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Studies on yield and yield attributes in tomato and chilli using foliar application of oligo-chitosan

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Abstract

Chitosan is a very important linear polysaccharide used in agricultural and horticultural practices primarily for plant defense and yield increase in recent decades. In this study, four levels of oligochitosan were used with control to optimize the level for obtaining maximum yield in tomato and chilli. It was observed that in case of tomato50 ppm chitosan level was found optimum in terms of yield (2.48 kg/plant). Positively linear correlation was also observed in leaves/plant (0.52), branch/plant (0.48), days to flowering (0.39) and fruit/plant (0.16) with the different levels of oligochitosan. The phenotypic coefficient of variance was found greater than the genotypic coefficient of variance. On the other hand, in case of chilli, 75 ppm chitosan level was found optimum in yield (333.01 g/plant). All the parameters of chilli i.e. plant height (49.36 cm), branch/plant (43.07), fruits/plant (151.86), fruit length (19.20 cm), fruit width (1.06 cm), the weight of 50 chilli (199.11 g) gave positive correlation with the different levels of oligochitosan. In case of yield, the phenotypic coefficient of variance was found greater than the genotypic coefficient of variance.

Keywords: Oligochitosan; Foliar spray; Yield; Tomato; Chilli

1. Introduction

Tomato (*Lycopersicon esculentum* Mill) is one of the most popular and nutritious vegetable crops and grown throughout the world as well as in Bangladesh. It belongs to the family Solanaceae. It ranks first among the vegetables and is a major source of carbohydrate, vitamin and minerals [1]. On the other hand, chilli (*Capsicum annu*um) is an important spice yielding plant and belongs to the family Solanaceae. It is a valuable and essential spice in our daily diet. The genus *Capsicum* native to South and Central America [2]. It is mainly used in the form of green, dried and powder. It becomes an essential ingredient in daily meals and usually used in all carry preparation like meat, fish, vegetables, pulses etc. for its typical color, taste and flavor [3]. It contains large amounts of vitamin C and a small amount of carotene and also volatile oil, fatty oils, capsaicinoids, protein, fiber and minerals [4]. The red color of tomato is due to lycopene and the yellow color is due to carotenes. The demand for tomato in our country is increasing day by day with the increase in population. The fruits are eaten as a salad, cooked vegetables in various ways like juice, ketchup, sauces, chutney etc. [5]. The yield of the tomato in the country is still low to those obtained in some advanced country in the world [6]. Although a number of local and improved varieties of tomatoes are being cultivated in Bangladesh but all of them has been suffering from various biotic and abiotic stresses [7-8]. Producing more tomato by increasing tomato producing

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area in the country is not possible due to limitation of land. These plants are widely grown in Bangladesh usually in winter season (October-January).

In case of tomato, to date, about 75,602 acres of land is brought under cultivation and the production is about 4,13,610 MT and yield is about 5471 kg/ acres and about 2, 27,754 acres of land is under chilli cultivation in Bangladesh and the production is about 1,22,848 MT and yield is about 1185 kg/ acres [9]. At present, although the area and the production have been raised but per unit yield is still low comparing to other chilli growing countries in the world such as China, Turkey, Mexico, Spain, USA, Indonesia, Nigeria, Italy and India [10]. Per unit yield could be increased by supplying nutrients and other management practices. Chitosan is a biopolymer, a chitin derivative, a compound which is completely safe for the environment [11]. Chitin is a fibrous substance consisting of polysaccharides, which is the major constituent in the exoskeleton of shellfish such as shrimp, lobster or crabs and cell wall of fungi [12]. Few efforts were done to study the effect of chitosan on plant growth, development and productivity, which is mainly, attributed stimulation of plants immunity against microorganisms like bacteria and [13-15]. This compound is characterized by unique properties, such as bioactivity and bio-compatibility [16]. The results from the literature showed that, when chitosan is being used in plants, it reduces transpiration [17] and induces a range of metabolic changes as a result of which, plants become more resistant to viral, bacterial and fungal infections [18]. Moreover, plants treated with chitosan may be less prone to stress evoked by unfavorable conditions, such as drought, salinity, low or high temperature [19-20]. Chitosan stimulates vital processes of plants on every level of biological process, from single cells and tissues, through physiological and biochemical processes, to changes on the molecular level related to expression of genes [21-24]. Recently some researchers reported that chitosan enhanced key enzymes activities of nitrogen metabolism and improved the transportation of nitrogen in the functional leaves which enhance plant growth and development [25-26]. Considering the above facts, the present investigation was undertaken to study the effect of chitosan on growth and yield of tomato and chilli in winter season.

2. Material and methods

2.1. Collection of seed and the location of study area

Seeds were collected from the Lal Teer Seed Ltd., Bangladesh. To prevent some seed-borne diseases such as leaf spot, blight, anthracnose, etc., seeds were treated by Vitavax-200 @ 5 g^{-1} kg^{-1} seed. Seedlings were grown in poly bags under shade house. About twenty days old seedlings were transplanted in the experimental field of Plant Biotechnology and Genetic Engineering Division (PBGED), Institute of Food and Radiation Biology (IFRB), Atomic Energy Research Establishment (AERE), Savar, Dhaka, during the period of November-March 2016.

2.2. Experiment and treatment

The experimental field was prepared by ploughing, harrowing and hand spade. The experimental plot size was 5.0×2.0 m^2 and in case of tomato, plant to plant and row to row distance was maintained to 40 cm×60 cm whilst in chilli it was 30cm×60cm. The experimental design was followed randomized complete block design (RCBD) with three replications. The physiochemical prosperities of soil in the experimental field are: pH= 6.30, sandy clay loam, soil organic carbon 0.60%, soil organic matter 1.20%, total nitrogen 0.25%, available phosphorus 80 mg/kg, available potassium 264 mg/kg, available sulphur 175 mg/kg, calcium 648mg/kg, sodium 204 mg/kg. For the tomato, recommended doses of fertilizer were urea @ 550 kg/ha, MP @250 kg/ha, cowdung @10 t/ha and in case of chilli recommended fertilizer doses of urea were @75 kg/ha, TSP@150 kg/ha and MP@200kg/ha. Full dose of cowdung, TSP, MP and one third (1/3) dose of urea were applied during land preparation and remaining dose of urea was applied during branching and fruiting stage. Intercultural operations such as irrigation, weeding etc. were done as and when necessary. Four (4) chitosan levels @25 ppm, 50 ppm, 75 ppm, and 100 ppm with control were used as treatments in these experiments. Chitosan was diluted with 1% acetic acid and converted into oligochitosan by gamma irradiation of 5KGy and was used for whole experiments. The different levels of oligochitosan were sprayed at three growth stages to tomato and chilli such as (a) vegetative stage (b) flowering stage and (c) fruiting stage in the morning by using hand sprayer. Oligochitosan application was done at each stage for five times at every alternate day. In case of Maize grain tomato, data were collected on days to flowering, plant height (cm), leaves/plant (no), Branch/plant (no), fruits/plant (no), average fruit weight (g) and yield/plant (kg).

2.3. Measurement

Plant height, leaf number and branches were measured on 40 days after planting and fruits number, fruits weight and the total yield/plant (kg) were recorded during harvesting time.In case of chilli, data were collected on plant height (cm), branch/plant (no), fruit/plant (no), fruit length (cm), fruit width (cm), weight of 50 chillis (g) and yield/plant (g) at the time of harvest.

2.4. Statistical analysis

The data were analyzed for the estimation of variance, linear correlation, F-value, p-value at 0.05% level by analysis of variance (ANOVA). Genotypic coefficient of variance (gcv) and phenotypic coefficient of variance (pcv) were estimated by using the formula, adopted from Burton and De vane (1953) and Johnson et al. 1955a and 1955b.The mean differences were adjusted with Duncan's Multiple Range Test (DMRT) using the statistical computer package program, MSTAT-C (Russell,1986).

3. Results

3.1. Foliar application of chitosan in tomato

The influence of oligochitosan at different concentrations with differential growth stages on yield and yield attributes were slightly increased comparing to control (table-1). The effect of different concentrations (0, 25, 50, 75 and 100 ppm) of oligochitosan in tomato on days to flowering, plant height, leaves/plant, branch/plant, fruits/plant, average fruit weight and yield/plant was presented in Table-1. The present study indicated that foliar application at 50 ppm oligochitosan level played a positive role on yield in tomato. But the yield decreased, when the level of oligochitosan application was crossed beyond 50 ppm. The highest yield/plant (2.84 kg) of tomato was recorded with the application of 50 ppm oligochitosan. Interestingly the maximum plant height and leaves/plant were obtained with the supplement of 100 ppm oligochitosan. The highest number of branch/plant was showed with the application of 100 ppm oligochitosan whilst the lowest branch number was found at 25 ppm. In contrast, early flowering was observed with the application of 75 ppm oligochitosan. It was obvious from the study that application of five different concentrations of oligochitosan obtained minor differences of flowering in plant. The highest number of fruit/plant was found at 50 ppm of oligochitosan comparing to other treatments studied.

Table 1 Effect of foliar application of chitosan on growth and yield of tomato

Level of oligochitosan application (ppm)	Plant height (cm)	Leaves/ plant (no.)	Branches / plant	Days to flowering	Fruits/plant (no.)	Average fruit weight (g)	Yield/ plant (kg)
0	99.42 ^{c}	39.03 ^{b}	5.51 ^{bc}	39.28 ^{b}	18.83 ^{c}	97.86 ^{b}	1.90 ^{b}
25	92.66 ^{d}	28.94 ^{d}	3.84 ^{d}	42.45 ^{a}	17.67 ^{d}	79.88 ^{e}	1.79 ^{bc}
50	104.54 ^{bc}	40.36 ^{b}	6.51 ^{b}	38.49 ^{b}	24.57 ^{a}	102.11 ^{a}	2.48 ^{a}
75	103.96 ^{c}	36.52 ^{c}	4.16 ^{cd}	42.48 ^{a}	17.66 ^{d}	92.08 ^{c}	1.70 ^{bc}
100	107.75 ^{a}	46.24 ^{a}	8.33 ^{a}	42.35 ^{a}	20.83 ^{b}	89.14 ^{d}	1.58 ^{c}
F-test	**	**	**	**	**	**	**
CV%	1.77	3.27	4.25	3.64	2.76	0.28	6.65

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; **= significant

In table-1, it was also found that the number fruit/plant was 24.57 at 50 ppm of oligochitosan application comparing to other levels of oligochitosan tested. The highest fruit weight/plant (102.11 g) was observed with the application of 50 ppm oligochitosan. The present findings indicate that the oligochitosan has positive effect in tomato yield. It is an evidence in this study. The lowest fruit yield was observed in control plants due to absence of oligochitosan. The decreasing trend of fruit yield and poor plant growth was found at oligochitosan level of 75 ppm and 100 ppm respectively, which might be due to toxic levels of oligochitosan or other unknown factors.

In table-2, the genotypic coefficient of variance (gcv) in case of plant height, leaves/plant, Branch/plant, days to flowering, fruits/plant, average fruit weight and yield/plant were observed 147.63 cm, 102.35, 55.38, 7.51, 41.99, 78.95 g and 6.08 kg respectively. On the other hand the phenotypic coefficient of variance (pcv) for plant height, leaves/plant, branch/plant, days to flowering, fruits/plant, average fruit weight and yield/plant were found 150.97 cm,106.44, 66.84, 13.04, 43.50, 79.02 g and 6.88 kg respectively.

Table 2 Study of PCV and GCV in tomato by foliar application of oligochitosan

	Plant height (cm)	Leaves/plant (no.)	Branches/ plant	Days to flowering	Fruits/plant (no.)	Average fruit weight (g)	Yield / plant (kg)
GCV%	147.63	102.35	55.38	7.51	41.99	78.95	6.08
PCV%	150.97	106.44	66.84	13.04	43.50	79.02	6.88

PCV= Phenotypic co-efficient of variance; GCV = Genotypic co-efficient of variance

In table-3, it was found that the treatments were negatively linear correlated with plant height, average fruit weight and yield/plant. The values of these parameters decreased due to the increasing levels of oligochitosan application. Average fruit weight was observed negatively very weak linear correlated with the treatments. On the other, hand plant height was found negatively weak linear correlated. Positively linear correlation was also found with the treatments of other parameters (table-3). Branch/plant and days to flowering showed positively moderate linear correlation. Fruits/plant was found positively very weak and leaves/plant showed positively moderate linear correlation.

Table 3 Study on correlation of oligochitosan with different parameters in tomato

	Treatment (ppm)	Plant height (cm)	Leaves /plant (no.)	Branches /plant (no.)	Days to flowering	Fruits/ plant (no.)	Average fruit weight (g)	Yield/ plant (kg)
Treatment (ppm)	1							
Plant height (cm)	-0.335	1						
leaves/plant (no.)	0.5172	0.4026	1					
Branches/plant (no.)	0.4801	0.2936	0.797	1				
Days to flowering	0.3958	-0.281	-0.203	-0.056	1			
Fruits/plant (no.)	0.1661	0.194	0.314	0.556	-0.182	1		
Average fruit weight (g)	-0.093	0.637	0.459	0.355	-0.560	0.646	1	
Yield/plant (kg)	-0.211	-0.182	0.120	-0.108	-0.713	-0.102	0.227	1

Correlation is an effect size and so we can verbally describe the strength of the Correlation using the guide that Evans (1996) suggests for the absolute value of r: (.00-.19 very weak; .20-.39 weak; .40-.59 moderate; .60-.79 strong; .80-1.0 very strong)

3.2. Foliar application of chitosan in chilli

The effect of different levels of oligochitosan on plant height, branch/plant, fruits/plant, fruit length, fruit width, weight of 50 chilli and yield/plant were presented in Table-4. This study showed that positive effect on yield and yield attributes was found in case of foliar application of oligochitosan at 75 ppm. But when the level of oligochitosan application was increased above 75 ppm then the yield decreased. The highest yield/plant (333.01 g) was observed with 75 ppm oligochitosan. The maximum (61.75 cm) and minimum (48.75 cm) plant height were recorded at the levels of 75 ppm and 0 ppm chitosan respectively. The highest number branch/plant (12.97) and fruit/plant (129.78) were showed at 75 ppm whilst the lowest branching number (7.84) and fruit number (97.32) were found at 0 ppm oligochitosan application. The three concentrations of oligochitosan i.e. 50 ppm, 75 ppm and 100 ppm showed almost the same value than that of 0 ppm and 25 ppm. In table-4, it was showed that the highest fruit width was observed at 75 ppm comparing to other concentrations of oligochitosan application. Among the treatments, 75 ppm showed the best for 50 number of chilli weight (125.42 g) comparing to other treatments studied. From the result, it is obvious that chitosan has better effect in chilli yield. It is also observed that oligochitosan application enhance luxurious plant growth and improved fruit yield. Therefore, it is suggested that foliar application of oligochitosan with optimum dose level at different growth stage could increase chilli production per unit area.

Table 4 Effect of foliar application of oligochitosan on growth and yield of chilli

Level of oligochitosan application (ppm)	Plant height (cm)	Branch/ plant (no.)	Fruit/plant (no.)	Fruit length (cm)	Fruit width (cm)	Weight of 50 chilli (g)	Yield/ plant (g)
0	48.75 ^{e}	7.84 ^{c}	97.32 ^{c}	7.92 ^{b}	0.57 ^{c}	88.26 ^{e}	181.68 ^{e}
25	52.55 ^{d}	8.93 ^{bc}	100.25 c	8.36 ^{b}	0.61 ^{bc}	93.45 ^{d}	191.72 ^{d}
50	57.22 ^{c}	9.92 ^{b}	111.72 b	10.56 ^{a}	0.68 ^{ab}	103.44 ^{c}	325.16 ^{b}
75	61.75 ^{a}	12.97 ^{a}	129.78 a	11.23 ^{a}	0.71 ^{a}	125.42 ^{a}	333.01 ^{a}
100	59.50 ^{b}	12.35 ^{a}	117.38 b	10.64 ^{a}	0.70 ^{ab}	107.41 ^{b}	282.94 ^{c}
F-test	**	**	**	**	**	**	**
CV%	1.34	9.91	3.31	10.16	7.01	1.63	1.20

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; **= significant

In table-5, the genotypic coefficient of variances (gcv) in case of plant height, branch/plant, fruits/plant, fruit length, fruit width, weight of 50 chilli and yield/plant were observed 49.36 cm, 43.07, 151.86, 19.20 cm, 1.06 cm, 199.11 g and 1982.10 g respectively. And the phenotypic coefficient of variance (pcv) in plant height, branch/plant , fruits/plant, fruit length, fruit width, weight of 50 chilli and yield/plant were found to 50.25 cm, 53.27, 164.03, 30.18 cm, 3.64 cm, 201.84 g and 1985.88 g respectively.

Table 5 Study of PCV and GCV in chilli by foliar application of oligochitosan

	Plant height (cm)	Branch/ plant (no.)	Fruit/ plant (no.)	Fruit length (cm)	Fruit width (cm)	Weight of 50 chilli (g)	Yield/ plant (g)
GCV	49.36	43.07	151.86	19.20	1.06	199.11	1982.10
PCV	50.25	53.27	164.03	30.18	3.64	201.84	1985.88

PCV= Phenotypic co-efficient of variance; GCV = Genotypic co-efficient of variation

Table 6 Study on correlation of oligochitosan with different parameters in chilli

	Treatment (ppm)	Plant height (cm)	Branch/ plant (no.)	Fruit/ plant (no.)	Fruit length (cm)	Fruit width (cm)	Weight of 50 chilli (g)	Yield/plant (g)
Treatment (ppm)	1							
Plant height (cm)	0.657	1						
Branch/plant (no.)	0.515	0.639	1					
Fruit/plant (no.)	0.599	0.733	0.089	1				
Fruit length (cm)	0.271	-0.433	-0.135	-0.180	1			
Fruit width (cm)	0.315	-0.035	-0.588	0.557	0.428	1		
Weight of 50 chilli (g)	0.710	0.734	0.287	0.917	0.060	0.489	1	
Yield/plant (g)	0.749	0.680	0.402	0.686	0.244	0.353	0.817	1

Correlation is an effect size and so we can verbally describe the strength of the Correlation using the guide that Evans (1996) suggests for the absolute value of r: (.00-.19 very weak; .20-.39 weak; .40-.59 moderate; .60-.79 strong; .80-1.0 very strong)

In table-6, it was showed that treatments were positively linear correlated with all the parameters observed. This indicated that the values of these parameters increased with the increasing dose levels of oligochitosan. Fruit length and fruit width were observed positively weak linear correlated with the treatments. Branch/plant and fruit/plant were found positively moderate linear correlated with treatments. This table also showed that other parameters were showed positively linear correlation with the treatment. The strong correlation was found in yield/plant.

4. Discussion

In the present investigation, foliar application of oligochitosan with different levels @25 ppm, @50 ppm, @75 ppm and @100 ppm has been found positive effect on plant height, leaves/plant and branch/plant in tomato plant. In case of chilli, it was observed that plant height, branch/plant, fruit/plant showed also positive effect with the application of different levels of oligochitosan. Many investigators reported that using oligochitosan as foliar spray increased vegetative growth, yield and quality of vegetable crops [27-29]. Algam et al., (2010) found that chitosan was able to enhance the growth and development of tomato plants [30]. These are in agreement with the present investigation. In case of tomato, results indicated that average fruit weight, fruit/plant and yield/plant increased with the increasing trends of oligochitosan application up to 50 ppm. Average fruit weight, number of fruit/plant of tomato and chilli showed luxurious growth and development in oligochitosan treated plants than control plants. This might be due to the fact that optimum levels of oligochitosan enhance to produce maximum yield. Similar result also reported by El-Miniawy et al., (2013) [31]. In case of tomato, the maximum yield 2.48 kg/plant was achieved by applying oligochitosan @50ppm whilst the control yielded1.90 kg/plant. This is an important intimation in this study. In case of chilli, the maximum yield 333.01 g/plant was achieved by applying chitosan level at 50 ppm whilst the control was 181.68 g/plant. These are also similar to the crop plant such as tomato, orka and wheat [32- 34]. These are similar to those reported by earlier literature [15, 30]. Mondal et al., [35] reported that the number of effective flower initiation and flowers/plant were highest in chitosan (25-75 mg L–1) applied summer tomato plants comparing to control plants. Reports were also available in soybean and rice plants where chitosan increased plant height, branch and leaf number over control plant [36-37]. Spraying with chitosan at different developmental stages in strawberry produced fruits with increased shelf life [38]. This indicates that chitosan has versatile effect in crop plant i.e., growth, development and post-harvest improvement. In our study, data are showed significantly different among the treatments (table-1& table-4). On the contrary, Pięta et al. (2006) obtained statistically non-significant data by foliar application of oligochitosan in soybean plant [39]. The dissimilar results are due to the effect of different crop plant studied. Besides, EI-Bassiony et al., (2014) obtained better yield in Chinese cabbage by foliar spraying with oligochitosan [40]. These results are also supported in our present investigation. Genotypic coefficient of variance (gcv) and phenotypic coefficient of variance (pcv) were estimated from analysis of variance which presented in (table-3 and table-5). This reveals that oligochitosan has good impact for crop yield. It was observed that the phenotypic coefficient of variance was greater than the genotypic coefficient of variance. This indicates that the application of oligochitosan has positive effect for the normal growth and development of tomato and chilli plants. In the present investigation, linear correlation (Table 3) showed that plant height, average fruit weight and yield/plant were negatively linear correlated with the treatments. This result is contrasted with the result of Shehata et al., (2012) [41]. The author reported that others parameters of tomato such as leaves/plant, branch/plant, days to flowering, and fruit/plant were found positively correlated with the treatments. The similar results were reported by Mondal et al., (2012) [42]. This is in compliance with the present study. From the present investigation, it could be concluded that oligochitosan has positive impact for normal growth and development of crop plants. It was also found from the study that application of optimum level of oligochitosan improve luxurious growth of the plant and yield and useful for the plant growth and development. Thus, chitosan could be applied in other crop plants to obtain better yield for sustainable agriculture.

5. Conclusion

The present study explores that foliar application of oligo-chitosan plays a significant role in growth promotion of tomato and Chilli 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.

Compliance with ethical standards

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Disclosure of conflict of interest

We declare that there are no conflict of interest in connection with this paper.

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