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Growth and yield performance of Sweet Pepper varieties by exogenous application of chitosan-raw-material (Shrimp shell powder)

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Abstract

From October 2022 to April 2023, a pot experiment was carried out to examine how several sweet pepper varieties responded to varying concentrations of chitosan-raw-material (Shrimp Shell Powder). The study used a completely randomized design (CRD) with seven replications and involved two varieties *viz.* BARI Sweet Pepper-1 (V_1) and BARI Sweet Pepper-2 (V_2) and the four different concentrations (% w/w) were: C_0 = 0%, C_1 = 0.1%, C_2 = 0.5%, and C_3 = 1%. The results showed that the V_2 (BARI Sweet pepper-2) treatment had the maximum fruit output plant^{-1} pot-1 (139.18 g). The use of 1% chitosan-raw-material (C_3) significantly increased the sweet pepper plant's growth and productivity. Based on these findings, it can be said that the application of chitosan-raw-material boosted the yield and yield-contributing traits of sweet peppers and some chemical aspects of the soil. When combined, our findings imply that chitosan-raw-material may be beneficial for soil pH, soil organic carbon, and slow-releasing nitrogen supplementation, all of which have an impact on plant growth, development, and yield.

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Introduction

Due to its delectable flavour and rich ascorbic acid content, along with other vitamins and minerals, sweet pepper has become a valued vegetable in Bangladeshi cuisine, earning it the title of "high-value low volume crop" in recent years (Islam *et al*., 2017). Fruit yield and quality are influenced by several pre- and post-harvest variables, such as harvest maturity, environmental factors, and post-harvest factors (Tyagi, 2017). Several research teams are having difficulty increasing the quantity and quality of sweet peppers. Hormones and chemicals have been used for this purpose for many years, but now there is a global increase in people's concerns about their health. Very few studies have been published on the application of bio-stimulants to improve the yield and quality of sweet pepper fruit, despite a substantial body of research on the improvement of sweet pepper quality through the use of mineral nutrition.

The process of deacetylating crustacean shells yields, which is mostly utilized in agriculture to activate defensive mechanisms in plants (Kumar *et al*., 2018). When directly applied to plant tissue, chitosan appears to function as a stress tolerance inductor; it increases a hypersensitive reaction and lignification, triggering lipid peroxidation and the formation of defense against pathogens (Hassnain *et al*., 2020). Chitosan-treated seeds had a shorter mean germination time; a higher germination index promotes better seedling growth in low-temperature environments; additionally, it was found that chitosan application decreased vanadium toxicity when applied to irradiated wheat and barley (Islam and Khatoon, 2021). By incorporating stomatal-type closure chemicals, which can minimize water loss from the leaf by boosting plant biomass or crop output, foliar application of chitosan helps to limit the loss of water from the leaves during drought stress (Hidangmayum *et al*., 2019).

While the precise procedures by which chitosan-raw-material promotes plant growth and development are unknown, it has been discovered that these activities are related to physiological functions that stop water loss through transpiration. According to Hidangmayum *et al.* (2019), stomatal closure has been shown to occur when plants are sprinkled with chitosan. This suggests that the growth-stimulating effect that occurs after stomatal closure may be connected to an antiperspirant effect on the ground. Additionally, foliar application of chitosan suspension in potatoes has been shown to lessen the effects of water stress (Jiao *et al*., 2012).

Considering the information mentioned above, the suggested study project was started to examine how varying amounts of chitosan-raw-material affect the growth and yield performance of sweet pepper.

Materials and methods

The purpose of the experiment was to find out how different concentrations of chitosan-raw-material (Shrimp Shell Powder) affected different kinds of sweet pepper varieties.

Soil

The soil in the experimental pot is classified as Shallow Red Brown Terrace Soils under the Tejgaon soil series, which is a general soil type. The pH of the soil is between 5.4 and 5.6. During the trial period, there was enough sunshine and the land was above flood level. Samples of soil were taken from the Sher-e-Bangla Agricultural University (SAU) Farm field at depths ranging from 0 to 15 cm. The Soil Resource and Development Institute (SRDI) in Dhaka conducted the soil analyses.

Experimental treatments

The experiment included two variables, which are as follows: different varieties of sweet pepper and varying concentrations of chitosan-raw-material as mentioned below:

Factor A: Sweet pepper varieties *viz.* (2):

V_1: BARI Sweet pepper-1 and V_2: BARI Sweet pepper-2

Factor B: Application of different levels of chitosan-raw-material (% w/w) *viz.* (4): C_0= 0% chitosan-raw-material, C_1= 0.1% chitosan-raw-material, C_2= 0.5% chitosan-raw-material and C_3= 1% chitosan-raw-material.

Selection and preparation of the pot

Earthen pots having 12 inches diameter, 12 inches height with a hole at the center of the bottom were used. The experiment was conducted using silt soil. The pots' upper edge diameter measured 30 cm (r = 15 cm). The top inch of the pot was left empty when it was filled with dirt so that a hose pipe could be used for irrigation. Because of this, the upper soil surface had a diameter of 15 inches (30 cm) and an area of (πr^2 = 3.14x 0.015x 0.015=0.07 m^2). Different concentrations of chitosan-raw-material powder were combined with the pot soil. On December 4, 2022, the pot was ready.

Fertilizer management

Initially, half as much cow manure was added to the pot soil. During the pot filling stage, the remaining half of the cow dung, the full amount of TSP, ZnO, Gypsum, and one-third of each of urea and MOP were applied. Additionally, varying amounts of chitosan raw material were added in accordance with the needs of the treatment. After transplanting in the large pot, the remaining urea and MOP were applied in two equal splits, 25 and 50 days later.

First transplanting

Seedlings that were 14 days old were moved into a tiny teacup pot. Different concentrations of soil mixtures containing powdered chitosan-raw material were put into the teacup pot. A solitary seedling was placed into a separate tea cup pot. On November 13, 2022, the first transplant of seedlings was completed.

Second transplanting to the pot

Seedlings were moved from the teacup into a 12-inch-diameter pot (Big pot). On December 5, 2022, the transplantation of seedlings was completed.

Intercultural operations

Each pot received irrigation water in accordance with the critical stage. It was administered via a water pipe. Some common weeds infested the crop, but during the experiment, they were uprooted and removed from the pot three times to control the infestation. After transplanting, weeds were removed 20, 30, and 45 days later. Each plot received two installments of the remaining two-thirds of urea and MoP applied as top dressing.

Harvesting and data analysis

The first harvesting of green sweet pepper was done on 18 February 2023, 21 February 2023, 23 February 2023, 4 March 2023, 13 March 2023, 18 March 2023 and 19 March 2023 respectively.

With the aid of a computer package called MSTAT-C, the gathered data were combined and statistically examined using the analysis of variance (ANOVA) approach. At a 5% probability level, the significance of the variation in treatment means was calculated (Gomez and Gomez, 1984).

Results and discussion

The combined effect of variety and different levels of chitosan-raw-material on plant height of sweet pepper

The plant height of sweet pepper at various DAT (Days After Transplanting) is greatly impacted by the types grown at varying concentrations of chitosan-raw-material (Table 1). According to experimental results, V_1C_3 had the highest plant height (23.67 and 29.17) at 35 and 50 DAT. On the other hand, V_2C_0 had the lowest plant height (11.17 and 15.17 cm) at 35 and 50 DAT.

According to Sultana *et al.* (2015), when chitosan was applied topically to rice plants, the morphological traits such as plant height, the number of tillers, the length of the panicle, and rice yield increased in comparison to the control.

The combined effect of variety and different levels of chitosan-raw-material on no. of primary branches plant^{-1} of sweet pepper

At various days following transplanting, the number of primary branches plant^{-1} of sweet pepper was significantly impacted by the combination of variety and varying concentrations of chitosan-raw-material (Table 2). According to the experimental results, V_1C_3 had the highest number of primary branches plant^{-1} (2.33, 3.00, and 2.83) at 35, 50, and 65 DAT. At 35 DAT, V_1C_3 (2.33), V_1C_2 (2.33), and V_1C_1 (2.33) all had statistically similar numbers. In contrast, V_2C_0 recorded the lowest primary branches plant^{-1} (0.00 and 1.50) at 35 and 50 DAT, which was statistically comparable to V_1C_0 (0.00) at 35 DAT. The lowest primary branches plant^{-1} (2.17) was observed in V_1C_0 at 65 DAT.

Table 1. The combined impact of variety and varying chitosan-raw-material raw material powder levels on sweet pepper plant height at various DAT

Treatments	Plant height at	
	35 DAT	50 DAT
V_1C_0	17.50 d	23.14 d
V_1C_1	17.83 c	24.17 c
V_1C_2	20.33 b	27.33 b
V_1C_3	23.67 a	29.17 a
V_2C_0	11.17 g	15.17 f
V_2C_1	13.67 f	24.00 c
V_2C_2	13.67 f	19.83 e
V_2C_3	15.17 e	23.50 d
$LSD_{0.05}$	0.31	0.41
CV (%)	1.74	1.62

In a column means having a similar letter(s) are statistically similar and those having a dissimilar letter(s) differ significantly as per 0.05 level of probability. Here; V_1: BARI Sweet pepper-1, V_2: BARI Sweet pepper-2, C_0= 0% chitosan-raw-material, C_1= 0.1% chitosan-raw-material, C_2= 0.5% chitosan-raw-material and C_3= 1% chitosan-raw-material.

Table 2. The number of primary branches plant^{-1} of sweet pepper at varying DAT as a result of variety and varying levels of chitosan-raw-material raw material powder

Treatments	No. of Primary branches plant^{-1} at		
	35 DAT	50 DAT	65 DAT
V_1C_0	0.00 d	2.33 d	2.17 d
V_1C_1	2.33 a	2.83 b	2.33 c
V_1C_2	2.33 a	2.67 c	2.50 b
V_1C_3	2.33 a	3.00 a	2.83 a
V_2C_0	0.00 d	1.50 g	2.33 c
V_2C_1	1.67 c	2.00 f	2.33 c
V_2C_2	1.83 b	2.17 e	2.33 c
V_2C_3	2.33 a	2.33 d	2.50 b
$LSD_{0.05}$	0.10	0.13	0.08
CV (%)	5.94	5.21	3.14

The combined effect of variety and different levels of chitosan-raw-material on the no. of leaves plant^{-1} of sweet pepper

Table 3 shows that the number of leaves plant^{-1} of sweet pepper was significantly impacted by the combination of variety and varying levels of chitosan-raw-material. The results of the experiment showed that V_1C_3 had the maximum number of leaves plant^{-1} (25.17 and 41.00) at 35 and 50 DAT. On the other hand, V_2C_0 had the fewest number of leaves plant^{-1} (10.17 and 18.33) at 35 and 50 DAT.

The reason behind the Increase in the number of leaves may be the supply of adequate nitrogen that comes from the chitosan-raw-material (Hammi *et al.*, 2020)

The combined effect of variety and different levels of chitosan-raw-material on no. of flowers plant^{-1} of sweet pepper

The number of sweet pepper flowers per plant at various days after transplanting was significantly influenced by different varieties and varying pot treatments with chitosan-raw-material (Table 4). The highest number of flowers plant^{-1} (11.43, 22.17, and 20.00) at 50, 60, and 70 DAT was observed in V_2C_3, according to the experimental results. On the other hand, V_1C_0 had the lowest number of flower plants^{-1} (1.00, 5.00, and 5.67) at 50, 60, and 70 DAT.

The higher number of flowers plant^{-1} is the result of genetic makeup of the crop and environmental conditions which play a remarkable role towards the final yield of the crop.

Combined effect of variety and different levels of chitosan raw material powder on no. of fruits plant^{-1} of sweet pepper

In terms of the number of sweet pepper fruits plant^{-1}, a significant variation was noted as a result of the interaction between variety and varying concentrations of chitosan raw material powder (Table 5). The results of the experiment indicated that V_2C_3 had the greatest number of fruits plant^{-1} (3.29). On the other hand, V_1C_0 had the lowest number of fruits plant^{-1} (1.00).

These results were comparable to those of Chookhongkha *et al.* (2012), who found that growing chilli seeds in soil with 1.0 percent high molecular weight chitosan produced significantly higher fresh fruit weights per plant, fruit counts per plant, fruit numbers per fruit, and seed weights in chilli.

Table 3. The combined impact of variation and varying dosages of raw chitosan material powder on the number of leaves per plant at varying DAT in sweet pepper plants

Treatments	No. of leaves plant^{-1} at	
	35 DAT	50 DAT
V_1C_0	15.67 f	28.83 e
V_1C_1	17.00 e	28.00 f
V_1C_2	24.67 b	37.33 b
V_1C_3	25.17 a	41.00 a
V_2C_0	10.17 g	18.33 g
V_2C_1	18.33 d	35.50 c
V_2C_2	17.00 e	30.83 d
V_2C_3	19.33 c	37.67 b
LSD $_{0.05}$	0.43	0.22
CV (%)	2.20	1.26

Table 4. The combined impact of variation and varying dosages of raw chitosan material powder on the number of flowers per plant at varying Days after Transplanting (DAT) for sweet peppers

Treatments	Flowers plant^{-1} at		
	50 DAT	60 DAT	70 DAT
V_1C_0	1.00 h	5.00 h	5.67 g
V_1C_1	6.42 d	18.67 c	6.67 f
V_1C_2	6.00 e	16.00 e	6.67 f
V_1C_3	7.67 c	16.50 d	8.67 e
V_2C_0	3.83 g	8.67 g	13.50 d
V_2C_1	4.50 f	9.83 f	15.83 c
V_2C_2	10.24 b	19.33 b	18.50 b
V_2C_3	11.43 a	22.17 a	20.00 a
LSD $_{0.05}$	0.39	0.23	0.23
CV (%)	2.52	1.48	1.80

Table 5. The combined impact of variation and varying concentrations of raw chitosan material powder on the number of fruits per plant, the weight of each individual fruit, and the fruit yield per plant per pot of sweet peppers

Treatments	Number of fruits plant^{-1}	Individual fruit weight plant^{-1}	Fruit yield plant^{-1} pot^{-1}
V_1C_0	1.00 g	74.14 a	74.14 f
V_1C_1	1.59 e	63.96 b	100.71 d
V_1C_2	2.71 d	46.05 d	125.00 c
V_1C_3	2.87 c	44.15 d	126.14 c
V_2C_0	1.14 f	77.13 a	88.14 e
V_2C_1	1.57 e	65.55 b	103.00 d
V_2C_2	3.14 b	56.36 c	177.14 b
V_2C_3	3.29 a	57.41 c	188.43 a
LSD $_{0.05}$	0.07	3.63	5.63
CV (%)	2.83	5.56	4.25

Combined effect of variety and different levels of chitosan-raw-material on individual fruit weight plant^{-1} of sweet pepper

Significant variation was observed in the individual fruit weight plant^{-1} of sweet pepper when combining the effects of variety and varying levels of chitosan-raw-material (Table 5). According to the experimental findings, V_2C_0 had the highest individual fruit weight plant^{-1} (77.13 g), which was statistically comparable to V_1C_0 (74.14 g). In contrast, V_1C_3 had the lowest individual fruit weight plant^{-1} (44.15 g), which was statistically comparable to V_1C_2 (46.05).

The combined effect of variety and different levels of chitosan-raw-material on fruit yield plant^{-1} pot^{-1} of sweet pepper

The combined effect of cultivating different varieties and varying the amount of chitosan-raw-material in the pot caused a significant variation in the fruit yield of plant^{-1} pot-1 of sweet pepper (Table 5). The results of the experiment indicated that V_2C_3 had the maximum fruit yield plant^{-1} pot-1 (188.43 g). On the other hand, V_1C_0 had the lowest fruit yield plant^{-1} pot-1 (74.14 g).

Kowalski *et al.* (2006) stated that chitosan has also been used to increase yield and tuber quality of micro propagated greenhouse-grown potatoes.

Chemical properties of pot soils after harvesting

pH and % total nitrogen

Table 6 showed that the pH and total nitrogen percentage of the soil were affected from the starting levels (5.8 and 0.04%) by varying the amount of chitosan-raw-material applied. Among the various treatments, the C_3 treatment (1% chitosan-raw-material) increased the pH of the soil (6.5) and the percentage of total nitrogen in the pot soil (0.12%) compared to the control treatment because chitosan-raw-material has a higher pH than the soil, which affected the pH of the soil. On the other hand, applying chitosan-raw-material increased the soil's capacity to supply nutrients, which increased the percentage of total nitrogen in the pot soil. Chitosan acts as an abundant nutrient source of Carbon

(47.9–54.4 %), Oxygen (30.19–42.3 %), Nitrogen (5.8–7.6 %), and Phosphors (3.4–6.1 %) for plants (Roohallah *et al.,* 2023).

Table 6. Effects of various treatments on the pH and percentage of total nitrogen in the pot soil following sweet pepper harvesting

Treatments	pH		% total nitrogen	
	Initial	After	Initial	After
C_0	5.8	5.60 d	0.04	0.02 d
C_1	5.8	6.00 c	0.04	0.05 c
C_2	5.8	6.30 b	0.04	0.11 b
C_3	5.8	6.50 a	0.04	0.12 a
$LSD_{0.05}$	0	0.18	0	0.003
CV (%)	0	1.97	0	2.34

Table 7. Effects of various treatments on the pH and percentage of total nitrogen in the pot soil following sweet pepper harvesting

Treatments	Organic carbon (%)		Organic matter (%)	
	Initial	After	Initial	After
C_0	0.5	0.50 c	0.87	0.87 d
C_1	0.5	0.63 b	0.87	1.09 c
C_2	0.5	0.75 a	0.87	1.20 b
C_3	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

Organic carbon and organic matter content

12.96% organic matter and 7.52% organic carbon can be found in chitosan-raw-material. Table 7 showed that, in comparison to the control treatment, the application of varying concentrations of chitosan-raw-material affected the percentages of organic carbon and organic matter. Comparable to the control treatment, the maximum levels of organic carbon (0.76%) and organic matter (1.31%) were observed in the C_3 treatment. The more chitosan-raw-material is applied, the more organic carbon and matter there is in the soil. Higher levels of organic matter and carbon have an impact on nutrient uptake, which leads to increased plant growth and yield.

A similar study by Bolto *et al.* (2004) stated that, chitosan can provide a carbon source for microbes in the soil; accelerate the transformation of organic matter into inorganic matter, and assist roots in absorbing more nutrients from the soil.

Conclusion

The findings of our experiment revealed that the growth and yield of sweet peppers were significantly influenced by chitosan-raw-material concentration and variety. The fruit yield plant^{-1} pot^{-1} (139.18 g) was the highest in the V_2 (BARI Sweet pepper-2) treatment. Applying varying amounts of chitosan-raw-material affects the nutrient characteristics of the soil and promotes plant growth. However, not every level of chitosan-raw-material can enhance the growth and yield of sweet peppers in the same way. In this experiment, the growth and yield of the sweet pepper plants were significantly influenced by 1% chitosan-raw-material (C_3). Comparable to the control treatment, the C_3 treatment had the highest number of fruits plant^{-1} (3.07), fruit yield plant^{-1} pot^{-1} (157.29 g), soil pH (6.5), soil total nitrogen content (0.12%), organic carbon (0.76%), and organic matter (1.31%). The cultivation of sweet peppers without chitosan-raw-material (C_0) resulted in a gradual decrease in yield and soil characteristics. V_1C_0 produced the lowest fruit yield plant^{-1} pot^{-1} (74.14 g). Plant growth and development were impacted by increasing the amount of chitosan-raw-material applied, and the BARI Sweet pepper-2 cultivation yielded the highest fruit yield (188.43 g) when 1% chitosan-raw-material was applied (V_2C_3).

Recommendation

It is challenging to suggest the right dosage of chitosan-raw-material for the influence of sweet pepper growth and development given the limited number of chitosan-raw-material levels and two sweet pepper varieties used in our experiment. Nonetheless, in light of our study's conclusions, we propose the following suggestions:

Of the four chitosan-raw-material concentrations (0.1%, 0.1%, 0.5%, and 1%), 1% worked best and had an impact on soil properties, yield, and sweet pepper growth. Research on varied trials is necessary. Nevertheless, more research involving a wider range of varieties and varying chitosan concentrations is necessary to reach a definitive determination about how chitosan-raw-material applications affect the growth and yield of sweet peppers.

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