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Impact of chitosan-raw-material (Shrimp shell powder) on the grain yield and agronomic characteristics of transplanted aman rice (BRRI dhan56)

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Abstract

To investigate the impact of chitosan-raw-material on BRRI dhan56 yield maximization, a field experiment was carried out. Four treatments with five replications each were used in the Randomized Complete Block Design (RCBD) experiment setup. Different dosages and application techniques (seedbed and main field applied methods) were used with the chitosan raw material. The following were the combinations of treatments: T_1: Seedbed applied with chitosan-raw-material at 0 g/m^2 + field applied with chitosan-raw-material at 0 ton ha^{-1}, T_2: Seedbed applied with chitosan-raw-material at 0 g/m^2 + field applied with chitosan-raw-material at 0.5 tons ha^{-1}, T_3: Seedbed applied with chitosan-raw-material at 250 g/m^2 + field applied with chitosan-raw-material at 0 tons ha^{-1}, T_4: Seedbed applied with chitosan-raw-material at 250 g/m^2 + field applied with chitosan-raw-material at 0.5 tons ha^{-1}. Applying chitosan-raw-material to the seedbed greatly increased the height, dry matter production, and strength of the seedlings. Grain yield and yield characteristics of *T. aman* rice were significantly impacted in seedlings treated with chitosan-raw-material (BRRI dhan56). When chitosan-raw-material was applied to rice seedlings, the yield traits such as filled grain/panicle, effective tillers/hill, and 1000-grain weight increased. Treatment T_4 yielded the highest grain yield (6.64 tons/ha), which was statistically equal to treatment T_3's grain yield (6.51 tons/ha). The control treatment T_1 yielded a minimum grain yield of 5.28 tons/ha, which was statistically equivalent to the grain yield of treatment T_2. More yield was also observed as a result of earlier primary tiller production, higher levels of several effective tillers, earlier flowering and maturity times, and earlier maturation. When considered collectively, our findings show that adding chitosan-raw-material to the seedbed enhanced the strength of the seedlings, which may be a sign of a higher BRRI dhan56 yield.

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Introduction

When compared to other rice-growing nations like China (6.30 t ha^{-1}), Japan (6.60 t ha^{-1}), and Korea (6.30 t ha^{-1}), Bangladesh's national average rice yield (4.2 t ha^{-1}) is extremely low (FAO, 2009). In Bangladesh, Sonarbangla-1 yielded 20% more rice (7.55 t ha^{-1}) than the reference variety, BRRI dhan56 (6.26 t ha^{-1}) (Parvez *et al.*, 2003).

Bangladesh's population is expected to rise by an additional 30 million during the next 20 years, on top of its current annual growth of two million. As a result, Bangladesh will need roughly 27.26 million tons of rice in 2020 (BRRI, 2011). The total area of rice will decrease to 10.28 million hectares during this period as well. Thus, a 53.3% increase in rice yield is required (Mahamud *et al.*, 2013). Food security has been and will continue to be a major concern in Bangladesh as the country's population grows at an alarming rate, resulting in increased food requirements. The yield of rice in Southeast Asian countries is generally lower due to factors such as salinity, severe insect infestation, and drought. When all of the leaf sheaths and leaf blades were infected, susceptible rice varieties showed yield losses of up to 50% (Kumar *et al.*, 2012). Recent studies have demonstrated that the product chitosan has a highly beneficial effect on rice production.

Commercial chitosan is made by deacetylating chitin, the structural component of fungal cell walls and the exoskeleton of crustaceans (such as shrimp and crabs). On the other hand, the raw and powdered form of crustacean shell is known as chitosan-raw material.

In recent years, different forms of chitosan have been used to increase rice production and reduce the cost of production as well. Sludge and chitosan spray are examples of organic manures that can be utilized as an alternate source of nitrogen to boost the effectiveness of nitrogen applied (Saravanan *et al.*, 1987). In addition to raising the N content of rice soil, the integrated use of organic manures and inorganic fertilizers can improve ecological sustainability over the long term and boost productivity (Gill and Meelu, 1982).

The application of sludge and chitosan spray in conjunction with chemical nitrogen fertilizer enhances soil health and productivity; however, prolonged use of nitrogenous fertilizer alone degrades the soil's organic matter status and physical condition and lowers crop yield. The decline in organic carbon is stopped and the difference between the potential and actual yields is mostly closed when sludge and chitosan spray are used in conjunction with chemical fertilizers for effective crop growth (Rabindra *et al.*, 2005).

It is unclear what causes the yield increase caused by chitosan-raw material. In light of these facts, the following goals were pursued:

First, to assess the impact of chitosan raw material on BRRI dhan56 growth, yield, and yield-contributing characteristics, and second, to assess the chitosan-raw-material application techniques for BRRI dhan56 yield enhancement.

Materials and methods

The experiment was conducted in the kharif season of 2022 in a typical rice-growing soil. During the trial period, there was enough sunshine and the land was above flood level. The soil had a pH of 6.3 and a texture similar to clay loam.

Planting material

Rice (*Oryza sativa*) variety BRRI dhan56 was used as plant material. This variety was developed by the Bangladesh Rice Research Institute (BRRI) and released in 2008. Due to its high-yielding potential and suitability for planting between June 15 and July 15, it is currently the most popular variety.

Via the specific gravity method, healthy seeds were gathered. After being soaked for a full day, the chosen seeds were placed in gunny bags. After 48 hours, the seed began to sprout, and after 72 hours, nearly all of the seeds had done so.

On August 1, 2022, the seedbed was ready for the sowing of sprouting seeds, and care was taken to raise seedlings. There, the seedbed soil was cleared, properly irrigated, and levelled using a ladder. On August 6, 2022, seeds were sprouted in the moist soil (Table 1). When needed, irrigation was applied to the seedbed and weeds were pulled.

Table 1. Physical and chemical properties of the initial soil sample

Characteristics	Value
% Sand	30
% Silt	40
% Clay	30
Textural class	Clay loam
Consistency	Granular and friable when dry
pH	6.3
Organic carbon (%)	0.68
Organic matter (%)	1.163

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

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

Ref. According to the Fertilizer Recommendation Guide, 2012.

August 20 was the first ploughing day, and August 22, 2022, was the last day of land preparation. The experiment's design led to the division of the experimental land into unit plots.

Treatments of the experiment

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

T_1: Seedbed applied with chitosan-raw-material at 0 g/m^2 + field applied with chitosan-raw-material at 0 ton ha^{-1}

T_2: Seedbed applied with chitosan-raw-material at 0 g/m^2 + field applied with chitosan-raw-material at 0.5 tons ha^{-1}

T_3: Seedbed applied with chitosan-raw-material at 250 g/m^2 + field applied with chitosan-raw-material at 0 ton ha^{-1}

T_4: Seedbed applied with chitosan-raw-material at 250 g/m^2 +field applied with chitosan-raw-material at 0.5 tons ha^{-1}

Every treatment received N, P, K, S and Zn as basal doses. The rates and sources of nutrients used in the study are given in Table 2. Composition of the used chitosan-raw-material (less than 2 mm in size) is also shown in Table 3.

Table 3. Composition of the used chitosan-raw-material (less than 2 mm in size)

Name of the nutrients	Methods name	Nutrient content
Nitrogen (N)	Micro Kjeldahl method	12.61 %
Phosphorus (P)	Olsen method	0.67 %
Potassium (K)	Flame photometer method	0.08 %
Sulphur (S)	BaCl2 extraction method	0.08 %
Calcium (Ca)	Atomic Absorption Spectrophotometer method	0.0094 %
Magnesium (Mg)	Atomic Absorption Spectrophotometer method	0.00029 %
Zinc (Zn)	Atomic Absorption Spectrophotometer method	0.012%
Boron(B)	Spectrophotometer method	26.21 ppm
Organic Carbon (OC)	Wei oxidation method	17%
Organic Matter (OM)	Wei oxidation method	29.44%
pH of the chitosan-raw-material	Glass electrode pH meter method	8.05

Chitosan-raw-materials were analyzed in the Soil Resource Development Institute, (SRDI), Farmgate, Dhaka.

A Randomized Complete Block Design was used to set up the experiment (factorial). Five copies of each treatment were conducted. A unit plot had dimensions of 3 m by 3 m. In the experimental field, there were twenty plots in total. Each block received a random distribution of the treatments. There was a 1 m gap between two neighbouring replications (blocks) and a 0.5 m gap between rows. The areas between rows and blocks served as drainage or irrigation channels as well as walkways. On August 26, 2022, twenty-day-old seedlings were carefully removed from the seedbed and replanted in the experimental plots with varying spacing. Each hill received one transplanted seedling. 90% of the crops turned brown on December 4, 2022, marking the end of harvesting. Mature crops were manually chopped and gathered from a 1 m^2 pre-marked area in the middle of each plot.

Using Statistic-10 software, the data collected on various parameters were statistically analysed to determine the significance level. A 5% significance level was applied to compare the mean differences between the treatments.

Results and discussion

Characters of seedlings applying chitosan-raw-material to the seedbed increased the height, fresh weight, oven-dry weight, and strength of the seedlings (Table 4). The seedbed-treated seedling (20-day-old seedling) had an average height increase of 8 cm. A treated single seedling's average dry matter content increased to 25.88 mg. The treated seedling exhibited a seedling strength of 1.91 mg/cm, while the non-treated seedling's strength was recorded at 0.38 mg/cm. The findings suggest that the raw chitosan material serves as a modifier of rice seedling strength.

Plant height (cm)

For every treatment employed in the experiment, plant height was found to be statistically insignificant (Table 5). The T_4 treatment yielded the highest plant height of 105.33 cm, while the T_1 treatment produced the lowest plant height of 92.33 cm. Treatments may be arranged as $T_4>T_3>T_2>T_1$ based on plant height. Numerous other scientists have also reported on the increased plant height achieved by applying chitosan foliarly along with N, P, K, and S (Kobayashi *et al.*, 1989; Maskina *et al.*, 1987).

Total tillers/hill

Table 5 shows that the effects of various treatments on the total number of tillers/hill were statistically significant. The T_3 treatment yielded the maximum number of total tillers/hill (18.333), which was statistically identical to the T_2 and T_4 treatments and significantly higher than the T_1 control's number. In the T_1 treatment, the bare minimum of total tillers/hill (13.667) was achieved. It is possible to arrange the treatments so that $T_3>T_4>T_2>T_1$ to produce the total number of tillers/hill. It has been noted that adding chitosan raw materials to soil raises the number of tillers per hill.

Non-effective tillers/hill

One agronomic characteristic, non-effective tillers/hill, was found to be statistically insignificant across all experiment treatments (Table 5). The T_3 treatment yielded the highest number of non-effective tillers (4.33), while the T_1 treatment produced the lowest number of non-effective tillers (2.00).

Effective tillers/hill

The effects of various treatments on effective tillers/hill are depicted in the following Fig. 1. The T_3 treatment yielded the highest number of effective tillers/hill (14) and was statistically identical to the T_4 treatment. This number was significantly higher than that of the T_1 control and T_2 treatment. In the T_1 control treatment, the fewest effective tillers/hill (11.67) were recorded. Treatments may be arranged in the following order to produce the effective number of tillers/hill: $T_3>T_4>T_2>T_1$. It was found that adding chitosan raw materials to the soil increases the number of effective tillers per hill.

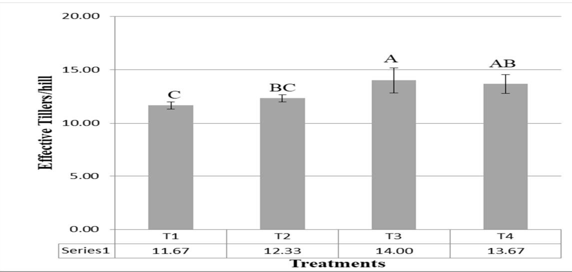

Fig. 1. Effects of different treatments on the number of effective tillers/hill of *T. aman* rice (BRRI dhan56). Mean was calculated from five replicates for each treatment. Bars with different letters are significantly different at $p \leq 0.05$ when applying LSD.

According to Boonlertnirun *et al.* (2012), chitosan application techniques had a significant impact on the number of tillers per plant.

Table 4. Effect of chitosan-raw materials on seedlings characteristics of rice (BRRI dhan56)

Applied Doses of chitosan-raw-material	Seedling Height (cm)	100 Seedlings fresh weight (g)	100 Seedlings oven dry weight (g)	Single Seedlings Oven dry weight (mg)	Seedlings Strength (mg/cm)
0 g/m²	20	10.5	2.76	27.60	1.38
250 g/m²	28	17.2	5.35	53.48	1.91

Data in the above table were averaged using five replications and each case 100 seedlings data were used.

Table 5. Effects of different treatments on plant height (cm), total tillers/hill and non-effective tillers/hill of *T. aman* rice (BRRI dhan56) at harvest

Treatments	Plant height (cm)	Total tillers/hill	Non-effective tillers/hill
T_1	92.33	13.667	2.00
T_2	95.00	14.667	2.33
T_3	103.67	18.333	4.33
T_4	105.33	16.333	2.67
LSD (0.05)	14.768	4.3288	2.9783
CV (%)	7.46	13.76	52.61

Table 6. Effects of different treatments on total number of grains/panicle, 1000-grains weight and panicle length of T. aman rice (BRRI dhan56) at harvest

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

Table 7. Effects of different treatments on Straw yield (t ha^{-1}), Biological Yield (t ha^{-1}) and Harvest Index (%) of T. aman rice (BRRI dhan56) at harvest. Mean was calculated from five replicates for each treatment

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

Total grains/panicle count

One agronomic characteristic, the total number of grains/panicle, was found to be statistically insignificant in all experiment treatments (Table 6). The T_4 treatment yielded the highest total number of grains/panicle (173.67), while the T_1 treatment produced the lowest total number of grains/panicle (165.00).

1000 grains weight (g)

For every treatment employed in the experiment, 1000-grains weight was shown to be statistically insignificant (Table 6). T_3 (19.567g) had the highest weight of 1000 grains, and its results were statistically comparable to those of T_4 (19.400 g), T_1 (19.00 g), and T_2 (19.00 g) treatments. T_4 (19.400 g) was the second-highest treatment in terms of 1000-grains weight. At least 1000-grains were noted in T_1 (19.00 g) and T_2 (19.00 g) control groups.

Length of panicle (cm)

For each of the experiment's treatments, panicle length was determined to be statistically insignificant (Table 6). The T_4 treatment yielded the maximum panicle length of 23.00, while the T_2 and T_3 treatments produced the minimum panicle length of 22.33.

Filled grains/panicle

Packed grains and panicles were found to be statistically significant (Fig. 2). The T_3 treatment produced the greatest number of filled grains/panicle (16.00), which was statistically comparable to the T_4 treatment and significantly higher than the results of the T_1 control and T_2 treatments. In the T_1 control treatment, the fewest filled grains/panicle (140.00) were recorded. $T_3>T_4>T_2>T_1$ may be the order in which the effects of treatments on the quantity of filled grains/panicle occur. It has been noted that adding chitosan-raw-material to the soil increases the amount of filled grains/panicles. According to Wang *et al.* (2011), applying chitosan solution along with the suggested chemical fertilizer greatly increased the quantity of filled grains and panicles as well as their height.

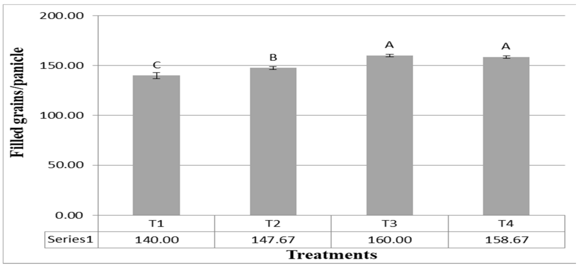

Fig. 2. Effects of different treatments on filled grains/panicle of T. aman rice (BRRI dhan56)

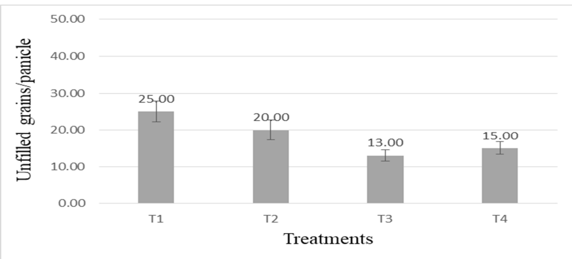

Fig. 3. Effects of different treatments on Unfilled grains/panicle of T. aman rice (BRRI dhan56)

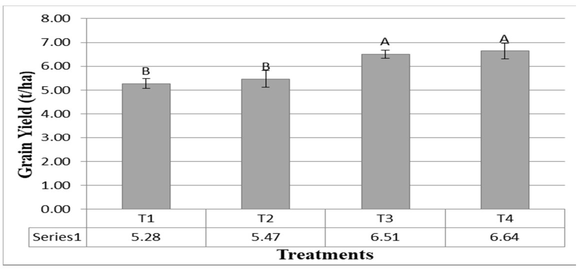

Fig. 4. Effects of different treatments on Grain yield (ton/ha) of T. aman rice (BRRI dhan56).

Unfilled grains/panicle

Because filled treatments were applied, it was found that unfilled grains/panicle were statistically significant (Fig. 3). The T_1 treatment yielded the greatest number of unfilled grains/panicle (25.00), which was statistically comparable to T_2 and significantly higher than that of the T_3 and T_4 treatments. The T_3 treatment had the fewest unfilled grains/panicle (13.00), which is statistically comparable to the T_2 and T_4 treatments. $T_1>T_2>T_4>T_3$ is one possible arrangement for the treatments when producing unfilled grains or panicle.

The findings of Sarkar and Singh *et al.* (2002), who found a significant increase in the number of filled grains per panicle and a decrease in the number of unfilled grains per panicle with the application of N, P, and K with chitosan, supported these results.

Yield components

Grain yield (ton/ha)

Grain yield (ton/ha) was found to be statistically significant (Fig. 4). The T_4 treatment yielded the highest grain yield (6.64 tons/ha), which was statistically equivalent to T_3 and significantly higher than that of the T_1 control and T_2 treatments. The T_1 control treatment yielded the lowest grain yield (5.28 tons/ha), which is statistically equivalent to that of T_2. The treatments may be arranged as follows to produce grain yield (ton/ha): $T_4>T_3>T_2>T_1$. It was found that applying chitosan-raw materials to the seedbed and main field increased the BRRI dhan56 grain yield. Furthermore, it is hypothesized that a higher yield of T. aman rice could be predicted by employing healthy seedling production technology that uses chitosan-raw materials in the seedbed (BRRI dhan56).

According to Abdel-Mawgoud *et al.* (2010), chitosan applied at a dose of 2 mgL^{-1} enhanced the yield components (number and weight) of strawberries. Moreover, chitosan application tended to increase rice plant grain yield in comparison to unapplied seed. In an experiment, Nguyen Toah *et al.* (2013) found that applying chitosan solution significantly increased rice yields (~31%) based on field data from their studies.

Chitosan application generally resulted in a significant reduction in production costs and an increase in rice production.

Straw yield (ton/ha)

In all of the experiment's treatments, straw yield was determined to be statistically insignificant (Table 7). The T_4 treatment produced the highest straw yield (10.140 tons/ha), while the T_1 treatment produced the lowest straw yield (9.400 tons/ha).

Biological yield (ton/ha)

The results of the experiment showed that the T_4 treatment produced the highest biological yield (16.973 tons/ha), while the T_2 treatment produced the lowest biological yield (14.50 tons/ha) (Table 7).

Harvest index (%)

The harvest index (%) was shown to be statistically significant (Table 7). The T_3 treatment yielded the highest Harvest Index (41.276%), which was statistically identical to the T_4 treatment and significantly higher than the results of the T_1 control and T_2 treatment.

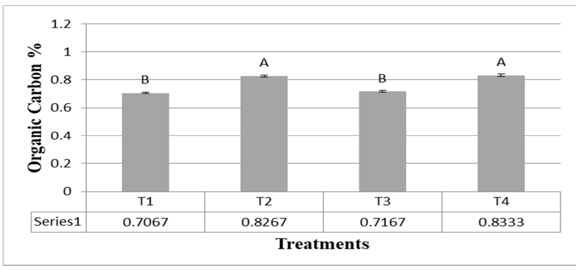

Fig. 5. Effects of different treatments on Organic Carbon % of post-harvest soils of T. aman rice (BRRI dhan56)

Organic carbon status of post-harvest soils

The organic carbon status of post-harvest soils was found to be statistically significant (Fig. 5). The T_4 treatment yielded the highest percentage of organic carbon (0.83%), which was statistically equivalent to T_2 and considerably higher than that of the T_1 control and T_3 treatments. The T_1 control treatment yielded the lowest level of organic carbon (0.70%), which was statistically equivalent to that of the T_3 treatment. It has been noted that adding chitosan-raw-material to post-harvest soils raises their organic carbon status.

Table 8. Effects of different treatments on pH of post-harvest soils of T. aman rice (BRRI dhan56) at harvest

Treatments	pH of post-harvest soils
T_1	5.8
T_2	5.7
T_3	5.7
T_4	5.6

pH of post-harvest soils

The pH value of the post-harvest soils did not differ significantly due to the use of modified chitosan in the field (Table 8). The pH remains almost similar among all the treatments.

Conclusion

The seedlings with higher strength and significant effects on effective tillers/hill, 1000 grain weight, filled grain/panicle, grain yield, straw yield, and biological yield were produced in the seedbed using chitosan-raw materials @ 250 g/m^2. These outcomes could be the result of early flowering, earlier maturity, more productive tillers/hill, and early tiller production. It is hypothesized that a good indicator for maximizing T. aman rice grain yield would be the use of chitosan-raw materials in the seedbed in healthy seedling production technology (BRRI dhan56).

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