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RESIDUAL EFFECT OF RAW MATERIAL OF CHITOSAN POWDER ON CHEMICAL PROPERTIES OF SOIL UNDER RICE-RICE CROPPING SYSTEM

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ABSTRACT

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The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, during 2015-2016, to investigate residual effect of raw material of chitosan (CHT) powder on chemical properties of rice growing soils. The field experiment was done using BRRI dhan29. The experiment was laid out in randomized complete block design (RCBD) with four replications. The first experiment was done using four different doses of the raw material of CHT powder with one control. The treatments were as follows: T₁= 0.5 t/ha, T₂ = 1.0 t/ha, T₃ = 2.0 t/ha, T₄ = 4.0 t/ha and T₅ = 0 t/ha. The second experiment was conducted in the same plot using the following treatments were T₁= Residual effect of the raw material of CHT powder @ 0.5 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T₂ = Residual effect of the raw material of CHT powder @ 1.0 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T₃ = Residual effect of the raw material of CHT powder @ 2.0 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T₄ = Residual effect of the raw material of CHT powder @ 4.0 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer and T₅ = Residual effect of the raw material of CHT powder @ 0 t/ha + recommended N (control). The total nitrogen content, soil pH, organic carbon and organic matter status in the post-harvest-soils were increased due to the residual effect of the powder in rice growing soils. The maximum value of the pH (7.01), organic carbon content (0.72%), and organic matter content (1.24%) in the post-harvest soils were found in the treatment T₄ and lowest values were observed in the control treatment (T₅). From the results it could be concluded that some of the chemical properties of rice growing soils were improved due to the residual effect of the raw material of CHT powder. Residual nitrogen value indicates that the raw material of CHT powder has a slow releasing effect of organic nitrogen supplementation in soil. These results suggest that the residual effect of the raw material of CHT powder could play a significant role to improve the sustainable soil health.

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INTRODUCTION

Reduction of organic matter, nutrient mining, increasing cropping intensity and soil acidification are the serious problem for the sustainable soil health management in Bangladesh (BFRG, 2012). To feed the tremendous increasing population the increasing of cropping intensity is a basic need. To fulfill this requirements soil become degraded to deliver the agricultural production. Organic matter level is a serious issue in Bangladesh soil. The improvement of soil health indicates the management of organic matter for the improvement soil health is the time demanded need. Chitosan (CHT) is a natural biopolymer modified from chitin, which is the main structural component of squid pens, cell walls of some fungi and shrimp and crab shells. Chitin and chitosan are copolymers found together in nature. They are inherent to have specific properties of being environmentally friendly and easily degradable. Bangladesh is a world-leading exporter of frozen shrimps. Therefore, there are abundant raw materials for chitosan powder production. Chitosan has a wide scope of application. Chitosan is a naturally occurring polymer that became available in the 1980s in industrial quantities enabling it to be tested as an agricultural chemical. In agriculture, chitosan is used primarily as a natural seed treatment and plant growth enhancer and also as an ecologically friendly biopesticidal substance that boosts the innate ability of plants to defend themselves against fungal infections (Linden *et al.*, 2000). Plants with high content of chitin show better disease resistance (Khan *et al.*, 2003). With high affinity and non-toxicity, it has no harmful effects on human beings and livestock. Chitosan induces the excretion of resistant enzymes and thus it regulates the immune system of plants. Moreover, chitosan activates the cells besides the improvement of its disease and insect resistant ability (Doares *et al.*, 1995). Chitosan has strong effects on agriculture such as acting as the carbon source for microbes in the soil. It accelerates the transformation process of organic matter into inorganic matter. Moreover, it assists the root system of plants to absorb more nutrients from the soil. Chitosan is absorbed by the roots after being decomposed by bacteria in the soil and chitin secreted by the roots (Somashekar and Ricard, 1996, Brian *et al.*, 2004). Application of chitosan in agriculture, even without chemical fertilizer can increase the microbial population by large numbers and transforms organic nutrient into inorganic nutrient which is easily absorbed by the plant roots (Bolto *et al.*, 2004). The chitosan powder, the acetylated form of chitosan, is the raw material prepared from the shrimp shell byproducts by the sequential process of grinding, drying and finally by sieving.

Chitosan may be used as an alternative source of N which increases efficiency of applied N (Saravanan *et al.*, 1987). The residual chitosan can contribute to increase N content of rice soil as well as to increase long term productivity and enhancement of ecological sustainability (Gill and Meelu, 1982). Chitosan and its residue improve soil health and soil productivity but only use of nitrogenous fertilizer for a long period causes deterioration of physical condition and organic matter status and reduces crop yield. The residual modified chitosan is applied for efficient growth of crop, decline in organic carbon is arrested and the gap between potential yield and actual yield is bridged to large extent (Rabindra *et al.*, 2005). Soil application of chitosan powder is a new theme to us to improve the chemical properties of soils. Therefore, the research was designed to investigate the residual effect of chitosan powder on the chemical properties of rice growing soils.

MATERIALS AND METHODS

Experimental site and soil

The experiments were carried out during the period from July 2015 to May 2016 at the field of Sher-e-Bangla Agricultural University, Dhaka. The experiment was conducted under the Agro-ecological zone of "The Modhupur Tract" (AEZ-28) having the general soil type of Shallow Red Brown Terrace soils under Tejgaon Soil Series. The location of the experimental site was situated at 23°77'N latitude and 90°33'E longitude at an altitude of 8.6 meter from the mean sea level. The following properties of the initial soil were analyzed.

Table 1. Physical and chemical properties of the initial soil

Characteristics	Value	Name of the Methods
% Sand	27	Marshals Textural triangular method
% Silt	43	Marshals Textural triangular method
% Clay	30	Marshals Textural triangular method
Textural class	Silty-clay	Marshals Textural triangular method
pH	5.44	Glass electrode pH meter method
Organic carbon (%)	0.60	Wet oxidation method
Organic matter (%)	1.03	Wet oxidation method
Total N (%)	0.05	Kjeldahl methods
Available P (ppm)	19.00	Olsen method
Exchangeable K (me/100 g soil)	0.11	Ammonium acetate extraction method
Available S (ppm)	44	Barium chloride extraction method

Experimental design and treatments

Two consecutive experiments were carried out in the same plot following randomized complete block design (RCBD). The experiment was done having five treatments with four replications. The first experiment was done using the four different doses of the raw material of CHT powder with one control. The treatments were as follows: $T_1 = 0.5$ t/ha, $T_2 = 1.0$ t/ha, $T_3 = 2.0$ t/ha, $T_4 = 4.0$ t/ha and $T_5 = 0$ t/ha. Residual effects of the raw material of CHT powder were examined as the second experiment in the same plot using the following treatments: $T_1 =$ Residual effect of the powder @ 0.5 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer, $T_2 =$ Residual effect of the powder @ 1.0 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer, $T_3 =$ Residual effect of the powder @ 2.0 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer, $T_4 =$ Residual effect of the powder @ 4.0 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer and $T_5 =$ Residual effect of the powder @ 0 t/ha + recommended N (control). The raw material of the CHT powder was applied at the final land preparation stage in the first experiment only.

Plant materials

The experiment was carried out using BRR1 dhan29. It is a super high yielding variety of Bangladesh having 95 cm height. Average life cycle of the variety is 160 days and average yield performance is 7.5 t ha⁻¹ (Modern Rice Cultivation, 2018). The amylose content of this variety is 29.5%.

Fertilizer management

The experimental plots were fertilized following the recommendation of Bangladesh fertilizer recommendation guide. The ureas, triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate were applied @ 150, 58, 58, 38 and 10 kg/ha, respectively. The entire amounts of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied as basal dose at the time of transplanting of seedlings. Urea was applied as three equal splits. No Urea was applied during land preparation. The first split of urea was applied after the seedling recovery, second split was applied at the maximum tillering stage and third split was applied at 7 days before panicle initiation stage. For transplantation 35 days old seedlings were used in the experiment. All the intercultural operations were done as per the requirements.

Soil sample collection and chemical analysis

Soil samples were collected from the upper most 15 cm of the research area. The initial soil samples, post harvest soil samples of the first experiment and post harvest soil samples of the second experiment were collected and used for chemical properties analysis in the Departmental laboratory of Soil Science, Sher-e-Bangla Agricultural University, Dhaka. Soil pH was measured with the help of a glass electrode pH meter

method using soil suspension of 1:2.5 as described by Jackson (1962). Organic carbon in soil was determined by wet oxidation method of Walkley and Black (1934), soil total nitrogen was determined using micro Kjeldahl method, available phosphorus was determined by olsen method, exchangeable potassium was determined by ammonium acetate extraction method, available sulphur was determined by Barium chloride extraction method.

Weather condition of the experimental period

The weather data was collected from the Bangladesh meteorological department, meteorological complex, Agargaon, Dhaka-1207. The maximum relative humidity and rainfall was recorded in the month of November (81%) and May (272 mm), respectively (Figure 1A). The highest and lowest temperatures were recorded in the month of April (34.5 °C) and January (12.2 °C), respectively (Figure 1B).

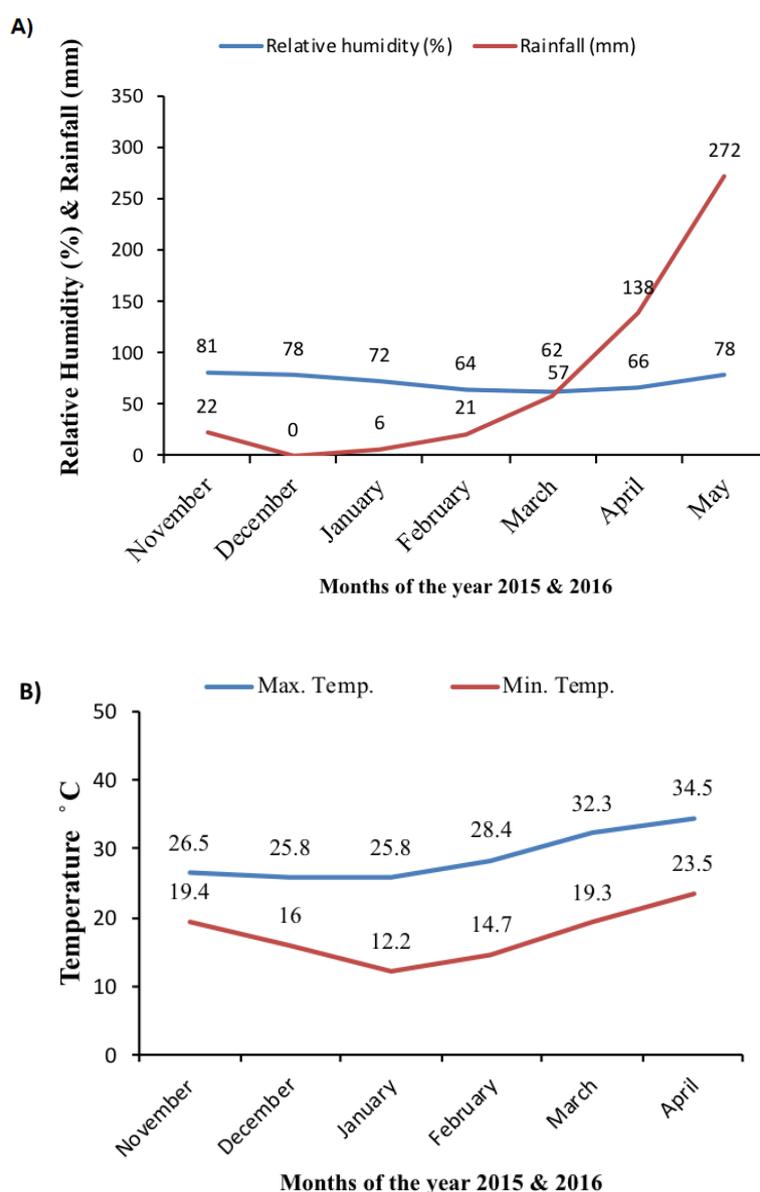


Figure 1. Monthly record relative humidity, rainfall (average) and temperature of the experimental site during the experimental time

Collection and Preparation of the raw material of CHT powder

Dried shrimp shells were used as the raw material of CHT powder were collected from the Khulna region of Bangladesh. Milling the dried shrimp shells and sieving the powder using 30 mesh sieves to prepare the usable raw material of the CHT powder. Analytical results of the CHT powder (Table 2) revealed that a number of essential (macro and micro elements) were available in the CHT powder. The powder is a good sources of organic nitrogen, organic carbon and alkaline in nature.

Table 2. Chemical composition of the raw material of CHT powder

Name of the nutrients	Nutrient content
pH	8.05
Organic Carbon (OC)	17.00 %
Organic Matter (OM)	29.31 %
Total Nitrogen (N)	12.61 %
Phosphorus (P)	0.67 %
Potassium (K)	0.14 %
Sulphur (S)	0.10 %
Calcium (Ca)	0.0094 %
Magnesium (Mg)	0.00029 %
Zinc (Zn)	0.012%
Boron(B)	26.21 ppm

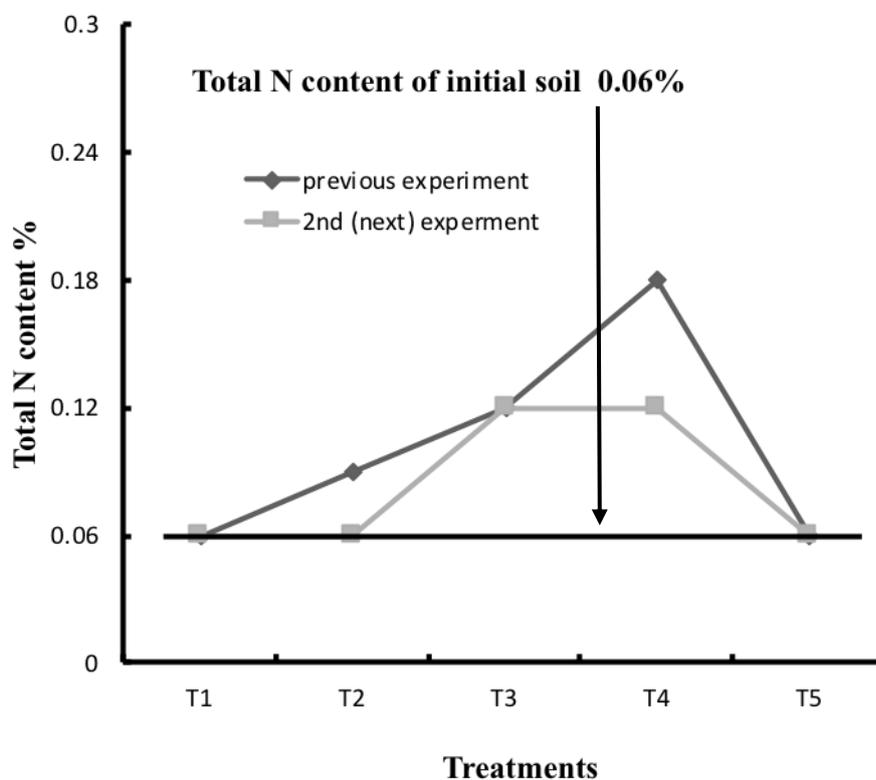
Statistical analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique and the mean differences were adjudged by LSD test using the statistical computer package program, Statistics 10.

RESULT AND DISCUSSION

Residual effect of N in the post-harvest soil

Although more than 60% of the added nitrogen is lost from the soil (FRG, BARC, 2012), the residual value of the total N was significantly increased in the previous (1st experiment) experiment due to the addition of higher doses of the CHT powder under the treatment T3 (0.12%) and T4 (0.18%) compare to the T5 (Control, recommended fertilization) (Figure 2). Similar to the first experiment, the 2nd experiment (next experiment) also showed significant variation in the residual nitrogen content under the treatments T3 (0.12%) and T4 (0.12%) compare to the T₅ (Control) (Figure 2). These results suggested that residual nitrogen value was observed in the raw material of CHT powder indicating slow releasing effect of the organic N in soils. Slow releasing effect of organic N from the raw material of CHT powder might be due to its slow decomposing effect in soil.

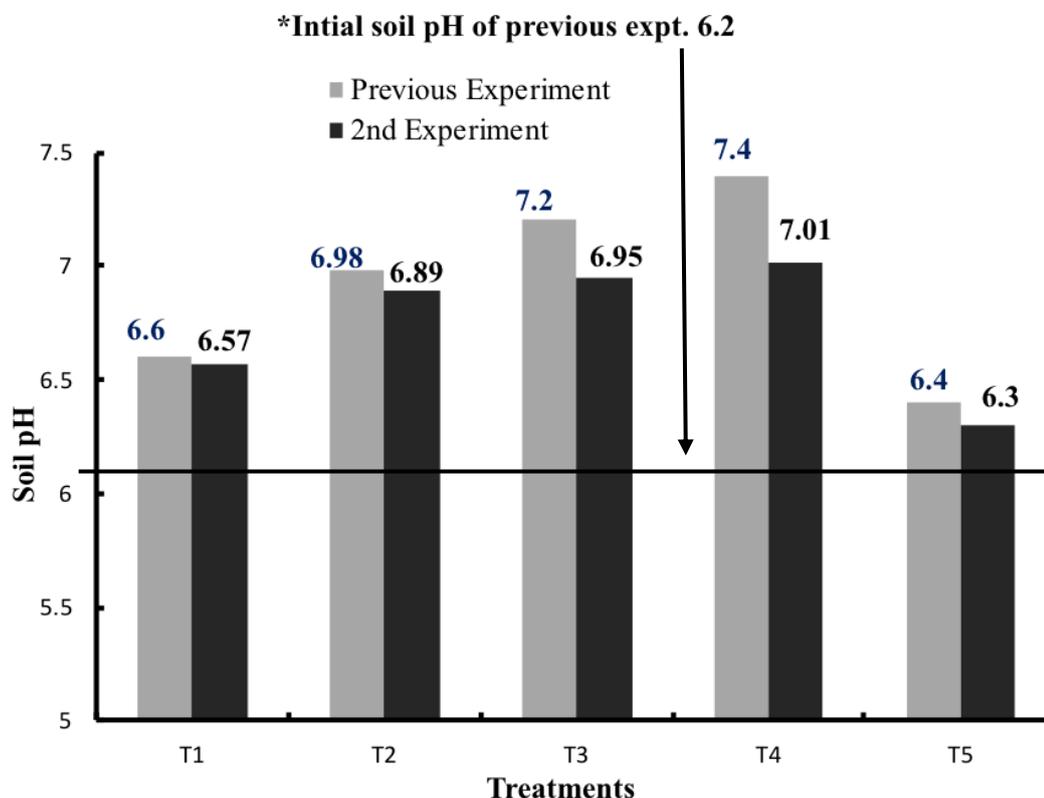


T₁= Residual effect of the raw material of CHT powder @ 0.5 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T₂ = Residual effect of the raw material of CHT powder @ 1.0 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T₃ = Residual effect of the raw material of CHT powder @ 2.0 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T₄ = Residual effect of the raw material of CHT powder @ 4.0 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer and T₅ = Residual effect of the raw material of CHT powder @ 0 t/ha + recommended N (control).

Figure 2. Residual effect of the raw material of CHT powder on total N content in the post-harvest soils.

pH status of the post-harvest soil

The pH status of the post-harvest soil of running experiment was affected by the different treatments of the powder and ranged from 6.3 to 7.01 (Figure 3). It was found that pH status of soil was statistically significant. The highest pH value (7.01) was recorded in T₄ treatment which was significantly greater than from the T₅ treatment. The lowest pH value (6.3) was recorded in T₅ treatment (Figure 3). According to the pH values treatments may be arranged as T₄>T₃>T₂>T₁>T₅. The pH was decreased in the post-harvest soils of the second experiment compare to the post-harvest soils of the first experiment. After that all the treated soils pH were higher than that of the initial soil pH (6.2) (Figure 3). These results suggest that residual effect of CHT powder increases the post-harvest soil pH. The results were supported by Kananont *et al.* (2015) who conducted an experiment with Fermented chitin waste (FCW) along with CF = soil supplemented with chemical fertilizer and CMF = soil supplemented with chicken manure fertilizer. The results found that FCW @ 1% the ph differ significantly from 0.5% FCW, 0.25% FCW and the rest of the treatment. Arif, (2015) found that chitosan powder increases the soil pH that could be a good point of nutrient mineralization in soil from the organic source. The raw material of the CHT powder affect the soil pH, it might be due to the shrimp shells contents most abundantly carbonates of Ca & Mg (Synowiecki *et al.* 2003;Beaney *et al.* 2005; Mahmoud *et al.* 2007).

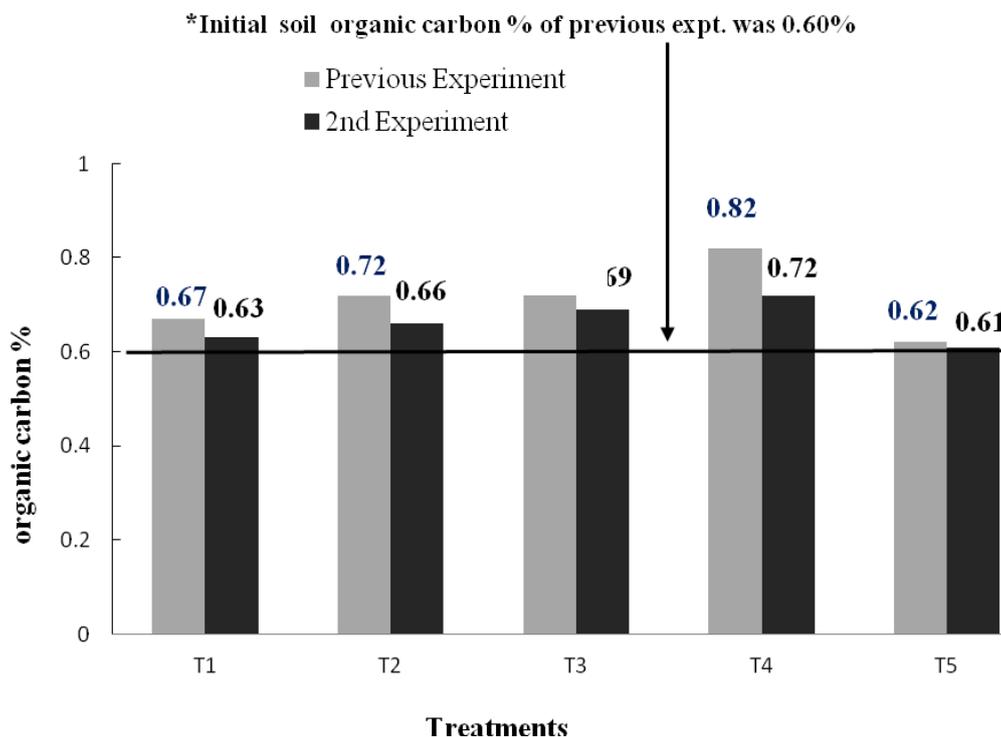


T₁= Residual effect of the raw material of CHT powder @ 0.5 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T₂ = Residual effect of the raw material of CHT powder @ 1.0 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T₃ = Residual effect of the raw material of CHT powder @ 2.0 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T₄ = Residual effect of the raw material of CHT powder @ 4.0 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer and T₅ = Residual effect of the raw material of CHT powder @ 0 t/ha + recommended N (control).

Figure 3. Residual effect of different doses of chitosan powder on soil pH of rice growing soils. Mean was calculated from three replicates for each treatment.

Organic carbon content in the post-harvest soils

The organic carbon content in the post-harvest soils was affected by the different treatments of residual chitosan and ranged from 0.61% to 0.72 % (Figure 4). It was found that effects of different residual doses of chitosan on organic carbon content of post-harvest soils were statistically significant. Maximum organic carbon content (0.72%) was found in T₄ (treatment which was significantly greater than the T₅ treatment (Figure 4). However, minimum organic carbon content (0.61%) was found in the T₅ treatment. According to the organic carbon content of soil the treatments may be arranged as T₄>T₃>T₂>T₁>T₅. The organic carbon content in the post-harvest soils of the second (running) experiment was decreased compared to the first (previous) experiment. After that the organic carbon content in the post-harvest soils of the second experiment was greater than that of the initial soil carbon content of the first experiment (Figure 4). From this study it can be suggested that residual effect of chitosan powder increase the organic carbon content in soil. The results were supported by Kananont *et al.* (2015) who conducted an experiment and found that fermented chitin waste increase organic carbon content in soil and by Arif (2015) who found that chitosan application increases the level of organic carbon in soils.



T₁= Residual effect of the raw material of CHT powder @ 0.5 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T₂ = Residual effect of the raw material of CHT powder @ 1.0 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T₃ = Residual effect of the raw material of CHT powder @ 2.0 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer, T₄ = Residual effect of the raw material of CHT powder @ 4.0 t/ha (applied in the previous experiment) + 2/3rd of recommended N fertilizer and T₅ = Residual effect of the raw material of CHT powder @ 0 t/ha + recommended N (control).

Figure 4. Residual effect of different doses of the raw material of chitosan powder on organic carbon content in the post-harvest soils

Organic matter content in the post-harvest soils

Organic matter content in the post-harvest soils showed significant differences among treatments with different doses of the raw material of CHT powder. The organic matter content ranged from 1.05% to 1.24 % (Table 3). Maximum organic matter content (1.24%) was found in T₄ treatment which was significantly greater than from the T₁ and T₅ treatment (Table 3). However, minimum organic matter content (1.05%) was found in T₅ treatment. According to the organic matter content of soil the treatments may be arranged as T₄>T₃>T₂>T₁>T₅. From this study it can be concluded that residual effect of the raw material of CHT powder increased organic matter content in the rice growing soils. The results were supported by the Kananont *et al.* (2015) findings who found that fermented chitin waste was increased organic matter content in soil in a dose dependent manner. Arif (2015) found that raw material of CHT powder application increase the organic matter content in soils. Increasing organic matter content for the sustainable agriculture is a big challenge in Bangladesh soils; however, the raw material of CHT powder application could play a significant role to increase the organic matter content in soils.

Table 3. Residual effect of different doses of chitosan powder on soil organic content of rice growing soils at harvesting stage of the second experiment

Treatment (dose)	Soil organic carbon (%)	Soil organic matter (%)
T ₁	0.63b	1.09b
T ₂	0.66ab	1.14ab
T ₃	0.69ab	1.19ab
T ₄	0.72a	1.24a
T ₅	0.61c	1.05c
Level of significance	**	**
Initial soil	0.60	1.03

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD. ** = Significant at 1% level of probability

SUMMARY AND CONCLUSION

In agriculture, use of the raw material of CHT powder is a new chapter and can be used as an alternative source of organic N which increases efficiency of applied inorganic N and can be contributed to increase the N content of rice growing soils of Bangladesh. Besides that, the residual effect of the raw material of CHT powder had a profound influence on morphological, reproductive, yield attributes and grain yield of BRR1 dhan29. The residual effect of the powder also has a positive effect on the increaser of organic nitrogen, organic carbon, organic matter and pH of the rice growing soils. Among all the treatments T₄ perform best compare to the control treatment and other treat. But in case of non significant parameters the treatment may differ. The research was conducted to clarify the residual effect of the powder to the improvement the chemical properties of soils. Taken together, our results indicate that residual effect of the raw material of CHT powder could play a significant role to improve the sustainable soil health.

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CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

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