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Research Article
Effect of Foliar Application of Oligo-chitosan on Growth, Yield and Quality of Tomato and Eggplant

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Abstract
Background and Objective: Plant growth promoters are important factors for higher yield of vegetables to meet the population demand and earn a considerable amount of foreign exchange through exporting it. The present research work was undertaken to study the effect of oligo-chitosan (*O. chitosan*) on growth, yield attributes and economic yield in tomato and egg-plant under Bangladesh conditions. **Materials and Methods:** Randomized complete block design (RCBD) with three replications was done during the period from 2015-2016 to investigate the effect of oligo-chitosan application on morphological characters, growth and yield in tomato and eggplant). Three levels of oligo-chitosan concentration *viz.* 0 (control), 60 and 100 ppm. O-chitosan was sprayed five times after sowing. Biochemical compositions of tomato and eggplant from chitosan treated plants were observed. The collected data were analyzed statistically using MSTAT-C v 3.2 and the mean difference were adjudged by Duncan's Multiple Range test. **Results:** The present results revealed that plant height and number of flowers plant^{-1} increased with increasing concentration of chitosan till 100 ppm. Treatments with 60 and 100 ppm O-chitosan were effective in increasing total yield plot^{-1} of tomato (41.67 and 38.30 kg, respectively) than control (22.79 kg). In tomato, the acidity and protein content has been significantly ($p<0.05$) decreased from plant treated with 60 ppm chitosan whereas 100 ppm chitosan treatment significantly ($p<0.05$) increased protein content in eggplant. There were no significant differences between 60 ppm chitosan treatment and control on ash and pH value of tomato and eggplants. Chitosan treatment (60 and 100 ppm) significantly ($p<0.05$) decreased total soluble solids (TSS) content in tomato but showed reverse phenomenon in eggplant. Higher dose of chitosan reduced vitamin C content in both tomato and eggplant although 60 ppm increases vitamin C compared to control in tomato. The powerful antioxidant (phenolic content) component has been found to be increased ($p<0.05$) significantly with chitosan treatment in eggplant but decreased only with lower dose in tomato. **Conclusion:** It was concluded that foliar application of oligo-chitosan at early growth stage enhances growth and functional components of tomato and eggplant.

Key words: Oligo-chitosan, foliar spray, plant growth, morphological characters, fruit yield

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) is one of the most important and popular vegetables in Bangladesh. It is a good source of Vitamin A and C and it provides antioxidant elements such as lycopene which prevents cancer[1]. Tomato contains a number of nutritive elements almost double as compared to fruit apple and shows superiority with regard to food values[2]. Tomato is composed mainly of water (approximately 90%), soluble and insoluble solids (5-7%) citric acid and other organic acids, vitamins and minerals[3]. Tomato is also effective in curing morning sickness, excessive gas formation in the intestine, gastro intestine diseases, indigestion etc. Tomato is also helpful in preventing joint pain problems and the respiratory disorder as well[4]. It is cultivated in almost all home gardens and also in the field for its adaptability to a wide range of soil and climate in Bangladesh. It ranks next to potato and sweet potato in respect of vegetable production in the world[5]. In Bangladesh, tomato is cultivated all over the country due to its adaptability to wide range of soil and climate[6]. Nutritionally, raw eggplant is low in calories and fats, contains mostly water, some protein, fiber and carbohydrates. It is a good source of minerals and vitamins and rich in total water soluble sugars, free reducing sugars, amide proteins among other nutrients[7].

The most logical way to increase the total production at the national level from our limited land resources is to increase yield per unit area and increase tomato and eggplant cropping intensity through growing in summer. Plant growth promoters are one of the most important factors for increasing higher yield in these vegetables. Application of growth regulators has good management effect on growth and yield of fruits crops. Hormones regulate physiological process and synthetic growth regulators may enhance growth and development of field crops thereby increased total dry mass of a field crop[8]. Application of Plant Growth Promoter (PGP) seems to be one of the important practices in view of convenience, cost and labor efficiency. Recently, there has been global realization of the important role of PGP in agriculture for better growth and yield of crops. Developed countries like Japan, China, Poland, South Korea etc. have long been using PGPs to increase crop yield. Chitosan can be used as a PGP in the agricultural field; it can be subject to soak seeds or sprayed with Pieta[9]. Chitosan a new PGP like GA3 that may have many uses to modify the growth, yield and yield attributes to the plant. Application of chitosan enhances growth and yield attributes in rice and soybean[10], in sunflower[11], in maize[12] and in Indian spinach[13]. Chitosan can be extracted from the marine crustacean like prawn, shrimps, crab or from the exoskeletons of most insects under the name of chitin which can be transformed into chitosan by extracting the acetyl group and turn into amino[14,15]. Chitosan is a linear amino polysaccharide obtained by deacetylation of chitin (poly-N-acetylglucosamine), an abundant byproduct of the crab and shrimp processing industries. It is a cationic polymer. It possesses primary amino groups in its structure and acts as an antimicrobial agent due to the presence of these amino groups[16]. Bangladesh, the largest Delta country in the world, have 724 km long coastal belt. Moreover, Bangladesh is a reverie country[17]. The marine water shrimp and freshwater prawn is commercially cultured in Khulna district of Bangladesh. Now, the production of shrimp and prawn are turn over all around the year. The total production in shrimp and prawn from Khulna region is 21,611 ton in this fiscal year 2006[18]. Day by day, the shrimp cultivation area is increasing. Chitosan is derived from chitin, a polysaccharide found in exoskeleton shellfish such as shrimp, prawn, lobster or crabs and cell wall of fungi[19] which is available in our country. The degraded chitosan has potential application in agriculture as plant growth promoter and elicitor. It can clearly be concluded that irradiated chitosan can be used to ensure the food security and safety by means of increasing yield, reducing post-harvest lose as well as maintaining biodiversity by reducing the demand for hazardous chemicals throughout cultivation. Considering the above facts, the present research work was undertaken to study the effect of oligo-chitosan on growth, yield attributes and economic yield in tomato and eggplant under Bangladesh conditions.

MATERIALS AND METHODS

A semi field experiment was carried out at Atomic Energy Research Establishment, Savar, Bangladesh during November, 2015-March, 2016. The soil of the experiment was sandy loam having pH around 6.5 (acidic). The experiment comprised of three concentrations of oligo-chitosan viz. 0, 60 and 100 ppm were applied five times up to harvesting. The soil was thoroughly mixed with urea, phosphate and potash at the amount of 0.37, 0.5 and 0.37 kg plot^{-1}, respectively. In the case of tomato plants three plots were selected for these experiments. The size of per plot (land area) was 2×3 m^2. Every plot was contain 25 plants. For egg plants, three plots were selected for these experiments. The size of per plot (land area) was 2×3 m^2. Every plot was contain 20 egg-plants. 0. 60 and 100 ppm of oligo-chitosan were sprayed on tomato and egg plants at morning by using hand sprayer. Weeding

Table 1: Effect of different levels of oligo-chitosan on yield components and yield in tomato

Treatments Concentration (ppm)	Average fruit weight $plot^{-1}$ (in kg)at DAS						Total Yield $plot^{-1}$ (in kg)
	45	55	60	70	75	85	
0	0.30	0.552	4.46	7.68	5.80	4.0	22.79
60	2.92	2.25	5.90	12.0	6.50	12.1	41.67
100	1.80	3.0	7.80	13.1	7.00	5.6	38.30

Values are the mean of 3 replicates

Table 2: Effect of different levels of oligo-chitosan on yield components and yield in Eggplant

Treatments concentration (ppm)	Average fruit weight $plot^{-1}$ (kg) at DAS						Average size $fruit^{-1}$ (cm)	Single fruit weight (g)	Total yield $plot^{-1}$ (kg)
	60	65	75	85	95	105			
0	30.5^{b}	75^{b}	593^{c}	2350^{c}	5130^{c}	1040^{b}	6.0	30	9.18
60	161.5^{a}	258^{a}	2850^{a}	4640^{b}	8860^{a}	1800^{b}	12.0	162	18.57
100	164.5^{a}	275.5^{a}	2070^{b}	6100^{a}	7340^{b}	3830^{a}	13.5	164	19.68
F-test	NS	NS	NS	NS	NS	NS	NS	NS	
CV(%)	28.98	34.83	32.34	22.07	18.34	51.81	25.30	8.67	

In a column, the figures with similar letter (s) do not differ significantly by DMRT (Duncan's multiple range test) at p<0.05; CV: Coefficient of variation; NS: Non significant

and soil watering were done when necessary. For tomato plants, the morphological values that is plant height (15, 30, 45, 60 DAS), average number of flowers $plant^{-1}$ (15, 30, 45, 60 DAS), average number of fruits $plant^{-1}$ were measured and six times selected for harvest (45, 55, 60, 70, 75 and 85 days after sowing, DAS). At each harvest, average fruit weight $plot^{-1}$ was recorded (Table 1). In the case of eggplant at different days after sowing (DAS), the morphological values that is plant height, average number of flowers $plot^{-1}$, average number of fruits $plot^{-1}$ were measured and different times selected (Table 2) for harvest (60, 65, 75, 85, 95 and105 days after sowing, DAS). At each harvest, average fruit weight $plot^{-1}$, size $fruit^{-1}$, weight $fruit^{-1}$also recorded.

Biochemical composition of tomato fruits was analyzed at Food Technology Division, Institute of Food and Radiation Biology (IFRB), AERE, Savar, Dhaka. The moisture content was determined according to the standard method of AOAC[20]. The TSS and pH was estimated using digital Refractometer (Hanna Instruments HI 96801, USA) and digital pH meter (Jenway 2510, United Kingdom) respectively. Determination of protein by micro-Kjeldahl's method was developed by Ma and Zuazaga[21]. Ash was determined by drying the sample in a Muffle Furnace (Nabertherm, Germany) at 600°C for 3-5 h. Acidity was determined by titration method and the results expressed as percentage of citric acid[20]. Ascorbic acid was determined by 2, 6-dichloroindophenol titrimetric method[22]. Total phenol content was determined according to the Folin-Ciocalteu (FC) method and the data was expressed as mg Gallic acid equivalents/100 g sample[23].

Statistical analysis: The collected data were analyzed statistically using the computer package programmer; MSTAT-C v 3.2 and the mean differences were adjudged by Duncan's Multiple Range Test[24]. Two types of probabilities were used to determine the level of significance: 99% (p = 0.01) and 95% (p = 0.05). All the biochemical determinations were obtained from triplicate measurements and results were expressed as Mean±Standard Deviation. The obtained data were subjected to statistical analysis using Student's t-test. Statistical differences between the treatment groups were carried out at significance level of p<0.05.

RESULTS

Oligo-chitosan on morphological characters in tomato: The effect of different concentrations (60 and 100 ppm) of oligo-chitosan on plant height, average number of flowers $plant^{-1}$ and average number of fruits $plant^{-1}$ of shown in Table 3. The present results indicated that foliar application of oligo-chitosan with different concentrations played a positive role on plant growth. Plant height and number of flowers $plant^{-1}$ increased with increasing concentration of chitosan till 100 ppm at all DAS. The highest number of fruit $plant^{-1}$ at 75 and 90 DAS observed when treated with 60 ppm oligo-chitosan in comparison with control and 100 ppm treatment (Table 3). In Table 1 it was shown that the fruit weight $plot^{-1}$ at 45-75 DAS increased with increasing concentration of chitosan but at 85 DAS 60 ppm oligo-chitosan showed highest fruit weight $plot^{-1}$ compare to control and 100 ppm. The present findings confirmed that both 60 and 100 ppm were effective treatment in increasing total yield $plot^{-1}$ than control and 60 ppm was the most effective treatment to increase total yield $plot^{-1}$ (Table 1).

Oligo-chitosan on morphological characters in eggplant: The data shown in Table 4 illustrated that foliar application of different concentration of oligo-chitosan on eggplant showed

Table 3: Effect of different levels of oligo-chitosan on some morphological characters in tomato plant

Treatments Concentration (ppm)	Plant height (cm) at DAS				Average no. of flowers plant^{-1} at DAS				Average no. of fruits plant^{-1} at DAS			
	15	30	45	60	15	30	45	60	45	60	75	90
0	24^{c}	47^{c}	60^{c}	73^{c}	5^{c}	11^{c}	12^{c}	17^{c}	2^{c}	6^{c}	11^{c}	12^{c}
60	34^{b}	68^{b}	80^{b}	77^{b}	11^{b}	21^{b}	33^{b}	38^{a}	6^{b}	9^{b}	19^{a}	26^{a}
100	38^{a}	73^{a}	88^{a}	92^{a}	15^{a}	25^{a}	38^{a}	39^{a}	9^{a}	13^{a}	13^{b}	24^{a}
F-test	*	*	NS	NS	**	**	NS	NS	NS	NS	*	**
CV(%)	12.75	7.75	8.75	8.47	15.98	13.24	13.56	13.78	36.01	24.19	14.17	9.60

In a column, the figures with similar letter (s) do not differ significantly by DMRT (Duncan's multiple range test) at $p<0.05$ * and **indicate significance at 5 and 1% levels of probability, respectively, CV: Coefficient of variation, NS: Non significant

Table 4: Effect of different levels of oligo-chitosan on some morphological characters in Egg-plant

Treatments Concentration (ppm)	Plant height (cm) at DAS				Average no. of flowers plot^{-1} at DAS				Average no. of fruits plot^{-1} at DAS			
	15	30	45	60	30	45	60	75	45	60	75	90
0	24^{b}	24^{b}	43.2^{b}	70^{b}	5	11	12	22	2	6	15	18
60	36^{a}	36^{a}	77.9^{a}	89^{a}	18	23	28	38	12	18	35	35
100	34^{a}	34^{a}	80.1^{a}	89^{a}	22	25	30	35	14	23	33	33
F-test	NS	**	*	NS	-	-	-	-	-	-	-	-
CV(%)	17.53	11.64	4.92	2.95	-	-	-	-	-	-	-	-

In a column, the figures with similar letter (s) do not differ significantly by DMRT (Duncan's multiple range test) at $p<0.05$ * and **indicate significance at 5 and 1% levels of probability, respectively, CV: Coefficient of variation, NS: Non significant

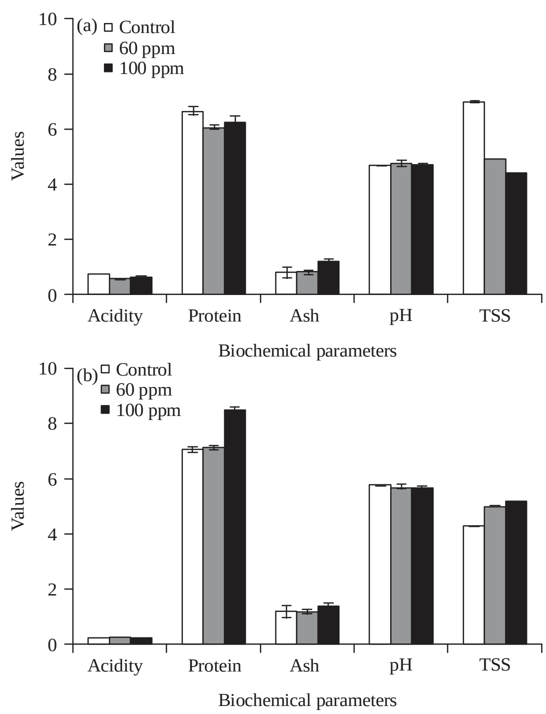

Fig. 1(a-b): Effect of chitosan treatment on biochemical parameters of (a) tomato and (b) eggplant
Results are given as the average values±standard deviation of three independent samples

increment of different morphological characters expressed in plant height , number of flowers plant^{-1},number of fruits plant^{-1} and fruit weight plot^{-1}at different DAS (days after sowing). During 15-30 DAS plant height was highest with 60 ppm oligo-chitosan compare to control and 100 ppm oligo-chitosan treatment. During 45 DAS plant height increased with increasing concentration of chitosan till 100 ppm whereas 60 and 100 ppm showed same plant height at 60 DAS. Average number of flowers plot^{-1} at different DAS (30-75) shown in Table 4 revealed that foliar application of chitosan (60 and 100 ppm) increased the number of flowers plot^{-1} compare to control plant. Average number of fruits plot^{-1} at different DAS (45-90) gradually increased with increasing concentration of chitosan upto 100 ppm. Average fruit weight plot^{-1} (kg) at different DAS (60-105) showed significant difference ($p<0.05$) between treatments with the mean levels throughout all DAS (except 95 DAS) in plants treated with 100 ppm <60 ppm < untreated/control (Table 2). Average size, weight and total yield of fruit plot^{-1} of eggplant were significantly increased ($p<0.05$) by chitosan application than those of control plant.

Oligo-chitosan on biochemical composition of tomato and eggplant: The effects of different concentrations (60 and 100 ppm) of oligo-chitosan on biochemical composition of tomato were shown in Fig. 1a. It was revealed that tomato from plant treated with 60 and 100 ppm chitosan showed reduction in acidity and total soluble acid compared to control samples. 60 ppm chitosan resulted in the highest vitamin C content while 100 ppm gave the lowest vitamin C content (Fig. 2a) compare to control. Foliar application of oligo-chitosan at 100 ppm led to a significant ($p<0.05$) increment in total phenol content (Fig. 2b) compare to control and 60 ppm.

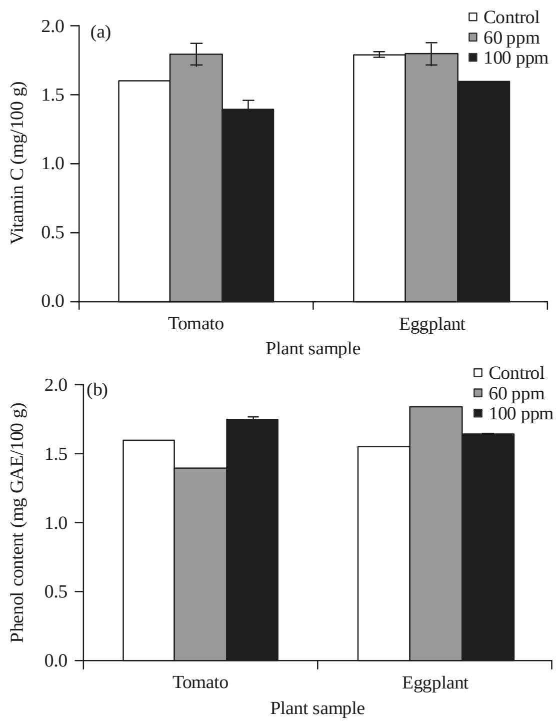

Fig. 2(a-b): Effect of chitosan treatment on (a) vitamin C and (b) phenol content of tomato and eggplant
Results are given as the average values±standard deviation of three independent samples

Regarding the biochemical analysis Fig. 1b showed that there were no significant differences among the treatments on acidity, ash and pH value in eggplants. Protein contents were significantly ($p<0.05$) increased with foliar spraying of chitosan at 100 ppm compared to control (7.05%). Furthermore, present results also revealed that TSS increased with increasing concentration of chitosan up to 100 ppm. In comparison with control sample, foliar application of chitosan at 100 ppm reduced vitamin C in eggplant but no significant influence on vitamin C content at 60 ppm chitosan application (Fig. 2a). The stimulating effect of chitosan (60 ppm) on the increase in the total phenol content of eggplant was confirmed statistically (Fig. 2b).

DISCUSSION

In the present investigation, foliar spraying of oligo-chitosan with different concentrations (60 and 100 ppm) has positive effect on plant height, number of flowers plant^{-1}, number of fruits plant^{-1} and fruit weight plot^{-1} of tomato and eggplant at different DAS (days after sowing). Mondal *et al.*[25] reported that foliar application of chitosan (25, 50, 75 and 100 mg L^{-1}) at early growth stages increased plant height of summer tomato. They also found that the number of effective flower cluster and flowers plant^{-1}were greater in chitosan (25-75 mg L^{-1}) applied to summer tomato plants than control plants. Similar results were found in soybean and rice by No *et al.*[26] and Lu *et al.*[27], respectively where chitosan increased plant height, branch and leaf number over control plant. Mondal *et al.*[13] found that number of fruits plant^{-1} and fruit size were increased with increasing concentration of chitosan upto 25 ppm, resulted the highest fruit yield (27.9% yield increased over the control) in okra. Chitosan has been reported as a high potential biomolecule had molecular signals that served as plant growth promoters[28-30]. Strawberry plants sprayed with chitosan at different developmental stages produced fruits with increased shelf life[31]. The yield of tomato plants increased with chitosan treatment[32]. Recently some researchers reported that the stimulating effect of chitosan on plant growth may be attributed to an increase in key enzymes activities of nitrogen metabolism (nitrate reductase, glutamine synthetase and protease) and improved the transportation of nitrogen in the functional leaves which enhanced plant growth and development[29,30,33]. Chitosan served as a plant growth promoters may be due to an increase in the availability and uptake of water and essential nutrients through adjusting cell osmotic pressure and reducing the accumulation of harmful free radicals by increasing antioxidants and enzyme activities[34].

The effects of different concentrations (60 and 100 ppm) of oligo-chitosan on biochemical composition of tomato and eggplant have been investigated in the present study. The 60 and 100 ppm chitosan showed reduction in acidity compared to control samples in tomato whereas there was no significant difference among the treatments on acidity in eggplants. Ghoname *et al.*[35] found that spraying with chitosan showed positive responses on total acidity content of sweet pepper. Chitosan has no significant effect on ash and pH value of tomato and eggplant. Foliar spraying with chitosan reduced TSS significantly in tomato but increased in eggplant with increasing concentration. El-Tantawy[36] reported that spraying tomato plants with chitosan did not reflect any significant effect on TSS of tomato fruits compared to control. On the other hand, Shehata *et al.*[37] found increment of TSS in cucumber when plant treated with chitosan (1-4 ppm).

The 60 ppm chitosan spraying resulted in increment of vitamin C in tomato but in eggplant 60 ppm chitosan has no significant effect on vitamin C. On the other hand, 100 ppm chitosan reduced vitamin C content in both tomato and eggplant. Abd El-Gawad and Bondok[38] found increment of vitamin C in tomato when plants sprayed with 1% chitosan. Highest rate of total phenol was found in tomato and eggplant at 100 and 60 ppm respectively compare to control. The pronounced promotional effect of chitosan on polyphenolic substances and vitamin C content compared with control could be due to the enhanceable nature of chitosan on photosynthesis process Khan *et al.*[33] that strongly correlated with the synthesis of sugars, polysaccharides and vitamins. Moreover, chitosan is involved in the biosynthesis of phenolic substances in plant[39]. In addition, application of chitosan may be encouraged phenolic substances accumulation[40] that in turn reflected in the polyphenolic substances contents of fruits.

CONCLUSION

It is concluded that foliar application of oligo-chitosan at early growth stage enhances plant growth both of tomato and eggplant. Among the concentrations 60 ppm had superiority for plant growth both of tomato and eggplant. In addition, 60 ppm had positive effect on vitamin C in tomato and 100 ppm increased protein and TSS in eggplant. About 60 and 100 ppm increased total phenol content in eggplant and tomato respectively. Therefore, foliar application of oligo-chitosan at 60 or 100 ppm may be recommended for tomato and egg-plant after more field trials in different locations and seasons to draw a valid conclusion regarding the foliar application of chitosan for improvement of plant growth and fruit qualities.

SIGNIFICANCE STATEMENTS

The present study explores that foliar application of oligo-chitosan plays a significant role in growth promotion of tomato and eggplants in terms of plant height, number of flowers, number of fruits, size of single fruit and weight of single fruit. Thus chitosan application could be a promising tool in modern agriculture to ensure food security for increased world population by limiting environmental hazards.

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