress the expression of Ehd1, a gene that is a critical convergence point for various flowering signals in rice. It is possible to bring one week before the flowering stage by application of chitosan raw material powder at optimum dose compare to control treatment.



Here, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5% chitosan raw material powder

Fig. 18. Effect of chitosan raw material powder on number of days to first flowering of BRRI dhan88. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

Plate 2. Effect of chitosan raw material powder on flowering. Picture A and B were chitosan treated seedlings and C was control treatment

Effect of seedling age on days to first flowering of BRRI dhan88

Different seedling age significantly effect on first flowering day of BRRI dhan88 (Fig. 19). Experimental result showed that, the maximum days for first flowering (72.46) was obtained in S_3 (50 days old seedling) treatment whereas the minimum days for first flowering (65.88) was obtained in S_1 (40 days old seedling) treatment. Transplants of 40 days old seedling might have availed weather conditions and environment properly through improved upper ground plant and below ground root development. Better root development of 40 days old transplant seedlings might has utilized plant nutrients and soil moisture in sufficient amount throughout life period, which influence early flowering comparable to late transplanting.

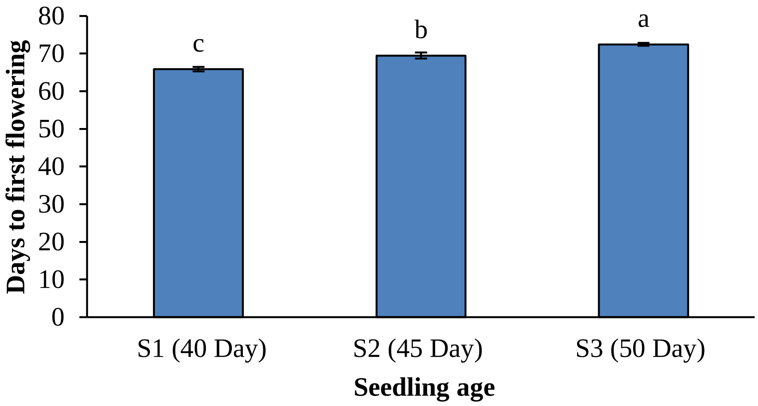


Fig. 19. Effect of seedling age on number of days to first flowering of BRRI dhan88. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

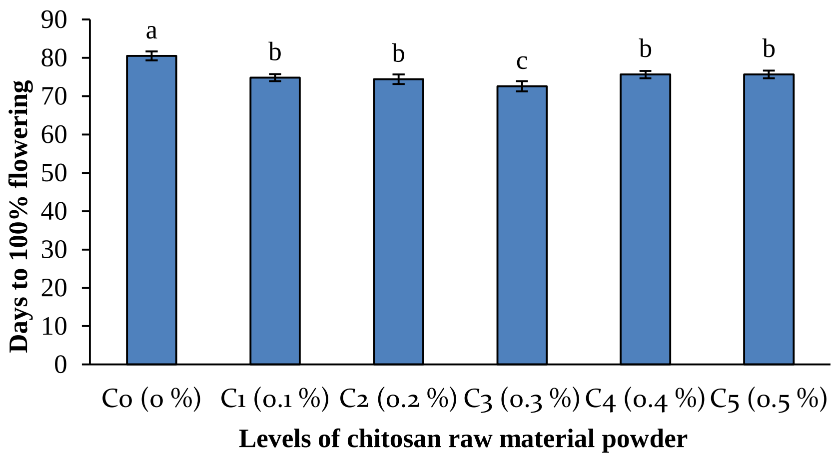
Combined effect of chitosan and seedling age on days to first flowering

Combined effect of chitosan raw material powder and seedling age significantly effect on days to first flowering of BRRI dhan88 (Table 7). Experimental result revealed that, the maximum days for first flowering (76.00) was obtained in C_0S_3 treatment combination which was statistically similar with C_0S_2 (74.00) treatment combination. Whereas the minimum days for first flowering (62.75) was obtained in C_3S_1 treatment combination, which was statistically similar with C_2S_1 (63.25) treatment combination.

4.8 Days to 100% flowering

Effect of chitosan raw material powder on days to 100% flowering of *Boro* Rice

Seedlings treated with different level of chitosan raw material powder significantly effect on 100 % flowering day of BRRI dhan88 (Fig. 20). Experimental result showed that, the maximum days for 100 % flowering (80.50) was obtained in C_0 (0 % chitosan) treatment, whereas the minimum days for 100 % flowering (72.58) was obtained in C_3 (0.3 % chitosan) treatment.



Here, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5% chitosan raw material powder

Fig. 20. Effect of chitosan raw material powder on number of 100 % flowering day of BRRI dhan88.Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

Effect of seedling age on days to 100% flowering of BRRI dhan88

Different seedling age significantly effect on 100% flowering day of BRRI dhan88 (Fig. 21). Experimental result showed that, the maximum days for 100% flowering (79.04) was obtained in S_3 (50 days old seedling) treatment whereas the minimum days for 100% flowering (71.58) was obtained in S_1 (40 days old seedling) treatment.

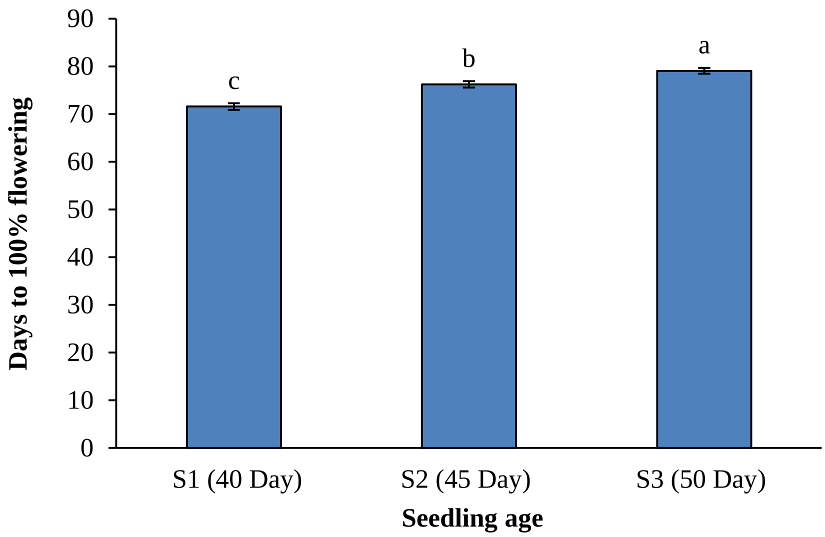


Fig. 21. Effect of seedling age on number of days for 100 % flowering of BRRI dhan88. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

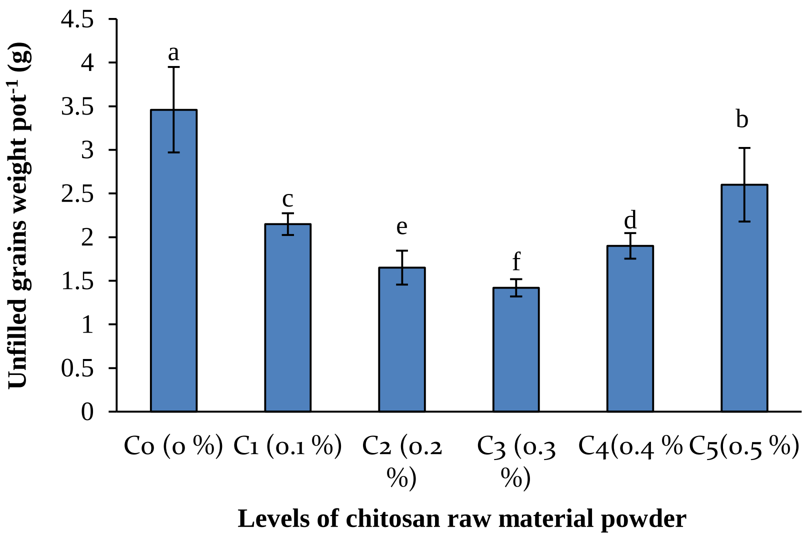
Combined effect of chitosan raw material powder and seedling age on days to 100% flowering of BRRI dhan88

Combined effect of chitosan and seedling age significantly effect on 100% flowering day of BRRI dhan88 (Table 7). Experiment result revealed that, the maximum days for 100% flowering (84.25) was obtained in C_0S_3 treatment combination which was statistically similar with C_0S_2 (82.00) treatment combination. Whereas the minimum days for 100% flowering (69.00) was obtained in C_3S_1 treatment combination which was statistically similar with C_2S_1 (69.25) and C_5S_1 (71.00) treatment combination.

4.9 Unfilled grains weight pot^{-1} (g)

Effect of chitosan raw material powder on unfilled grains weight pot^{-1} (g)

Different level of chitosan raw material powder treated seedlings significantly effect on unfilled grains weight pot^{-1} (g) of BRRI dhan88 (Fig. 22). Experimental result showed that, the maximum unfilled grains weight pot^{-1} (3.46 g) was obtained in C_0 (0 % chitosan raw material powder) treatment, whereas the minimum unfilled grains weight pot^{-1} (1.42 g) was obtained in C_3 (0.3 % chitosan raw material powder) treatment. Optimum application of chitosan influence fresh weight, oven dry weight of the seedling, increasing seedling strength and influence root development in early seedbed stage which ultimately impact on proper nutrient uptake, result in vigor growth, development and lower unfilled grains weight pot^{-1} comparable to higher level of chitosan application or control treatment.



Here, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5% chitosan raw material powder

Fig. 22. Effect of chitosan raw material powder on unfilled grains weight pot^{-1} (g) of BRRI dhan88. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

Effect of seedling age on unfilled grains weight pot^{-1} (g) of BRRI dhan88

Unfilled grains weight pot^{-1} (g) of BRRI dhan88 was significantly differ due to different age of seedling (Fig. 23). Experimental result revealed that the maximum unfilled grains weight pot^{-1}(3.20 g) was obtained in S_3 (50 days old seedling) treatment, whereas the minimum unfilled grains weight pot^{-1}(1.35 g) was obtained in S_1 (40 days old seedling) treatment. The variation of unfilled grains weight pot^{-1} (g) at different seedling age might be due to the reason that, transplanting seedling at early age into the field easily handle the transplanting shock and comparative little or no root damage was occurred during this time, whereas late transplanting result in poor growth, heavy transplanting shock, root damage, less solar radiation absorption and nutrient uptake occurred which ultimately impact on growth yield and yield contributing characters of rice.

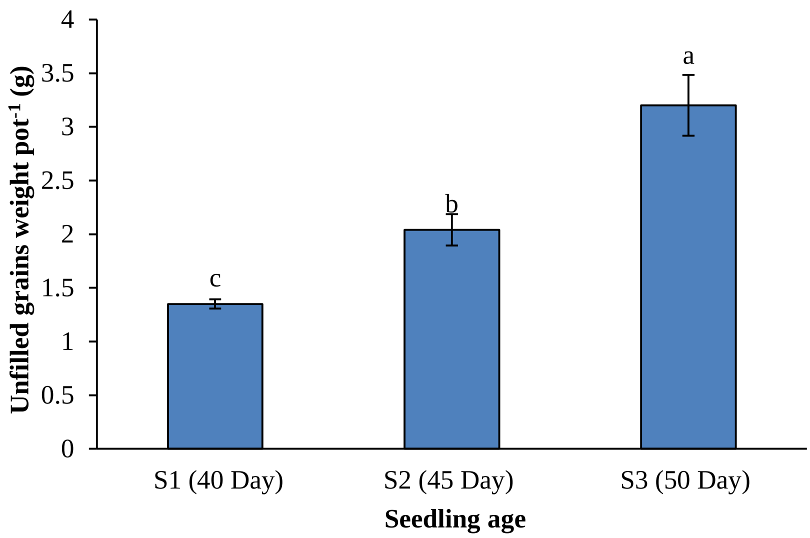


Fig. 23. Effect of seedling age on unfilled grains weight pot^{-1} (g) of BRRI dhan88. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

Combined effect of chitosan raw material powder and seedling age on unfilled grains weight of BRRI dhan88

Seedling treated with different level of chitosan raw material powder along with different ages of seedling significantly effect on unfilled grains weight pot^{-1} (g) of BRRI dhan88 (Table 7). Experimental result revealed that, the maximum unfilled grains weight pot^{-1} (5.53 g) was obtained in C_0S_3 treatment combination. Whereas the minimum unfilled grains weight pot^{-1} (1.02 g) was obtained in C_3S_1 treatment combination.

4.10 1000 grains weight (g)

Effect of chitosan raw material powder on 1000 grains weight (g)

Seedlings treated with different level of chitosan raw material powder significantly effect on 1000 grains weight (g) of BRRI dhan88 (Fig. 24). Experimental result showed that, the maximum 1000 grains weight (21.93 g) was obtained in C_3 (0.3 % chitosan raw material powder) treatment, whereas the minimum 1000 grains weight (19.46 g) was obtained in C_5 (0.5 %chitosan raw material powder) treatment which was statistically similar with (20.06) C_0 (0 %chitosan raw material powder) treatment. The result obtained from the present study was similar with the findings of Behboudi *et al.* (2018) and they observed that the chitosan application in soil considerably improved the 1000-grain weight in plants under water stress than that of control**.** Yadav and Christopher (2006) reported that chitosan spray recorded the maximum 1000 seed weight (16.55 g) as compared to without chitosan spray (15.59 g) respectively. Krivtsov *et al.* (1996) also found that thousand-grain weight and spike weight of wheat plants increased in treatment with low concentrations of polymeric chitosan.

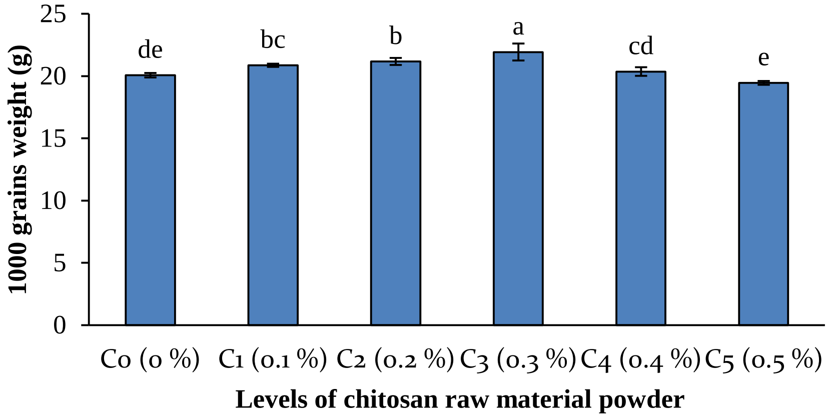


Fig. 24. Effect of chitosan raw material powder level on 1000 grains weight (g) of BRRI dhan88. Bars with different letters are significantly different at p ≤ 0.05 applying DMRT.

Effect of seedling age on1000 grains weight (g) of Boro Rice

Seedling age significantly effect on 1000 seeds weight (g) of BRRI dhan88 (Fig. 25). Experimental result revealed that the maximum 1000 seeds weight (21.15 g) was obtained in S_1 (40 days old seedling) treatment, which was statistically similar with (21.09) S_2 (45 days old seedling) treatment. Whereas the minimum 1000 seeds weight (19.67 g) was obtained in S_3 (50 days old seedling) treatment. Plants kept for longer time in nursery bed either get too leggy or become too woody due to check of growth and such old age seedlings do not make a quick start when transplanted in the main field as a result its causes negative impact on yield contributing characters compares to early transplanting of the seedling. The result obtained from the present study was similar with the findings of Tari *et al.* (2007) and they stated that appropriate time of transplanting resulted in higher 1000 grain weight. Singh and Singh (1998) revealed that yield attributes viz 1000-grain weight significantly increased with transplanting of younger seedlings as compared to older seedlings.

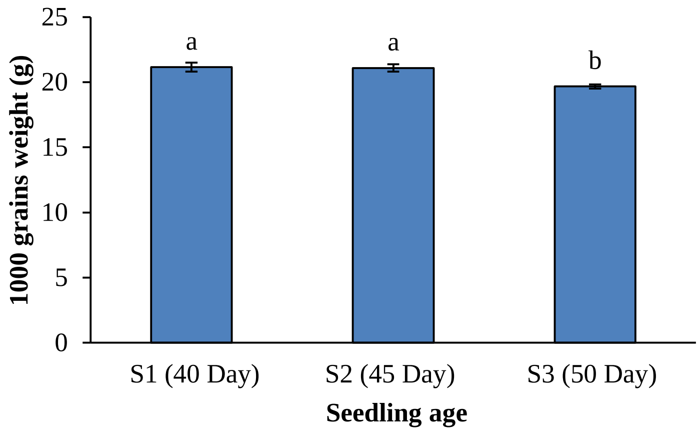


Fig. 25. Effect of seedling age on 1000 grains weight (g) of BRRI dhan88. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

Combined effect of chitosan raw material powder and seedling age on 1000 grain weight (g)

Seedling treated with different level of chitosan along with different age of seedling significantly effect on 1000 seeds weight (g) of BRRI dhan88 (Table 7). Experiment result revealed that, the maximum 1000 seeds weight (23.08g) was obtained in C_3S_1 treatment combination which was statistically similar with C_3S_2 (22.65 g) and C_2S_2

(22.23 g) treatment combination. Whereas the minimum 1000 seeds weight (18.75g) was obtained in C_5S_3 treatment combination which was statistically similar with C_4S_3 (18.88 g), C_5S_2 (19.68 g), C_2S_3 (19.90 g) and C_5S_1 (19.95g) treatment combination.

Table 7. Combined effect of chitosan raw material powder and seedling age on days to first flowering, days to 100 % flowering, unfilled grains weight and1000 grains weight of BRRI dhan88

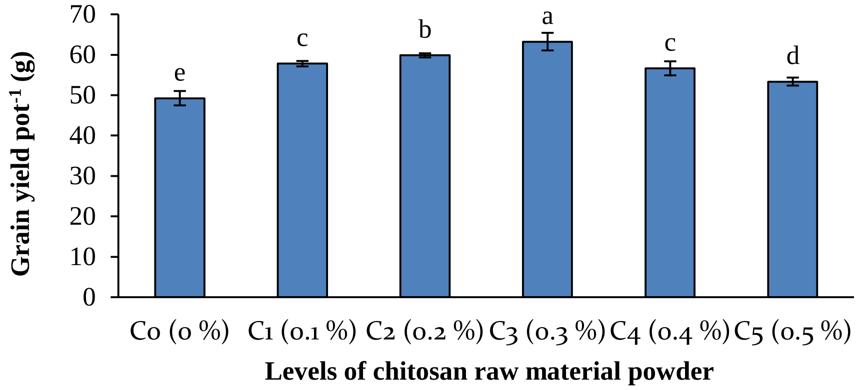
Treatment combinations	Days to first flowering	Days to 100 % flowering	Unfilled grains weight (g pot^{-1})	1000 grains weight (g)
C_0S_1	72.00bc	75.25 de	1.57 h	20.13f
C_0S_2	74.00ab	82.00 ab	3.29 c	20.05fg
C_0S_3	76.00a	84.25 a	5.53 a	20.00fg
C_1S_1	65.50fg	72.25 fg	1.56 h	20.70 d-f
C_1S_2	67.00f	73.25 e-g	2.43 de	21.45 c-e
C_1S_3	72.25bc	79.00 c	2.47 d	20.43ef
C_2S_1	63.25gh	69.25 h	1.22 i	21.38 c-e
C_2S_2	67.50ef	74.75 d-f	1.20 i	22.23 a-c
C_2S_3	72.00bc	79.25 bc	2.53 d	19.90 f-h
C_3S_1	62.75h	69.00 h	1.02 j	23.08a
C_3S_2	66.75f	74.50 d-f	1.43 h	22.65ab
C_3S_3	71.25cd	74.25 ef	1.82 g	20.05fg
C_4S_1	66.00f	72.75 e-g	1.21 i	21.68 b-d
C_4S_2	69.50de	75.50 de	2.18 f	20.50 d-f
C_4S_3	71.00cd	78.75 c	2.31 ef	18.88gh
C_5S_1	65.75f	71.00 gh	1.53 h	19.95fg
C_5S_2	72.00bc	77.25 cd	1.72 g	19.68 f-h
C_5S_3	72.25bc	78.75 c	4.56 b	18.75h
$LSD_{(0.05)}$	2.44	2.81	0.15	1.19
CV(%)	2.49	2.62	4.88	4.06

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability Here, S_1= 40 days old seedling, S_2= 45 days old seedling, S_3= 50 days old seedling, C_0= 0% Chitosan, C_1= 0.1% Chitosan, C_2= 0.2% Chitosan, C_3= 0.3% Chitosan, C_4= 0.4% Chitosan and C_5= 0.5% Chitosan.

4.11 Grain yield pot^{-1} (g)

Effect of chitosan raw material powder on grain yield pot^{-1} (g) of BRRI dhan88

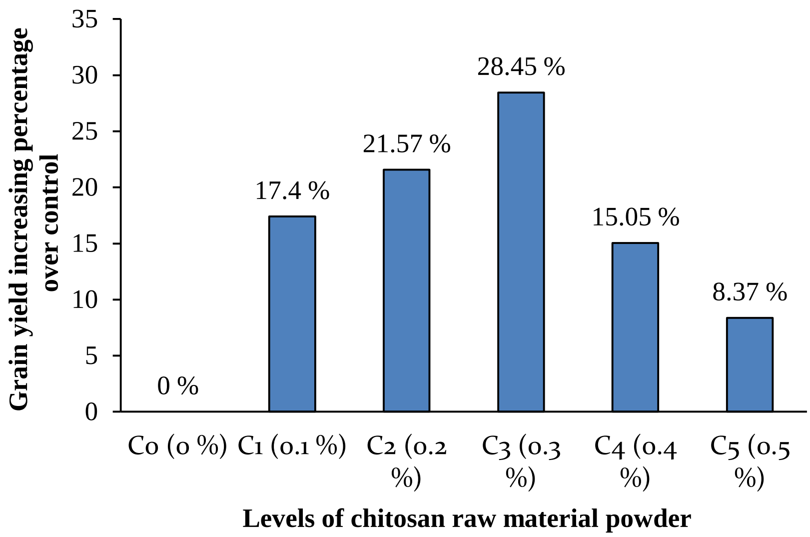
Seedlings treated with different level of chitosan raw material powder significantly effect on grain yield pot^{-1} (g) of BRRI dhan88 (Fig. 26). Experimental result showed that, maximum grain yield pot^{-1} (63.25g) was obtained in C_3 (0.3 % chitosan raw material powder) treatment, whereas the minimum grain yield pot^{-1} (49.24g) was obtained in C_0 (0 % chitosan raw material powder) treatment. It was observed from the experimental result that, chitosan raw material powder treated seedling in the seedbed influenced grain yield of BRRI dhan88 of this sequence ($C_3>C_2>C_1>C_4>C_5>C_0$). In optimum time BRRI dhan88 produced 63.25 g grains per pot, but in late sowing its reduced and obtained 49 g grains per pot. It is sown that late sowing decreased yield around 21 %. But seedling treated with chitosan raw material powder reduced this yield gap. The increase in grain yield pot^{-1} might be due to the reason that optimum doses of chitosan raw material powder application enhancing tillering number, effective tillers pot^{-1} and 1000 grains weight which influence the grain yield of rice. The result obtained from the present study was similar with the findings of Behboudi *et al.* (2018) and they reported that chitosan uses significantly improved the number of grain per spike and grain yield as compared to that in control. Ahmed *et al.* (2013) reported that 50 mg L^{-1} of Chitosan treated plants produced the highest grain yield (7.05 t ha^{-1}) followed by 75 mg L^{-1} (6.77 t ha^{-1}) and 100 mg L^{-1} (6.14 t ha^{-1}) of Chitosan where 75 and 100 mg L^{-1} Chitosan were statistically same. On the other hand, the lowest grain yield (5.83 t ha^{-1}) was observed at control treatment.



Here, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5% chitosan raw material powder

Fig. 26. Effect of chitosan raw material powder on grain yield pot^{-1} (g) of BRRI dhan88. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

From the Fig. 27 it was noticed that due to chitosan raw material powder application grain yield increased over control treatment. The maximum grain yield increased over control treatment (28.45%) was obtained in C_3 (0.3 % chitosan raw material powder) treatment, whereas minimum grain yield increased over control treatment (8.37%) was obtained in C_5 (0.5 % chitosan raw material powder). The result obtained from the present study was similar with the findings of Nguyen and Tran (2013) and 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.



Here, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5% chitosan raw material powder

Fig. 27. Effect of chitosan raw material powder on grain yield increasing percentage over control treatment of BRRI dhan88

Another field experiment was conducted at SAU farm in optimum time by using the same materials (data not shown) to investigate the impact of Chitosan raw material powder on the production of short durational *Boro* seedling (BRRI dhan88). In that experiment, 62 g grain yield pot^{-1} was found in control treatment. In the above experiment, maximum grain yield pot^{-1} (63.25g) was obtained in C_3 (0.3 % raw material powder) treatment in spite of late transplanting. By comparing the yield of both experiment, it can be seen that, late transplanting of chitosan raw material powder treated seedlings can increase 1.25g grain yield over peak season and farmers can cultivate any type of short durational crop like mustard in this time. This will increase the cropping intensity as well as income of farmers.

Effect of seedling age on grain yield pot^{-1} (g) of BRRI dhan88

Seedling age significantly effects on grain yield pot^{-1} (g) of BRRI dhan88 (Fig. 28). Experimental result revealed that, the maximum grain yield pot^{-1} (60.88 g) was obtained in S_1 (40 days old seedling) treatment. Whereas the minimum grain yield pot^{-1} (51.48 g) was obtained in S_3 (50 days old seedling) treatment. Transplants of early age seedlings might have availed weather conditions and environment properly through improved upper ground plant and below ground root development. Better root development of early age seedlings might has utilized plant nutrients and soil moisture in sufficient amount throughout life period in the field, thus improved plant growth, yield attributes and finally produced higher yield per unit area. Virk*et al*. (2020) reported that younger seedling (20 days) produced 22% more yield in comparison to (35 days) older seedling in both years, respectively. Reuben*et al.* (2016) reported that grain yield of rice significantly differs due to age of different seedling. Menete *et al*. (2008) reported that higher older seedling resulted in lesser grain yield *i.e.*9.3, 8.6 and 7.8 t ha^{-1}as against 10, 20 and 30 days old seedlings, respectively.

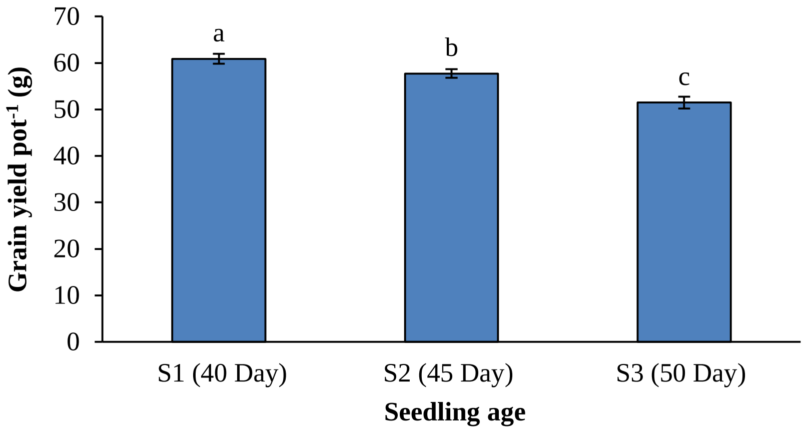


Fig. 28. Effect of seedling age on grain yieldpot^{-1} (g)of BRRI dhan88. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

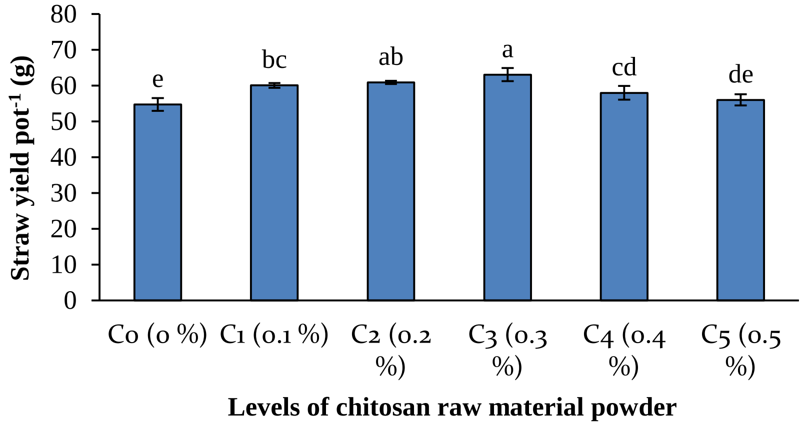
Combined effect of chitosan raw material powder and seedling age on grain yield pot^{-1} (g) of BRRI dhan88

Seedling treated with different level of chitosan raw material powder along with different ages of seedling significantly effect on grain yield pot^{-1} (g) of BRRI dhan88 (Table 8). Experimental result revealed that, the maximum grain yield pot^{-1} (68.92 g) was obtained in C_3S_1 treatment combination. Whereas the minimum grain yield hill^{-1} (41.26 g) was obtained in C_0S_3 treatment combination.

4.12 Straw yield pot^{-1} (g)

Effect of chitosan raw material powder on straw yield pot^{-1} (g) of BRRI dhan88

Straw yield pot^{-1} (g) of BRRI dhan88 was significantly varied due to the effect of different level of chitosan raw material powder application (Fig. 29). Experimental result showed that the maximum straw yield pot^{-1} (63.08g) was obtained in C_3 (0.3 % chitosan) treatment which was statistically similar with (60.92g) C_2 (0.2 % chitosan raw material powder). Whereas the minimum straw yield pot^{-1}(54.75g) was obtained in C_0 (0 % chitosan raw material powder) treatment which was statistically similar with (56.00g) C_5 (0.5 % chitosan).Sultana *et al.* (2015) also found similar result which supported the present finding and reported that straw yield shows significant differences between control plants and foliar sprayed chitosan plants and highest straw yield (4.38 t/ha) was recorded under 100 ppm oligomeric chitosan and lowest straw yield (3.24 t/ha) was observed under 0 ppm oligomeric chitosan. Kananont *et al.* (2015) also reported that (Fermented chitin waste) FCW @ 1% the straw yield differ significantly from 0.5% FCW, 0.25% FCW and the rest of the treatment.



Here, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5% chitosan raw material powder

Fig. 29. Effect of chitosan raw material powder on straw yield pot^{-1} (g)of BRRI dhan88. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

Effect of seedling age on straw yield (g) pot^{-1} of BRRI dhan88

Seedling age significantly effect on straw yield pot^{-1} (g) of BRRI dhan88 (Fig. 30). Experimental result revealed that the maximum straw yield pot^{-1} (62.58 g) was obtained in S_1 (40 days old seedling) treatment. Whereas the minimum straw yield pot^{-1} (53.67 g) was obtained in S_3 (50 days old seedling) treatment. Panigrahi*et al*. (2014) also found similar result which supported the present finding and reported that growth, yield and economics of basmati rice did not vary much between the crops planted with 10 and 15-day old seedlings. Bagheri *et al.* (2011) noticed that the highest (635.8 g m^{-2}) straw yield was obtained from 20 days old seedlings over 30 and 40 days. Rajesh and Thanunathan (2003) reported that the seedling age had significant difference on straw yield. Planting of 40 day old seedlings found to be optimum to get significantly higher (5.63 t ha^{-1}) straw yield compared to 30 (5.09 t ha^{-1}) and 50 (4.76 t ha^{-1}) days old seedlings. Sharma and Ghosh (1998) stated that younger seedlings produced significantly higher straw (7.53 t ha^{-1}) yields as compared to older seedlings from their studies on hybrids rice.

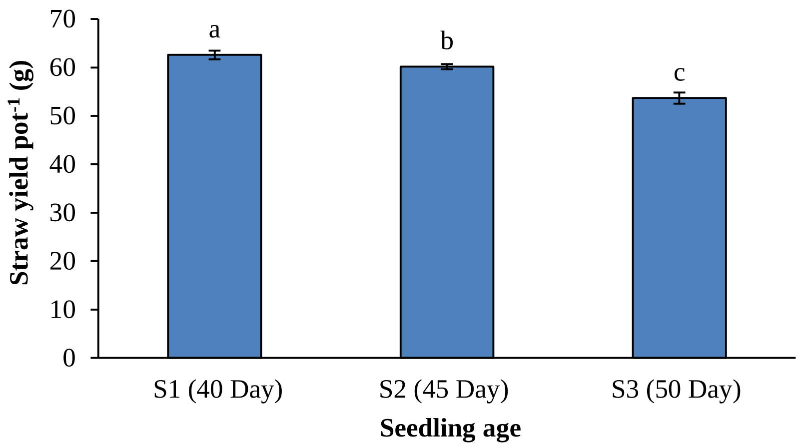


Fig. 30. Effect of seedling age on straw yield pot^{-1} (g) of BRRI dhan88. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

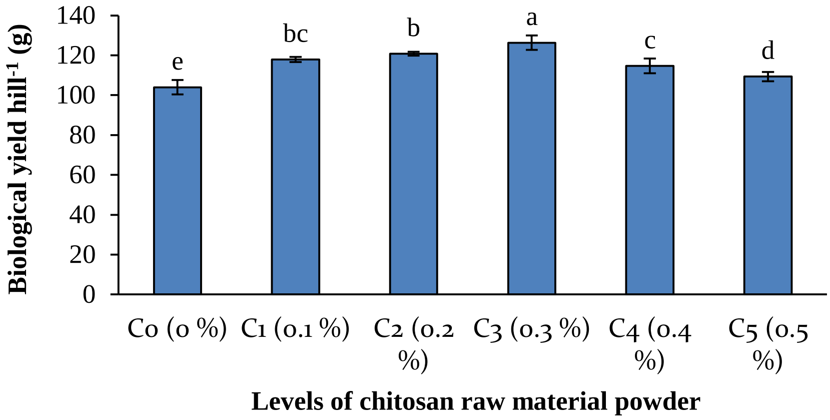
Combined effect of chitosan raw material powder and seedling age on straw yield (g) pot^{-1}

Seedling treated with different level of chitosan raw material powder along with different ages of seedling significantly effect on straw yield pot^{-1} (g) of BRRI dhan88 (Table 8). Experimental result revealed that, the maximum straw yield pot^{-1} (66.75 g) was obtained in C_3S_1 treatment combination which was statistically similar with C_4S_1 (65.25 g), C_3S_2 (64.50 g) and C_2S_1 (62.75 g). Whereas the minimum straw yield pot^{-1} (46.50 g) was obtained in C_0S_3 treatment combination which was statistically similar with C_4S_3 (49.75 g) treatment combination.

4.13 Biological yield pot^{-1} (g)

Effect of chitosan raw material powder on biological yield pot^{-1} (g) of BRRI dhan88

Biological yield pot^{-1} (g) of BRRI dhan88 was significantly varied due to the effect of different level of chitosan raw material powder application (Fig. 31). Experimental result showed that, the maximum biological yield pot^{-1} (126.34 g) was obtained in C_3 (0.3 % chitosan raw material powder) treatment. Whereas the minimum biological yield pot^{-1}(103.99 g) was obtained in C_0 (0 % chitosan raw material powder) treatment. The result obtained from the present study was similar with the findings of Ahmed (2015) who reported that chitosan application showed non-significant effect to biological yield, but slightly influenced biological yield comparable to control treatment.



Here, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5% chitosan raw material powder

Fig. 31. Effect of chitosan level on biological yield pot^{-1} (g) of BRRI dhan88. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

Effect of seedling age on biological yield pot^{-1} (g) of BRRI dhan88

Seedling age significantly effect on biological yield pot^{-1} (g) of BRRI dhan88 (Fig. 32). Experimental result revealed that the maximum biological yield pot^{-1} (123.46 g) was obtained in S_1 (40 days old seedling) treatment. Whereas the minimum biological yield pot^{-1} (105.14 g) was obtained in S_3 (50 days old seedling) treatment. Chakrabortty (2013) also found similar result which supported the present finding and reported that seedling age significantly varied biological yield of *Boro* rice and the maximum biological yield (9.84 t ha^{-1}) was recorded in 16 days old seedling and the minimum biological yield (8.73 t ha^{-1}) was found in 30 days old seedling.

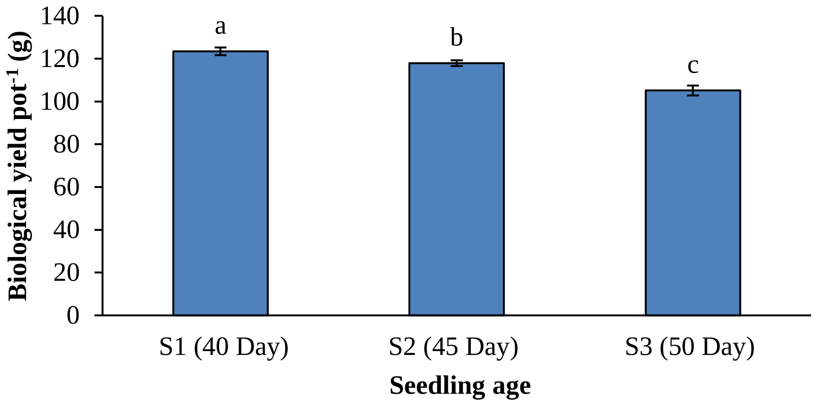


Fig. 32. Effect of seedling age on biological yieldpot^{-1} (g) of BRRI dhan88.Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

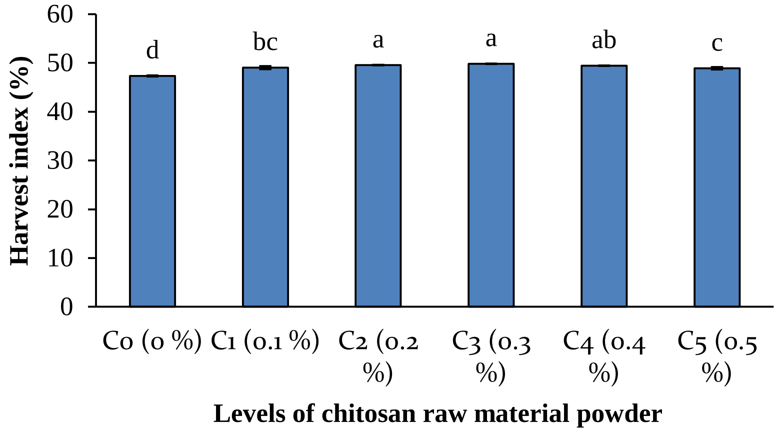
Combined effect of chitosan and seedling age on biological yield pot^{-1} (g) of BRRI dhan88

Combined effect of chitosan raw material powder and seedling age significantly effect on biological yield pot^{-1}(g) of BRRI dhan88 (Table 8). Experiment result revealed that, the maximum biological yield pot^{-1} (135.67 g) was obtained in C_3S_1 treatment combination. Whereas the minimum biological yield hill^{-1}(87.76 g) was obtained in C_0S_3 treatment combination.

4.14 Harvest index (%)

Effect of chitosan raw material powder on harvest index (%) of BRRI dhan88

Different chitosan raw material powder treated seedling significantly effect on harvest index of BRRI dhan88 (Fig. 33). Experimental result showed that, the maximum harvest index (49.84 %) was obtained in C_3 (0.3 % chitosan) treatment which was statistically similar with (49.56 %) C_2 (0.2 % raw material powder) and (49.43 %) C_4 (0.4 % chitosan) treatment. Whereas the minimum harvest index (47.32 %) was obtained in C_0 (0 % raw material powder) treatment. The result obtained from the present study was similar with the findings of Chibu *et al.* (2000) and they found that in soybean, harvest index was significant in chitosan application plants compare to control.



Here, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5% chitosan raw material powder

Fig. 33. Effect of chitosan level on harvest index (%) of BRRI dhan88.Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

Effect of seedling age on harvest index (%) of BRRI dhan88

Seedling age showed non significantly effect on harvest index of BRRI dhan88 (Fig. 34). Experiment result revealed that the maximum harvest index (49.14 %) was obtained in S_1 (40 days old seedling) treatment. Whereas the minimum harvest index (48.92 %) was obtained in S_3 (50 days old seedling) treatment.

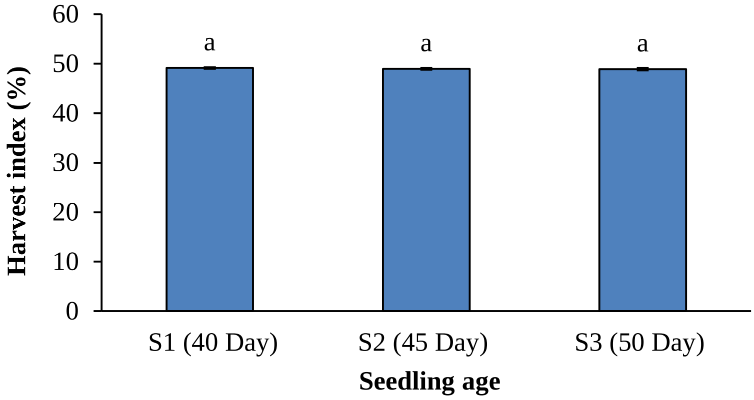


Fig. 34. Effect of seedling age on harvest index (%) of BRRI dhan88. Bars with different letters are significantly different at $p \leq 0.05$ applying DMRT.

Combined effect of chitosan raw material powder and seedling age on harvest index (%) of BRRI dhan88

Different level of chitosan raw material powder along with seedling age showed non-significant effect on harvest index of BRRI dhan88 (Table 8). Experimental result revealed that, the maximum harvest index (50.03 %) was obtained in C_0S_1 treatment combination. Whereas the minimum harvest index (47.01 %) was obtained in C_5S_3 treatment combination.

Table 8. Combined effect of chitosan raw material powder and seedling age on grain, straw, biological yield pot^{-1} and harvest index of BRRI dhan88

Treatment combinations	Grain yield (gpot^{-1})	Straw yield (gpot^{-1})	Biological yield (gpot^{-1})	Harvest index (%)
C_0S_1	55.51 f	60.50 c-f	116.01 d-f	50.03
C_0S_2	50.95 g	57.25f	108.20 g	49.98
C_0S_3	41.26 h	46.50h	87.76 i	49.75
C_1S_1	59.57 cd	61.75 b-e	121.32 cd	49.68
C_1S_2	59.09 c-e	61.50 b-e	120.59 c-e	49.61
C_1S_3	54.77 f	57.00f	111.77 fg	49.50
C_2S_1	61.95 bc	62.75 a-d	124.70 bc	49.39
C_2S_2	59.80 cd	60.75 c-f	120.55 c-e	49.27
C_2S_3	57.82 d-f	59.25 d-f	117.07 d-f	49.27
C_3S_1	68.92 a	66.75a	135.67 a	49.10
C_3S_2	63.70 b	64.50 a-c	128.20 b	49.00
C_3S_3	57.14 d-f	58.00ef	115.14 ef	49.00
C_4S_1	63.38 b	65.25ab	128.63 b	48.92
C_4S_2	57.31 d-f	59.00 d-f	116.31 d-f	48.88
C_4S_3	49.25 g	49.75gh	99.00 h	48.88
C_5S_1	55.94 ef	58.50ef	114.44 f	47.85
C_5S_2	55.54 f	58.00ef	113.54 fg	47.09
C_5S_3	48.61 g	51.50g	100.11 h	47.01
$LSD_{(0.05)}$	3.34	4.10	5.73	NS
CV(%)	4.15	4.92	3.50	1.24

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, S_1= 40 days old seedling, S_2= 45 days old seedling, S_3= 50 days old seedling, C_0= 0% Chitosan, C_1= 0.1% Chitosan, C_2= 0.2% Chitosan, C_3= 0.3% Chitosan, C_4= 0.4% Chitosan and C_5= 0.5% Chitosan.

4.15 Chemical Properties of seedbed soils after transplant

pH and percent total nitrogen

Form the table 9 it was noticed that application of different level of chitosan raw material powder influenced seedbed soil pH and total nitrogen percentage from initial level (5.8 and 0.04 %). Among different treatments, C_5 treatment (0.05 % chitosan raw material powder) increasing seedbed soil pH (6.5) and C_4 treatment recorded the highest total nitrogen (0.12 %) comparable control treatment due to reason that chitosan raw material powder has higher pH which influenced the soil pH whereas application of chitosan raw material powder increasing the nutrient supplying capacity to the soil result in increasing total nitrogen percentage in the seedbed soil.

Table 9. Effect of different chitosan raw material powder treatments on pH and % total nitrogen of seedbed soil after seedling transplant

Treatments	**pH**		**% total nitrogen**	
	Initial	**After**	**Initial**	**After**
C_0	5.8	5.80 d	0.04	0.04 e
C_1	5.8	6.00 c	0.04	0.05 e
C_2	5.8	5.90 c	0.04	0.09 c
C_3	5.8	6.30 b	0.04	0.07 d
C_4	5.8	6.30 b	0.04	0.12 a
C_5	5.8	6.50 a	0.04	0.11 b
$LSD_{(0.05)}$	0	0.18	0	0.003
CV(%)	0	1.97	0	2.34

Here, Level of chitosan raw material powder, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5%.

Percent organic carbon and organic matter

Chitosan raw material powder contents 7.52 % organic carbon and 12.96 % organic matter. From the table 10 it was noticed that, the application of different level of chitosan raw material powder influenced organic carbon percentages and organic matter comparable to control treatment. The maximum organic carbon (0.76 %) and organic matter (1.31 %) were recorded in C_5 treatment comparable to control treatment. More the application of chitosan raw material powder more the organic carbon and organic matter present in the seedbed soil. But higher amount of organic carbon and organic matter create toxicity and compactness of soil in the root zone of the plant. As a result, plant cannot uptake essential nutrients result in poor growth and development.

Table10. Effect of different chitosan raw material powder treatments on Percent organic carbon and organic matter of seedbed soil after seedling transplant

Treatments	**Organic carbon (%)**		**Organic matter (%)**	
	Initial	**After**	**Initial**	**After**
C_0	0.5	0.50 d	0.87	0.87 e
C_1	0.5	0.59 c	0.87	1.02 d
C_2	0.5	0.58 c	0.87	1.00 d
C_3	0.5	0.63 b	0.87	1.09 c
C_4	0.5	0.75 a	0.87	1.20 b
C_5	0.5	0.76 a	0.87	1.31 a
LSD$_{(0.05)}$	0	0.02	0	0.03
CV(%)	0	2.62	0	2.16

Here, Level of chitosan raw material powder, C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5%.

CHAPTER V

SUMMARY AND CONCLUSION

A pot experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during November-2019 to April-2020, to investigate the improvement of late sowing *Boro* seedling characters by using chitosan raw material powder and their yield performance at different seedling age. The experiment was consisted of two factors, and followed Randomized complete design (RCD) with four replications. Factor A: chitosan raw material powder level (6) *viz;* C_0= 0%, C_1= 0.1%, C_2= 0.2%, C_3= 0.3%, C_4= 0.4% and C_5= 0.5% of chitosan raw material powder and Factor B: Different ages of seedling (3) *viz;* S_1= 40 days old seedling, S_2= 45 days old seedling and S_3= 50 days old seedling. Data on different parameters were collected for assessing results for this experiment and showed significant variation in respect of different characteristics of BRRI dhan88 due to the effect of different chitosan raw material powder level, seedling age and their combinations.

In case of different chitosan raw material powder level, experimental result showed that, the average seedling height (17.75 cm), fresh weight seedling^{-1} (531.67 mg), oven dry weight seedling^{-1} (96.67 mg), seedling strength (5.44 mg/cm), number of tillers pot^{-1} (6.50, 13.75, 26.67 and 36.42) at 30, 40, 50 and 60 DAT and effective tillers pot^{-1} (28.33) were obtained in C_3 (0.3 % chitosan raw materials powder) treatment. The maximum days for first flowering (74.00), 100 % flowering (80.50), unfilled grains weight pot^{-1} (3.46 g) were obtained in C_0 (0 % chitosan raw materials powder) treatment. The maximum 1000 grains weight (21.93 g), grain yield pot^{-1} (63.25 g), straw yield pot^{-1} (63.08 g), biological yield pot^{-1} (126.34 g) and harvest index (49.84 %) was obtained in C_3 (0.3 % chitosan raw materials powder) treatment.

Whereas the minimum average seedling height (13.53 cm) was obtained in C_0 (0 % chitosan raw materials powder) treatment. The minimum average seedling height (13.53 cm), fresh weight seedling^{-1} (323.58 mg), oven dry weight seedling^{-1} (58.83 mg) and seedling strength (4.35 mg/cm) were obtained in C_0 (0 % chitosan raw materials powder) treatment. The minimum number of tillers pot^{-1} (4.67) at 30 DAT was obtained in C_0 (0 % chitosan raw materials powder) treatment. At 40 DAT the minimum number of tillers pot^{1} (8.42) was obtained in C_5 (0.5 % chitosan raw materials powder) treatment. At 50 and 60 DAT the minimum number of tillers pot^{-1}

(15.33 and 31.08) was obtained in C_0 (0 % chitosan raw materials powder) treatment. The minimum effective tillers pot^{-1} (18.83) was obtained in C_0 (0 % chitosan raw materials powder) treatment. The minimum days for first flowering (66.92) and minimum days for 100 % flowering (72.58) were obtained in C_3 (0.3 % chitosan raw materials powder) treatment. The minimum unfilled grains weight pot^{-1} (1.42 g) was obtained in C_3 (0.3 % chitosan raw materials powder) treatment. The minimum 1000 grains weight (19.46 g) was obtained in C_5 (0.5 %chitosan raw materials powder) treatment. The minimum grain yield pot^{-1} (49.24 g), straw yield pot^{-1} (54.75 g), biological yield pot^{-1} (103.99 g) and harvest index (47.32 %) were obtained in C_0 (0 % chitosan raw materials powder) treatment.

In respect of different seedling age, experimental result revealed that, the maximum average seedling height (16.50 cm), fresh weight seedling^{-1} (458.33 mg), oven dry weight seedling^{-1} (83.33 mg), seedling strength (4.98 mg/cm) were obtained in S_3 (50 days old seedling) treatment. The maximum number of tillers pot^{-1} (6.67, 14.46, 26.83 and37.63) at 30, 40, 50 and 60 DAT were obtained in S_1 (40 days old seedling) treatment. The maximum effective tillers pot^{-1} (22.96) was obtained in S_1 (40 days old seedling) treatment. The maximum days for first flowering (72.46), the maximum days for 100% flowering (79.04), unfilled grains weight pot^{-1} (3.20 g) were obtained in S_3 (50 days old seedling). The maximum 1000 seeds weight (21.15 g), grain yield pot^{-1} (60.88 g), straw yield pot^{-1} (62.58 g), biological yield pot^{-1} (126.34 g) and harvest index (49.14 %) were obtained in S_1 (40 days old seedling) treatment. Whereas the minimum average seedling height (14.07 cm), fresh weight seedling^{-1} (368.04 mg), oven dry weight seedling^{-1} (66.92 mg), minimum seedling strength (4.72 mg/cm) were obtained in S_1 (40 days old seedling) treatment. The minimum number of tillers pot^{-1} (4.96, 8.58, 19.58 and 28.63) at 30, 40, 50 and 60 DAT was obtained in S_3 (50 days old seedling) treatment. The minimum effective tillers pot^{-1} (21.33) was obtained in S_3 (50 days old seedling) treatment. The minimum days for first flowering (65.88), the minimum days for 100% flowering (71.58), unfilled grains weight pot^{-1} (1.35 g) were obtained in S_1 (40 days old seedling) treatment. The minimum 1000 seeds weight (19.67 g), grain yield pot^{-1} (51.48 g), straw yield pot^{-1} (53.67 g), biological yield pot^{-1} (105.14 g) and harvest index (48.92 %) were obtained in S_3 (50 days old seedling) treatment.

In case of combined effect, experimental result showed that, the maximum average seedling height (20.06 cm), fresh weight seedling^{-1} (605.00 mg), oven dry weight seedling^{-1} (110.00 mg) and seedling strength (5.48 mg/cm) were obtained in C_3S_3 treatment combination. The maximum tiller number pot^{-1} (8.25, 20.25, 36.50 and 43.25) at 30, 40, 50 and 60 DAT was obtained in C_3S_1 treatment combination. The maximum effective tillers pot^{-1} (30.25) was obtained in C_3S_1 treatment combination. The maximum days for first flowering (76.00), maximum days for 100% flowering (84.25) and unfilled grains weight pot^{-1} (5.53 g) were obtained in C_0S_3 treatment combination. The maximum 1000 seeds weight (23.08 g), grain yield pot^{-1} (68.92 g), straw yield pot^{-1} (66.75 g) and biological yield pot^{-1} (135.67 g) were obtained in C_3S_1 treatment combination. The maximum harvest index (50.03 %) was obtained in C_0S_1 treatment combination.

Whereas the minimum seedling height (13.13), fresh weight seedling^{-1} (299.75 mg), oven dry weight seedling^{-1} (54.50 mg) and seedling strength (4.15 mg/cm) were obtained in C_0S_1 treatment combination. The minimum tiller number pot^{-1} (2.50, 6.25, 12.00 and 18.75) at 30, 40, 50 and 60 DAT was obtained in C_0S_3 treatment combination. The minimum days for first flowering (62.75), minimum days for 100% flowering (69.00), unfilled grains weight pot^{-1} (1.02 g) were obtained in C_3S_1 treatment combination. The minimum 1000 seeds weight (18.75 g) was obtained in C_5S_3 treatment combination. The minimum grain yield pot^{-1} (41.26 g), straw yield pot^{-1} (46.50 g) and biological yield pot^{-1} (87.76 g) were obtained in C_0S_3 treatment combination. The minimum harvest index (47.01 %) was obtained in C_5S_3 treatment combination.

Conclusion

Based on the above results of the present study, the following conclusions may be drawn

i. Chitosan raw material powder improved the seedling characters (seedling height, fresh weight, oven dry weight and seedling strength), yield and yield attributing characters of BRRI dhan88.
ii. All the treatments using chitosan raw material powder showed better performance by the following sequence $C_3>C_2>C_1>C_4>C_5>C_0$. Among the

treatments, C_3 showed the superior performance. Among the treatment combinations, C_3S_1 showed the best performance.

iii. Late sowing decreases grain yield up to 21% compared to optimum season due to cold injury & other environmental factors. Late sowing farmers may overcome this yield gap by using optimum doses of chitosan raw material powder in seedbed soil.

iv. Chitosan raw material powder improves chemical properties of soil for sustainable agriculture.

Recommendations

From the above experimental findings, it is apparent that the application of chitosan raw material powder @ 0.3% in seedbed soil improved seedling characters, yield and yield parameters of BRRI dhan88. So, it is suggested to the late sowing farmers to apply 0.3% chitosan raw material powder in seedbed soil for better performance. In order to recommend the practices for the rice growers, the following aspects would be considered in future:

i. Similar experiments need to be conducted in field condition in different locations and seasons of Bangladesh to draw a final conclusion regarding to the effect of chitosan raw material powder application in the seedbed along with different ages seedling for obtaining better grain yield of BRRI dhan88.

REFERENCE

Abel-Mawgoud, 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.

Ahmed, F. (2015). Performance of BRRI dhan49 as influenced by modified chitosan in the seedbed and in the main field. M. S. Thesis, Department of soil science, Sher-e-Bangla Agricultural University, Dhaka−1207, Bangladesh.

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.

Ahmed, R., Hossain, M. E., Ullah, M. A. Gazi, A. R. and Rahman, M. Z. (2013). Effect of chitosan on growth and yield of rice cv. BRRI dhan29. *J. Agrofor. Environ.* **7**(2): 33-35.

Ali, M. S., Hasan, M. A., Sikder, S., Islam, M. R., & Hafiz, M. H. (2013). Effect of seedling age and water management on the performance of boro rice (Oryza sativa L.) variety BRRI dhan28. *The Agric.* **11**(2): 28-37.

Ali, S. M., Hasan, M. A., Sikder, S., Islam, M. R., Hafiz, M. H. R. (2013). Effect of seedling age and water management on the performance of boro rice (*Oryza sativa*) Variety BRRI dhan 28. *Agric.* **11**: 28–37.

Anonymous, (1989). Annual Weather Report, meteorological Station, Dhaka, Bangladesh.

Anonymous. (1988 a). The Year Book of Production. FAO, Rome, Italy.

Anonymous. (1988 b). Land resources appraisal of Bangladesh for agricultural development. Report No.2. Agro-ecological regions of Bangladesh, UNDP and FAO. pp. 472–496.

Anonymous. (2004). Effect of seedling throwing on the grain yield of wart landrace compared to other planting methods. Crop Soil Water Management Program Agronomy Division, BRRI, Gazipur-1710.

APCAS (Asia and pacific commission on agricultural statistics). (2016). Agriculture Market Information System (AMIS) in Bangladesh. Twenty-sixth session on Asia and Pacific Commission Agriculture Statistics. pp. 15–19.

Bagheri, R., Mobasser, H. R., Ghanbari-Malidarreh, A and Dastan, S. (2011). Effect of seedling age and potassium rates on morphological traits related-lodging, yield and yield components of rice (*Oryza sativa* L.) in Iran. *American-Eurasian J. Agric. Env. Sci.* **11**(2): 261-268.

Basu, S., Sharma, S. P. and Basu, S. (2003). Effect of transplanting on vegetative, floral and seed characters of maize (*Zea mays*) parental lines in spring-summer season. *Indian J. Agril. Sci.* **73**(1): 44-48.

BBS (Bangladesh Bureau of Statistics). (2017). Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning. Dhaka. Bangladesh.

BBS (Bangladesh Bureau of Statistics). (2018). Statistical Monthly Bulletin of Bangladesh, Bureau of Statistics, Statistics Division, Ministry of Planning, Government of People's Republic. Bangladesh, Dhaka. pp. 140–144.

Behboudi F. Tahmasebi Z. Sarvestani M. Zaman Kassaee S.A.M. Modares Sanavi A. Sorooshzadehand S.B. Ahmadi. 2018. Evaluation of Chitosan Nanoparticles on Yield and Yield Components of Barley (*Hordeum vulgare* L.) under Late Season Drought Stress. *J. Water and Environ. Nanotech.* **3**: 22–39.

Bolto, B., Dixon, D. and Eldridge, R. (2004). Ion exchange for the removal of natural organic matter. *Rea. Fun. Poly*. **60**: 171-182.

Boonlertnirun, S., Boonlertnirun, K., Suvannasara, R., and Promsomboon, P. (2012). Chitosan inCombination with Chemical Fertilizer on Agronomic Traits and Some PhysiologicalResponses to Yield Potential of Rice (*Oryza sativa* L). Bangkok, Thailand: KasetsartUniv. Res. *J. Bio. Sci*. **7**(2): 64-68.

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

Boonlertnirun, S., Sarobol, A., Mechoui, S. and Sooksathan. A. (2006 A). Effect of Molecular Weight of Chitosan on Rice Yield Potentialcv. Suphanburi 1. *Kasetsart J. Nat. Sci*: **40**(4): 1-2.

Chakrabortty, S. (2013). Growth and Yield of Boro Rice as Affected by Seedling Age and Planting Geometry Under System of Rice Intensification. M. S. Thesis, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.

Chandrapala, A. G., Yakadri, M., Kumar, M. R. and Raj, G. B. (2010). Productivity and economics of rice (*Oryza sativa*) -maize (*Zea mays*) as influenced by methods of crop establishment, Zn and S application in rice. *Indian J. Agron.* **55**(3): 171-176.

Chibu, H., Shibayama, H., Mitsutomi, M. and Arima, S. (2000). Effects of chitosan application on growth and chitinaseactivity in several crops. Marine Highland Biosci. *Center. Rep.* **12**: 27-35.

Dahal, K. R. and Khadka, B. R. (2012). Performance of rice withvaried age of seedlings andplanting geometry under system of rice intensification (SRI) in farmer's field in Western Terai, Nepal. *Nepal J. Sci. Tech*. **13**(2): 1-6.

Dhillon, B. S., Sharma, P. K. and Dhingra, M. (2018). Boron and TIBA induced physiological and anatomical changes in relation to dry matter partitioning in spring sunflower (*Helianthus annus* L.) under delayed sowing. *Indian J. Plant Physiol*. **23**: 352–359.

Diechar, G., Koma, Y. and Saing. (2002). Experiments with system of rice intensification in Cambodia, Deutscher Tropentaq Witzenhausen, pp. 9-11.

Edris, K. M., Islam, A. M. T., Chowdhury, M. S. and Haque, A. K. M. M. (1979). Detailed Soil Survey of Bangladesh, Dept. of Soil Survey, BAU and Govt. Peoples Republic of Bangladesh. p 118.

Express, T., 2021. Boro acreage falls to three-year low. [online] The Financial Express. Available at: <https://thefinancialexpress.com.bd/trade/boro-acreage-falls-to-three-year-low-1589600548> [Accessed 19 June 2021].

Faghani, R., Mobasser, H. R., Dehpor, A. A. and Kochaksarai, S. T. (2011) The effect of planting date and seedling age on yield and yield components of rice (Oryza sativa L.) varieties in North of Iran. *Afr. J. Agric. Res.* **6**: 2571–2575.

FRG (Fertilizer Recommendation Guide). (2012). Fertilizer Recommendation Guide, Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka- 1215. p. 274.

Gani, A., Makarim, A. K., Balasubramanian, V., Zaini, Z., Syamsiah, I., Diratmadja, I. G. P. A., Arafah, H. and Wardana, I. P. (2002). System of rice intensification (SRI): Evaluation of seedling age and selected components in Indonesia, In Water wise rice production-IRRI. pp. 129-139.

Gomez, M. A. and Gomez, A. A. (1984). Statistical procedures for Agricultural Research. John Wiley and sons. New York, Chichester, Brisbane, Toronto. Pp. 97–129, 207–215.

Hidangmayum A, Dwivedi P, Katiyar D, Hemantaranjan A (2019). Application of chitosan on plant responses with special reference to abiotic stress. *Physiol. Mole. Bio. Plants.* **25**: 313-326.

Hussain, A. M. M., Barua, P. and Halder, S. R. (2003). Verification and refinement of the system of rice intensification (SRI) project in selected areas of Bangladesh. Trial Monitoring Survey Report on Chatkhil and Begumgonj in Noakhali District.

Islam, M. S. A. and Ahmed, J. U. (1981). Effect of age of seedlings on yield of the transplant aman rice cultivars. *Bangladesh J. Agril. Sci.* **892**: 175–179.

Islam, M., Hossen, K., Afroge, M., Hosen, A., Masum, K., Osma, M., Joy, M. and Chowdhury, F. (2021). Effect of different age of seedlings on the growth and yield performance of transplanted Aus rice variety. *Inn. Agric.* **4**: 1-6.

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.

Jia, X., Zhu, Q., Yang, Z., Sun, Y., Guo, X., Shi, Y. and Ma, J. (2014) Effect of seedling age on yield and population quality of mechanized transplanted hybrid rice. Transactions of the Chinese Society of Agricultural Engineering. **30**: 18–25.

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

Katiyar, D., Hemantaranjan, A. and Singh, B. (2015). Chitosan as a promising natural compound to enhance potential physiological response in plant: a review. *Indian J. Plant Physiol.* **20**: 1-9.

Katsura, K., Maeda, S., Horie, T. and Shiraiwa, T. (2007) Analysis of yield attributes and crop physiological traits of Liangyoupeijiu, a hybrid rice recently bred in China. *Field Crops Res.***103**: 170–177.

Kavitha, M. P. and Ganesharaja, V. (2012). Evalution of agronomic options under system of rice intensification (SRI) in Periyar-Vaigai command area. Extended summaries, 3, 3rd International Agronomy Congress. New Delhi. pp. 770-772. 26-30 November.

Khan, W.M., Prithiviraj, B. and. Smith,D. L (2002). Effect of foliar application of chitin and chitosan oligosaccharide on photosynthesis of maize and soybean. *Photosynthetica.* **40**:624-624.

Krishana, A., Biradarpatil, N. K. and Channappagoudar, B. B. (2009). Influence of system of rice intensification (SRI) cultivation on seed yield and quality, Karnataka J. *Agric. Sci.* **21**(3): 369-372.

Krishna, A. (2006). Influence of system of rice intensification (SRI) on seed yield, quality and storeability of rice. Ph.D. Thesis, University of Agricultural Sciences, Dharwad.

Krivtsov, G.G., Loskutova, N. A., Konyuknova, N.S. Khor'kov, E. I., Kononenko, N.V. and Vanyushine,B.F, (1996). Effect of chitosan elicitors on wheat plants. Biology Bulletin of the Russian Academy of Sciences. **23**: 16-21.

Kueneman, F. A. (2006). Improved rice production in a changing environment: From concept to practice. *Intl. Rice Comm. Newsl.* **55**:1-20.

Lhendup, K. (2006). Ongoing Feasibility study of the system of rice intensification (SRI) in Bhutan. Poster presented at the Second International Rice Congress, in New Delhi. pp. 6-13.

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

Lizárraga-Paulín, E. V., Torres-Pacheco, I., Moreno-Martínez, E. and Miranda-Castro, S. P. (2011). Chitosan application in maize (*Zea mays*) to counteract the effects of abiotic stress at seedling level. *African J. Biotech.***10**(34):6439-6446.

Maclean, J. L., Dawe, D. C., Hardy, B. and Hettel, G. P. (2002). Rice Almanac. Los Banos (Philippines): International Rice Research institute, Bouake (Cote d'lvoire): West Africa Rice Development Association, Cali (Colombia): International Center for Tropical Agriculture, Rome (Italy). pp. 253.

Magzter. (2021). Business Standard Newspaper. September 16, 2020. pp. 1-2. https://www.magzter.com/IN/Business-Standard-PrivateLtd/BusinessStandard/Newspaper/519197.

Malerba, M. and Cerana, R. (2018). Recent advances of chitosan applications in plants. *Polymers.***10**(2): 118-127.

Martinez, L., Castro, I., Diaz, L. and Nunez, M. (2007). Influence of seed treatment with chitosan on tomato (Lycopersicum esculentum L.) plant growth. La Habana, Cuba: Instituto Nacional de Ciencias Agricolas. *Cultivos Tropicales.* **28**(4): 79-82.

Menete, M. Z. L., Van, E. H. M., Brito, R. M. L., DeGloria, S. D. and Famba, S. (2008). Evaluation of system of rice intensification (SRI) component practices and their synergies on salt-affected soils. *Field Crops Res.* **109**: 34-44.

Mobasser, H.R., Tari, D. B., Vojdani, M., Abadi, R. S. and Eftekhari, A. (2007). Effect of seedling age and planting space on yield and yield Components of rice (Neda Variety). *Asian J. Plant Sci.* **6**: 438–440.

Nguyen, V. and Tran, T. (2013). Application of chitosan solutions for rice production in Vietnam. *African J. Biotechnol.* **12**(4): 382-384.

Oteng, J. W. and Anna, R. (2003). Rice production in Africa through SRI, Senior research scientist, faculty of Agriculture University, Ghana, Accra. pp. 10-17.

Ouyang, S. and Langlai, X. (2003). Effect of chitosanon nutrient quality and someagronomic characteristic of non – headingchinese cabbage. *Plant Physiol. Comm*. **39**: 21-24.

Panigrahi, T., Garnayak, L. M., Ghosh, M., Bastia, D. K. and Ghosh, D. C. (2014). Productivity and profitability of basmati rice varieties under SRI. *Int. J. Bio. Stress Manag*. **5**(3): 333-339.

Pasuquin, E., Lafarge, T. and Tubana, B. (2008). Transplanting young rice seedlings in irrigated rice fields: early and high tiller production enhanced grain yield. *Field Crops Res.***105** :141–155.

Patra, P. S. and Haque, S. (2011). Effect of seedling age on tillering pattern and yield of rice (Oryza sativa L.) under system of rice intensification. *ARPN J. Agric. Bio. Sci.* **6** (11): 33-35.

Pingali, P. L., Hossain, M. and Gerpacio, R. V. (1997). The Asian rice bowls: The returning Crisis? CAB International, London and IRRI, MCPO box 3217. Makati 1271, Philippines.

Porpavi, S., Anbumani, S., Sathiyabama, K. and Ravi, V. (2006). Evaluation of varietal performance under SRI. In: National Symposium on System of Rice Intensification. Present Status -Future Prospects, Hyderabad Andhra Pradesh, Soil and water Management Research Institute, Kattuthottam, Thanjavur. pp. 613.

Pramanik, K and Bera, A. K. (2013). Effect of seedling age and nitrogen fertilizer on growth, chlorophyll content, yield and economics of hybrid rice (*Oryza sativa* L.). *Int. J. Agron. PlantProd.***4**: 3489-3499.

Prashanth, K. V. H. and Tharanathan, R. N. (2007). Chitin/chitosan: modifications and their unlimited application potential- an overview. *Trends in Food Sci. Technol.* **18**: 117-131.

Rajesh, V. and Thanunathan, K. (2003). Effect of seedling age, number and spacing on yield and nutrient uptake of traditional Kambanchamba rice. *Madras Agric. J.* **90**(1-3): 47-49.

Rajoka, M. S. R., Zhao, L., Mehwish, H. M., Wu, Y. and Mahmood, S. (2019). Chitosan and its derivatives: synthesis, biotechnological applications, and future challenges. *App. Mic. Biotech.***103**: 1557-1571.

Randriamiharisoa, R. and Uphoff, N. (2002). Factorial trials evaluating the separate and combined effects of SRI practices, In: Assessments of the System of Rice Intensification (SRI): Proceedings of the International Conference, Sanya, China. pp. 143-147.

Reuben, P., Katambara, Z., Kahimba, F. C. and Mahoo, H. F. (2016). Influence of Transplanting Age on Paddy Yield under the System of Rice Intensification. *Agric. Sci.* **7**: 154-163.

Rinaudo, M. (2006). Chitin and chitosan: Properties and applications. *Prog. Poly. Sci.* **31**(7): 603-632.

Sarkar, M. A. R., Paul, S. K. and Paul, U. (2017). Effect of water and weed management in *boro* rice (cv. BRRI dhan28) in Bangladesh. *Archive. Agric. Environ. Sci.* **2**(4): 325–329.

Sarvanan, A., Velu, V. and Ramanath,KM (1987). Effect of combined application of bioorganic and chemical fertilizers on physical properties, nitrogen transformation and yield of rice in submerged soils. *Oryza*. 1-6.

Sarwa, N., Maqsood, M., Wajid, S. A. and Haq, M. A. (2011). Impact of nursery seeding density, nitrogen, and seedling age on yield and yield attributes of fine rice. *Chilean J. Agric.Res.* **71**(3): 343-349.

Seang-Ngam S, Limruengroj K, Pichyangkura R, Chadchawan S, Buaboocha T (2014). Chitosan potentially induces drought resistance in rice *Oryza sativa* L. via calmodulin. *J. Chitin and Chitosan Sci.* **2**(2):117-122.

Sharma, A. R. and Ghosh, A. (1998). Performance of direct sown and clonal-propagated transplanted rice (*Oryza sativa*) under semi-deep water condition. Indian *J. Agric. Sci.* **68**(4): 347-351.

Singh, R. S. and Singh, S. B. (1998). Response of rice (*Oryza sativa* L.) to age of seedlings, and level and time of application of nitrogen under irrigated condition. *Indian J. Agron*. **43**: 632-635.

Sridevi, V. and Chellamuthu, V. (2007). Effect of system of rice intensification (SRI) practices on yield and yield attributes of rice,2ndNational Symposium on System of Rice Intensification. Progress and Prospects, Agartala, Tripura, India. pp. 74-75.

Sultana, N., Hossain, M., Salam, M. and Rasul, S., 2020. Effect of Age of Seedling and Level of Nitrogen on the Growth and Yield of Transplant Aman Rice CV. Binadhan-15. *Asian Plant Res. J.* **6**(4):75-85.

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

Tari, D. B., Pirdashti, H., Nasiri, M., Gazanchian, & A., Hoseini, S. S. (2007). Determination of morphological characteristics affected by different agronomical treatments in rice (IR6874-3-2 Promising Line). *Asian J. Plant Sci.* **6**(1): 61–65.

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

Uphoff, N. (2002). Questions and answers about the SRI for raising the productivity of land, labour and water. Cornell International Institute for Food, Agriculture and Development, Cornell University, Ithaca, NY, USA. http://ciifax.cornell.edu/sri/ganda.pdf.

USDA (United States Department of Agriculture). (2021). Foreign Agricultural Service, Bangladesh. pp. 1-2. https://www.fas.usda.gov/regions/bangladesh.

Virk, A., Farooq, M., Ahmad, A., Khaliq, T., Rehmani, M., Haider, F. and Ejaz, I. (2020). Effect of seedling age on growth and yield of fine rice cultivars under alternate wetting and drying system. *J. Plant Nut*. **44**(1): 1-15.

Yadav, B.K. and Christopher, L. (2006). Effect of organic manures and panchagavya spray yield attributes, yield and economics of rice (*Oryza sativa* L.). *Crop Res.* **31**(1): 1-5.

Yang, F., Hu, J., Li, J., Wu, X. and Qian, Y. (2009). Chitosan enhances leaf membrane stability and antioxidant enzyme activities in apple seedlings under drought stress. *Plant Growth Regul.* **58**(2):131-136.

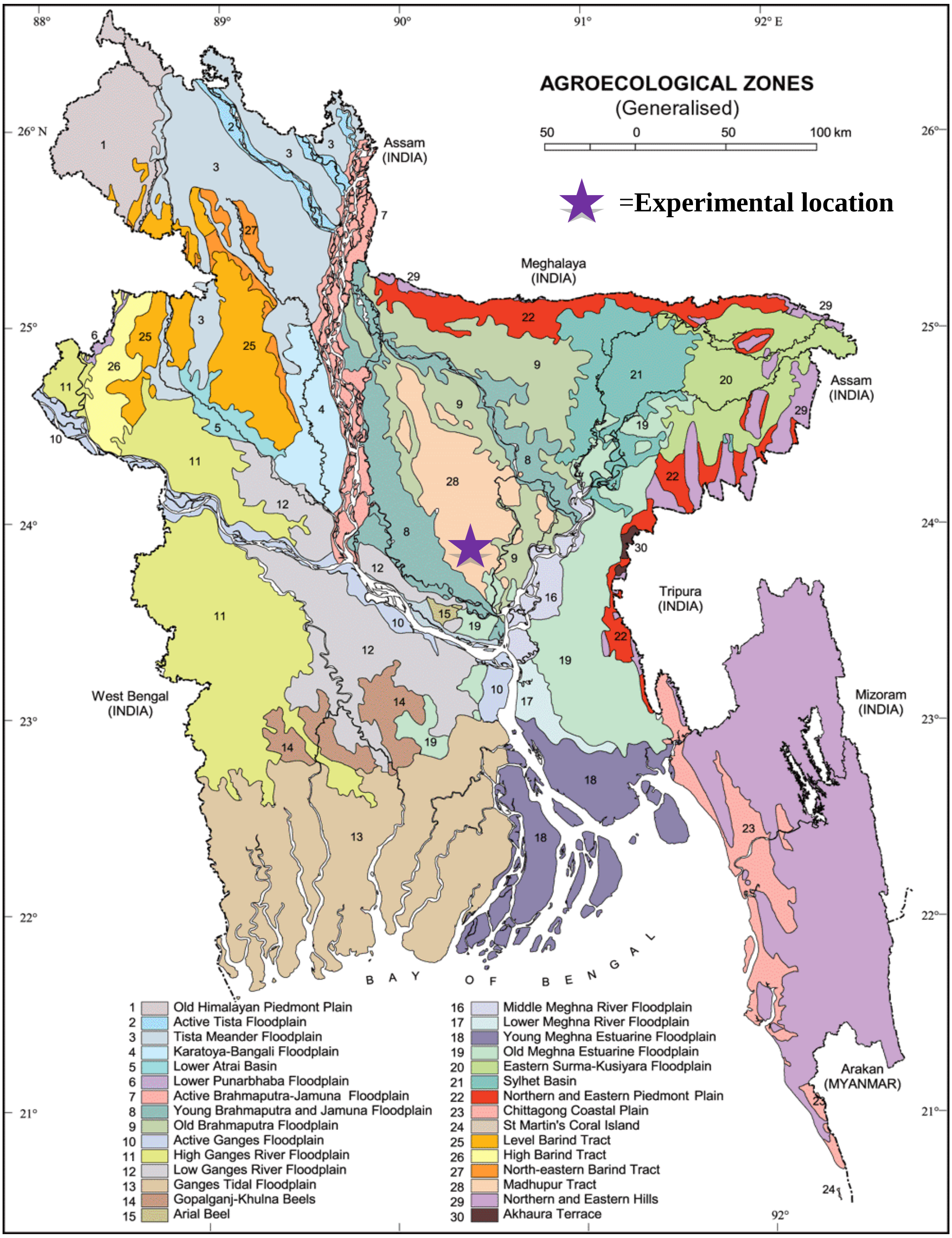
Yusuf, H. K. M. (1997). In: Report of the sustainable Food Security Mission in Bangladesh (FAO, Rome), Dhaka. 1997.

Zeng, D. and Luo, X. (2012). Physiological effects of chitosan coating on wheat growth and activities of protective enzyme with drought tolerance. *Open J. Soil Sci.* **2**(3):282-288.

Ziani K., Ursúa B., and Maté J.I. (2010). Application of bioactive coatings based on chitosan for artichoke seed protection. *Crop Prot.* **29**(8):853–859

APPENDICES

Appendix I. Map showing the experimental location under study



Appendix II. Monthly meteorological information during the period from November, 2019 to April 2020

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2019	November	29.6	19.8	53	00
	December	28.8	19.1	47	00
2020	January	25.5	13.1	41	00
	February	25.9	14	34	7.7
	March	31.7	20.2	60	73
	April	32.7	23.8	74	168

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

Appendix III. Analysis of variance of the data of average seedling height, fresh weight, oven dry weight seedling^{-1} and seedling strength of BRRI dhan88

Source	df	Mean square of			
		Average seedling height (cm)	**Fresh weight seedling^{-1} (mg)**	**Oven dry weight seedling^{-1} (mg)**	**Seedling strength (mg/cm)**
Replication	3	0.4815	515	16.26	0.00255
Chitosan (C)	5	39.3352**	102844**	3399.79**	3.26272**
Seedling (S)	2	36.8090**	49269**	1628.72**	0.43220**
C×S	10	2.6151**	1998**	66.06**	0.01588**
Error	51	0.3638	397	6.46	0.00302
Total	71				

**: Significant at 0.01 level of probability

Appendix IV. Analysis of variance of the data of number of tillers pot^{-1} at different DAT and number of effective tillers pot^{-1} of BRRI dhan88

Mean square of						
Source	**df**	**30 DAT**	**40 DAT**	**50 DAT**	**60 DAT**	**Effective tillers pot^{-1}**
Replication	3	0.0312	0.569	0.630	8.093	3.384
Chitosan (C)	5	5.7535**	41.347**	206.181**	52.614**	127.481**
Seedling (S)	2	18.3993**	227.681**	358.931**	488.722**	16.014**
C×S	10	12.3576**	28.764**	37.514**	60.239**	2.564**
Error	51	0.1489	0.373	0.943	4.955	0.796**
Total	71					

**: Significant at 0.01 level of probability

Appendix V. Analysis of variance of the data of first flowering day, 100 % flowering day, unfilled grains weight and 1000 grains weight of BRRI dhan88

Mean square of					
Source	**df**	**First flowering Day**	**100 % flowering day**	**Unfilled grains weight (g pot^{-1})**	**1000 grains weight (g)**
Replication	3	3.926	3.926	0.0178	1.0926
Chitosan (C)	5	84.256**	45.322**	6.6073**	9.1096**
Seedling (S)	2	340.181**	340.181**	20.9916**	16.9612**
C×S	10	8.647*	8.647*	2.3457**	1.9931**
Error	51	3.926	3.926	0.0115	0.7004
Total	71				

**: Significant at 0.01 level of probability

*: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data of grain, straw, biological yield pot^{-1} and harvest index of BRRI dhan88

Mean square of					
Source	**df**	**Grain yield (gpot^{-1})**	**Straw yield (gpot^{-1})**	**Biological yield (gpot^{-1})**	**Harvest index (%)**
Replication	3	17.000	13.458	59.12	0.37037
Chitosan (C)	5	290.233**	118.456**	772.41**	9.70511**
Seedling (S)	2	549.880**	510.389**	2117.22**	0.29307^{NS}
C×S	10	23.053**	26.422**	96.24**	0.26469^{NS}
Error	51	5.549	8.360	16.30	0.37037
Total	71				

^{Ns}; Non significant

**: Significant at 0.01 level of probability

Appendix VII. Analysis of variance of the data of pH, percentage of total nitrogen, percentage of organic carbon and percentage of organic matter

Mean square of					
Source	**df**	**pH**	**% total nitrogen**	**Organic carbon (%)**	**Organic matter (%)**
Treatment	5	0.43200**	5.71E-03**	0.04172**	0.09719**
Error	18	0.01444	3.222E-06	0.00028	0.00054
Total	23				

^{Ns}; Non significant

**: Significant at 0.01 level of probability

PLATES

Plate 3. Seed pot preparation and seed sowing in seed pot

Plate 4. Main pot preparation for seedling transplant

Plate 5. Transplanting seedling

Plate 6. Tiller initiation

Plate 7. Vegetative stage

Plate 8. Flowering stage

Plate 9. Grain filling stage

Plate 10. Harvesting stage

Plate 11. Measuring 1000 grains weight

Plate 12. Determination of organic carbon

Plate 13. Determination of total nitrogen content