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# Influence of chitosan on morphological, physiological and growth parameters of cotton (*Gossypium hirsutum* L.)

**Vaishnavi Gawande, Dr. TH Rathod, Dr. SB Deshmukh and SB Bakal**

## Abstract
Cotton plays an important role in the agrarian as well as an industrial economy. Concerning the importance of cotton from an economical point of view, it becomes very essential to cultivate cotton with higher yield expectations. Though chemical fertilizers enhanced crop production, their overuses cause pollution. Newly formed alternatives to avoid the use of chemical compounds are biopolymers such as Chitosan. The investigation was conducted during *Kharif* season, 2020-2021 at Central Demonstration Farm, Wani Rambhapur, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The experiment was laid out in RBD with four replications and seven treatments comprising of different concentrations of chitosan *viz.*, control, 25 ppm, 50 ppm, 75 ppm, 100 ppm, 125 ppm, and 150 ppm. Foliar sprays of chitosan were carried out on 35 and 55 DAS. Significantly maximum values of morphological parameters like plant height, leaf area, leaf area index; physiological parameters like dry matter production, relative water content and growth parameters like crop growth rate, relative growth rate, net assimilation rate were recorded in treatment $T_4$ (75 ppm chitosan) over control.

**Keywords:** Chitosan, cotton, foliar sprays, morphological, physiological and growth

## Introduction
Indian economy is ago-based and agriculture is the primary source of rural livelihood. Cotton, being a major agricultural crop in India, has a major impact on the overall Indian agriculture sector. It is one of the heavily traded agricultural commodities. Millions of people derive livelihood through cotton production, textile sectors, and processing trades. Therefore, it is one of the important sectors for employment in the country. Cotton being a fiber crop provides the world's premier source of fiber which is a very important component of the textile industry. Cotton, being a versatile fiber, contributes about 58% of fiber consumption in the textile industry. Now a Days consumption of cotton seed oil in the human diet has increased. Hence, in the future, cotton will become a source of fiber, oil, and protein.

By recognizing, the importance of cotton, it becomes very indispensable to raise cotton with a higher yield probability. But the increase in chemical inputs and advances in technology have hurt natural resources. Though chemical fertilizers enhance crop production, their overuses have hardened the soil by building up harmful residues. So, it is necessary to ensure environmental conservation. The biopolymer term associated with the biodegradability of polymers derived from organic matter goes directly into nature after the completion of usage. They enhance agro-ecosystem health, biological cycles, soil biological activities, biodiversity and contribute to environment conservation. So, a substitute for this is biopolymers.

Chitosan is a natural, safe, and cheap biopolymer produced from chitin, the major constituent of arthropods exoskeleton and fungi cell walls, and the second renewable carbon source after lignocellulosic biomass (Kurita, K., 2006; Malerba and Cerana, 2016) [12, 16]. Chitosan is a biopolymer with antiviral, antibacterial, and antifungal properties (El Hadrami *et al*., 2010; Lizarraga-Paulin *et al*., 2013) [6, 15]. When chitosan is being used in plants, it reduces transpiration (Dzung *et al*., 2011; Islam *et al*., 2018) [5, 9]. Chitosan plays a key role in the defense system of plants. Foliar application of CHT enhanced fruit yield, plant height, and leaf number in okra (*Hibiscus esculentus* L.) (Mondal *et al*., 2012) [19].

By taking the above important facts into account, the experiment was conducted to evaluate the effect of chitosan on morphological, physiological, and growth parameters of cotton.

## Materials and Methods

The field experiment was laid out in Randomized Block Design (RBD) with seven treatments and four replications comprising of different doses of chitosan *viz*., $T_1$ (control), $T_2$ (25 ppm), $T_3$ (50 ppm), $T_4$ (75 ppm), $T_5$ (100 ppm), $T_6$ (125 ppm) and $T_7$ (150 ppm). After receiving sufficient rainfall, sowing was done on 28th June 2020 and the seed rate was 9 kg $ha^{-1}$ and sown by dibbling method at a spacing of 60 cm x 30 cm. After the germination, gap filling was completed on 6th July 2020. Then after full emergence thinning was carried out to maintain the required number of plants $plot^{-1}$. Intercultural operations were also undertaken as and when required. Spraying of chitosan was done on 3rd August 2020 and 24th August 2020 with a hand sprayer. Observations were recorded at 30, 60, 90, 120, and 150 DAS. The field crop was kept free from disease and pests during the growth period. After maturity harvesting in all treatments was undertaken. Observations were taken as follows:

### Morphological observations

#### Plant height (cm)

Plant height was recorded with the help of a meter scale in centimeters from the base of the plant to the topmost developing node.

#### Leaf area per plant ($dm^2$)

Leaf area was measured by using the following formula given by Ashley *et al.* (1963) [1].

#### Leaf area index (LAI)

Leaf area indices were calculated from the data of leaf area per plant put down with spacing of 60 × 30 $cm^2$ by using the following formula given by Watson (1952) [23]

#### Days to 50% flowering

Here the number of days from sowing to the date on which fifty percent of plants were flowered was recorded. Then mean value was calculated and noted.

### Physiological Observations

#### Dry matter production (g $plant^{-1}$)

To determine the dry matter put the plant samples in big brown paper bags and allow them to dry in a hot air oven at $70^0$ c, till the constant weight is achieved. Then by using weighing balance dry weighs were recorded. Finally means of dry weight noted in grams per plant.

#### Relative water content (RWC) (%)

Relative water content was calculated with the equation given by Barrs and Weatherley, (1962) [2].

### Computations of growth parameters

#### Crop Growth Rate (CGR) (g $m^{-2}$ $day^{-1}$)

The crop growth rate is calculated to estimate the production efficiency of the crop. It was calculated by using the formula given by D. J. Watson (1952) [23].

#### Relative growth rate (RGR) (g $g^{-1}$ $day^{-1}$)

The relative growth rate is computed by using Fisher' s formula (1921).

#### Net assimilation rate (NAR) (g $dm^{-2}$ $day^{-1}$)

Net assimilation rate calculated by using the formula suggested by Williams (1946) [24].

### Statistical Analysis

The analysis of variance was performed to test the significance of differences between the treatment for all the characters as per the methodology suggested by Panse and Sukhatme (1954) [20].

## Results and Discussion

### Morphological parameters

#### Plant height (cm)

The data on plant height regarding the influence of chitosan were recorded at 30, 60, 90, 120, and 150 DAS. At 30 DAS, the plant height was found non-significant. At 60 DAS, significantly maximum plant height was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$ and $T_5$. Treatment $T_4$, $T_3$, and $T_5$ were found at par with each other. However, significantly minimum plant height was recorded in treatment $T_1$ (control) followed by treatment $T_7$ and $T_2$ when compared with other treatments. Treatments $T_1$, $T_7$, and $T_2$ were at par with each other. At 90 DAS, significantly maximum plant height was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$ and $T_5$. Treatments $T_4$, $T_3$, and $T_5$ were at par with each other. However, significantly minimum plant height was found in treatment $T_1$ (control) followed by treatment $T_7$ and $T_2$ when compared with other treatments. Treatments $T_1$, $T_7$, and $T_2$ were at par with each other. At 120 DAS, significantly maximum plant height was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$ and $T_5$. Treatments $T_4$, $T_3$, and $T_5$ were at par with each other. However, significantly minimum plant height was found in treatment $T_1$ (control) followed by treatment $T_7$ when compared with other treatments. Treatments $T_1$ and $T_7$ were at par with each other. At 150 DAS, significantly maximum plant height was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$ and $T_5$. Treatments $T_4$, $T_3$, and $T_5$ were at par with each other. However, significantly minimum plant height was found in treatment $T_1$ (control) followed by treatment $T_7$ and $T_2$ when compared with other treatments. Treatments $T_1$, $T_7$, and $T_2$ were at par with each other.

Chitosan application showed an increase in morphological characters like plant height, which might be because of an increase in internode number and internode length due to an increase in cell number (Hong Yan and Shu Yu, 2001). Mondal *et al.* (2013, a) [17] carried out an experiment in which different concentrations of chitosan (0, 50, 75, 100, and 125 ppm) were sprayed three times at 35, 50, and 65 DAS. They suggested that foliar application of chitosan at 100 ppm significantly increased the plant height of maize. Deotale *et al.* (2018) [4] revealed the response of soybean to treatment with chitosan and IBA @ 25, 50, 75, 100, 125 ppm. The foliar spray was given at 30 DAS on soybean. The increase in plant height was recorded at a 25 ppm concentration of chitosan.

#### Leaf area of the plant ($dm^2$ per plant)

Data in respect of leaf area $plant^{-1}$ influenced by chitosan treatments were recorded at 30, 60, 90, 120, and 150 DAS. At 30 DAS, the data on leaf area were found non-significant. At 60 DAS, significantly maximum leaf area was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$. Treatment $T_4$ and $T_3$ were found at par with each other. However, significantly minimum leaf area was found in treatment $T_1$ (control) followed by the treatment $T_7$ when compared with other treatments. Treatment $T_1$ and $T_7$ were at par with each other. At 90 DAS, significantly maximum leaf area was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$ and $T_5$. Treatment $T_4$, $T_3$, and $T_5$ were found at par with each other. However, significantly minimum leaf area was found in treatment $T_1$ (control) followed by the treatment $T_7$ when compared with other treatments. Treatment $T_1$ and $T_7$ were at par with each other. At 120 DAS, significantly maximum leaf area was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$. Treatment $T_4$ and $T_3$ were found at par with each other. However, significantly minimum leaf area was found in treatment $T_1$ (control) followed by the treatments $T_7$ and $T_2$ when compared with other treatments. Treatments $T_1$, $T_7$, and $T_2$ were at par with each other. At 150 DAS, significantly maximum leaf area was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$. Treatment $T_4$ and $T_3$ were found at par with each other. However, significantly minimum leaf area was found in treatment $T_1$ (control) followed by the treatment $T_7$ when compared with other treatments. Treatment $T_1$ and $T_7$ were at par with each other.

Chitosan application showed an increase in morphological characteristics like leaf area which may be because of an increase in key enzyme activities of nitrogen metabolism and increased photosynthesis which enhanced plant growth which come up with the increase in leaf area (Gornik *et al*., 2008; Mondal *et al*., 2012) [7, 19]. Chitosan application in okra reported an increase in leaf number (Mondal *et al*., 2012) [19] which might contribute to an increase in leaf area. Sharifa and Abu-Muriefah (2013) [22] experimented to study the effect of chitosan @ 100, 200, and 400 ppm on common bean. The result reported that the application of chitosan @ 200 ppm has significantly increased leaf area $plant^{-1}$. Rabbi *et al*. (2016) [21] studied different concentrations of chitosan *viz*., 0 (control), 25, 50, 75, and 100 ppm and sprayed at 30 and 40 DAS on Mungbean plants. Results showed that foliar application of chitosan @ 50 ppm significantly enhanced plant leaf area over control.

**Leaf area index (LAI)**

The data were recorded at 30, 60, 90, 120, and 150 DAS. At 30 DAS, the data on the leaf area index was found non-significant. At 60 DAS, a significantly maximum leaf area index was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$. Treatment $T_4$ and $T_3$ were found at par with each other. However, a significantly minimum leaf area index was found in treatment $T_1$ (control) followed by the treatment $T_7$ when compared with other treatments. Treatment $T_1$ and $T_7$ were at par with each other.

**Table 1:** Influence of chitosan on Morphological parameters

| Treatment(s) | Plant height (cm) | | | | | Leaf Area (dm2) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS | 30 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS |
| T1 (Control) | 19 | 55.05 | 72.71 | 78.15 | 85.92 | 2.42 | 8.78 | 14.01 | 17.55 | 13.67 |
| T2 (25 ppm Chitosan) | 19.37 | 58.87 | 77.34 | 85.81 | 92.49 | 3.09 | 11.99 | 17.78 | 19.83 | 16.65 |
| T3 (50 ppm Chitosan) | 19.95 | 62.65 | 83.52 | 92.68 | 100.02 | 3.04 | 14.1 | 21.37 | 23.55 | 21.64 |
| T4 (75 ppm Chitosan) | 20.92 | 65.28 | 86.15 | 96.47 | 102.46 | 3.7 | 16.63 | 23.26 | 25.09 | 23.19 |
| T5 (100 ppm Chitosan) | 20.55 | 60.91 | 82.59 | 91.37 | 96.71 | 3.84 | 13.41 | 20.76 | 22.13 | 19.64 |
| T6 (125 ppm Chitosan) | 18.95 | 59.56 | 79.11 | 88.29 | 93.38 | 3.02 | 12.48 | 18.36 | 20.75 | 17.95 |
| T7 (150 ppm Chitosan) | 20.41 | 56.26 | 74.36 | 83.24 | 88.21 | 2.49 | 10.99 | 14.27 | 18.35 | 15.11 |
| F test | NS | Sig | Sig | Sig | Sig | NS | Sig | Sig | Sig | Sig |
| S.E(m)± | - | 1.49 | 2.09 | 2.3 | 2.41 | - | 0.98 | 1.2 | 0.93 | 0.72 |
| CD at 5% | - | 4.44 | 6.21 | 6.34 | 7.18 | - | 2.91 | 3.57 | 2.73 | 2.14 |

**Table 2:** Influence of chitosan on Morphological parameters

| Treatment(s) | Leaf Area Index | | | | | Days to 50% flowering |
|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS | |
| T1 (Control) | 0.134 | 0.487 | 0.773 | 0.97 | 0.759 | 71.52 |
| T2 (25 ppm Chitosan) | 0.171 | 0.665 | 0.937 | 1.095 | 0.924 | 70.12 |
| T3 (50 ppm Chitosan) | 0.168 | 0.782 | 1.137 | 1.305 | 1.202 | 63.42 |
| T4 (75 ppm Chitosan) | 0.205 | 0.923 | 1.292 | 1.337 | 1.255 | 62.53 |
| T5 (100 ppm Chitosan) | 0.213 | 0.744 | 1.153 | 1.225 | 1.091 | 64.32 |
| T6 (125 ppm Chitosan) | 0.167 | 0.693 | 1.02 | 1.147 | 0.997 | 66.25 |
| T7 (150 ppm Chitosan) | 0.138 | 0.61 | 0.792 | 1.015 | 0.339 | 63.51 |
| F test | NS | Sig | Sig | Sig | Sig | NS |
| S.E(m)± | - | 0.054 | 0.066 | 0.051 | 0.04 | - |
| CD at 5% | - | 0.161 | 0.198 | 0.153 | 0.119 | - |

At 90 DAS, significantly maximum leaf area index was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$ and $T_5$. Treatments $T_4$, $T_3$, and $T_5$ were at par with each other. However, a significantly minimum leaf area index was found in treatment $T_1$ (control) followed by treatment $T_7$ when compared with other treatments. Treatments $T_1$ and $T_7$ were at par with each other. At 120 DAS, a significantly maximum leaf area index was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$. Treatment $T_4$ and $T_3$ were found at par with each other. However, a significantly minimum leaf area index was found in treatment $T_1$ (control) followed by the treatments $T_7$ and $T_2$ when compared with other treatments. Treatments $T_1$, $T_7$, and $T_2$ were at par with each other. At 150 DAS, a significantly maximum leaf area index was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$. Treatment $T_4$ and $T_3$ were found at par with each other.

**Table 3:** Influence of chitosan on physiological parameters

| Treatment(s) | Dry Matte- Prolction | | | | | Relative water content (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS | 30 DAS | 60 DAS | 90 DAS | 120 DAS | 150 DAS |
| T1 (Control) | 1.7 | 22.71 | 43.65 | 62.5 | 61.01 | 78.49 | 69.01 | 62.75 | 5734 | 54.26 |
| T2 (25 ppm aitosan) | 1.52 | 25.65 | 4747 | 63.22 | M.64 | 78.42 | 74.93 | 6952 | 6535 | 61.4 |
| T3 (50 ppm aitosan) | 1.48 | 2521 | 51 | 73.45 | 7121 | 81.03 | 80.36 | 7435 | 7137 | 63.94 |
| T4 (75 ppm Clitosan) | 1.83 | 2998 | 5295 | 75.65 | 7432 | 82.53 | 82.11 | 76.62 | 7345 | 69.83 |
| T5 (100 ppm Clitosan) | 1.42 | 27.65 | 50.15 | 72.21 | 70.64 | 80.94 | 80.25 | 7399 | 7049 | 67.99 |
| T6 (125 ppm Clitosan) | 1.4 | 26.03 | 43.11 | 70.01 | 6323 | 77.27 | 75.88 | 70.11 | 66.02 | 62.56 |
| T7 (150 ppm Chitccan) | 1.63 | 2421 | 46.01 | 66.55 | 64.73 | 77.66 | 71.15 | 6529 | 61.75 | 59.21 |
| F tag | NS | Sig | Sig | Sig | Sig | NS | Sig | Sig | Sig | Sig |
| S.E(m)± | - | 1.04 | 1.23 | 1.87 | 1.91 | - | 1.97 | 2.16 | 2.38 | 2.39 |
| CD at 5% | - | 3.11 | 3.65 | 5.58 | 5.67 | - | 5.86 | 6.43 | 7.09 | 7.12 |

However, a significantly minimum leaf area index was found in treatment $T_1$ (control) followed by the treatment $T_7$ when compared with other treatments. Treatment $T_1$ and $T_7$ were at par with each other.

Chitosan application showed an increase in leaf area index which may be because of an increase in key enzyme activities of nitrogen metabolism and increased photosynthesis which enhanced plant growth which come up with the increase in leaf area (Gornik *et al*., 2008; Mondal *et al*., 2012) [7, 19]. Chitosan application in okra reported the increase in leaf number (Mondal *et al*., 2012) [19] which contributed to an increase in leaf area. As leaf area is directly proportional to leaf area index, an increase in leaf area was found in an experiment done by Sharifa and Abu-Muriefah (2013) [22] which was performed to study the effect of chitosan @100, 200, and 400 ppm on common bean. The result reported that the application of chitosan @ 200 ppm has significantly increased leaf area plant$^{-1}$ leading to an increase in leaf area index. Rabbi *et al*. (2016) [21] applied different concentrations of chitosan *viz*., 0 (control), 25, 50, 75, and 100 ppm at 30 and 40 DAS on the mungbean plant. Results showed that foliar application of chitosan @ 50 ppm significantly enhanced plant leaf area over control leading to an increase in leaf area index.

**Days to 50% flowering:** Days to 50% flowering was not significantly influenced by the chitosan treatment.

**Physiological observations**

**Dry matter production (g plant$^{-1}$)**

Data on dry matter production plant$^{-1}$ were recorded at 30, 60, 90, 120, and 150 DAS. At 30 DAS, the data on dry matter production were found non-significant. At 60 DAS, significantly maximum dry matter production was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$ and $T_5$ (27.65 g). Treatments $T_4$, $T_3$, and $T_5$ were at par with each other. However, significantly minimum dry matter was found in treatment $T_1$ (control) followed by treatments $T_7$ and $T_2$ when compared with other treatments. Treatments $T_1$, $T_7$, and $T_2$ were at par with each other. At 90 DAS, significantly maximum dry matter production was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_5$. Treatments $T_4$, $T_3$, and $T_5$ were at par with each other. However, the significantly minimum dry matter was found in treatment $T_1$ (control) followed by treatment $T_7$ when compared with other treatments. Treatments $T_1$ and $T_7$ were at par with each other. At 120 DAS, significantly maximum dry matter production was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$ and $T_5$. Treatments $T_4$, $T_3$, and $T_5$ were at par with each other.

**Table 4:** Influence of chitosan on Growth parameters

| Treatment(s) | Cat | | | | RGR. | | | | NAP. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 30-60 | 60-90 | 90-120 | 120-150 | 30-60 | 60-90 | 90-120 | 120-150 | 30-60 | 60-90 | 90-120 | 120-150 |
| T1 (Control) | 3.354 | 2.825 | 2.578 | -1.07 | 0.0676 | 0.0174 | 0.0101 | -0.0009 | 0.0944 | 0.0433 | 0.03074 | 0.0053 |
| T2 (25 ppm Chitosan) | 4.472 | 1676 | 3.564 | -098 | 01082 | 0.0217 | 0.0132 | -0.0009 | 01072 | 0M5012 | 00421 | 0.0034 |
| T3 (50 ppm Chitosan) | 4.976 | 4.536 | 4.523 | -0395 | 01226 | 0.0264 | 00163 | -0.0013 | 0A39 | 005688 | 004517 | 0.004 |
| T4 (75 ppm Chitosan) | 5.293 | 4389 | 4245 | -1171 | 0123 | 0.0284 | 0M192 | -0.0007 | 01409 | 0.0597 | 005011 | 0.0022 |
| T5 (100 ppm Chitosan) | 4.831 | 4.004 | 4A94 | -1138 | 01189 | 0.0247 | 0M162 | -00009 | 01274 | 00548 | 0M4438 | 0M03 |
| T6 (125 ppm Chitosan) | 4.491 | 3375 | 1675 | -1.41 | 01089 | 00225 | 0M161 | -0001 | 01199 | 0M5191 | 0M4391 | 0.0037 |
| T7 (150 ppm Chitosan) | 3.848 | 3342 | 1406 | -0587 | 0.0774 | 0.0198 | 0M13 | -00011 | 0.0993 | 0M4538 | 0M404 | 0.0044 |
| F test | Sig | Sig | Sig | NS | Sig | Sig | Sig | NS | Sig | Sig | Sig | NS |
| S.E(m)± | 0.258 | 0.308 | 0.317 | - | 0.0035 | 0.0016 | 0.001 | - | 0.0033 | 0.00235 | 0.00189 | |
| CD at 5% | 0.766 | 0.916 | 0.941 | - | 0.0104 | 0.0048 | 0.003 | - | 0.0098 | 0.00696 | 0.0056 | |

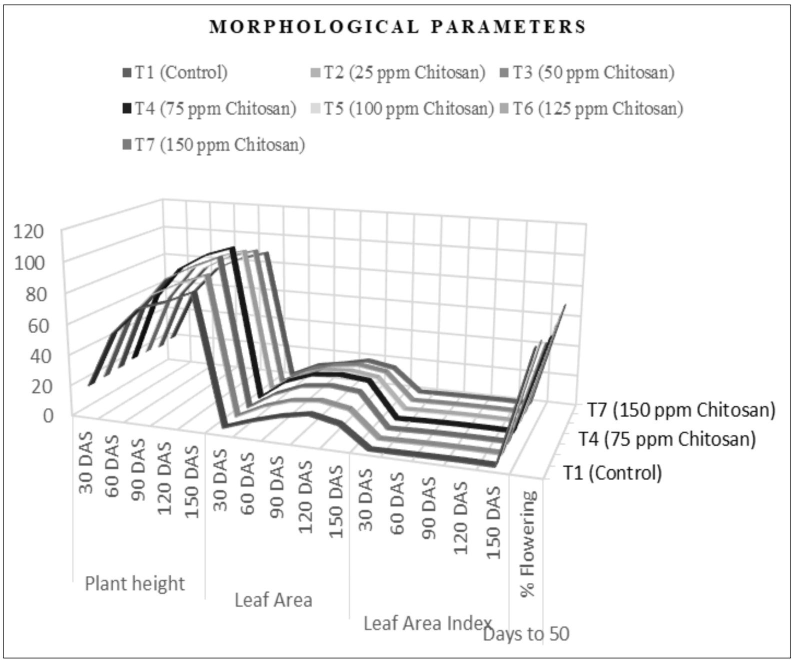


**Fig 1:** Influence of chitosan on morphological parameters

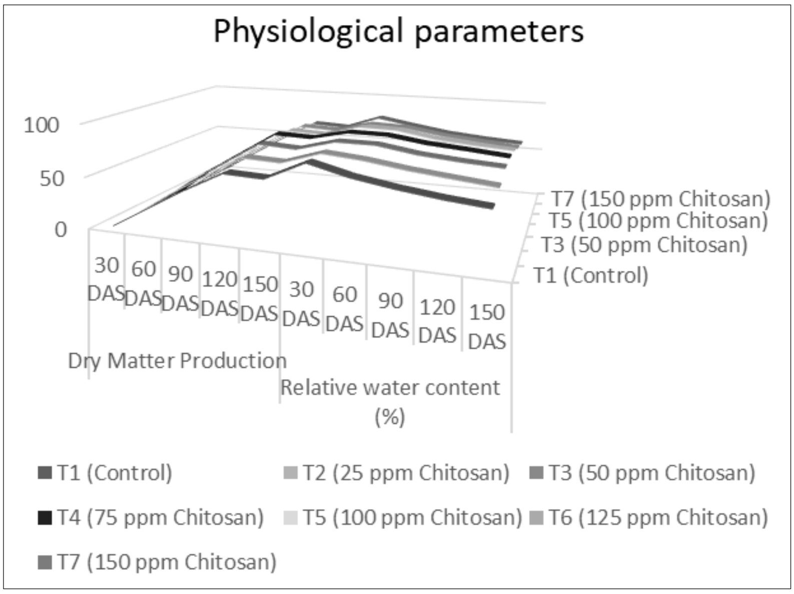


**Fig 2:** Influence of chitosan on physiological parameters

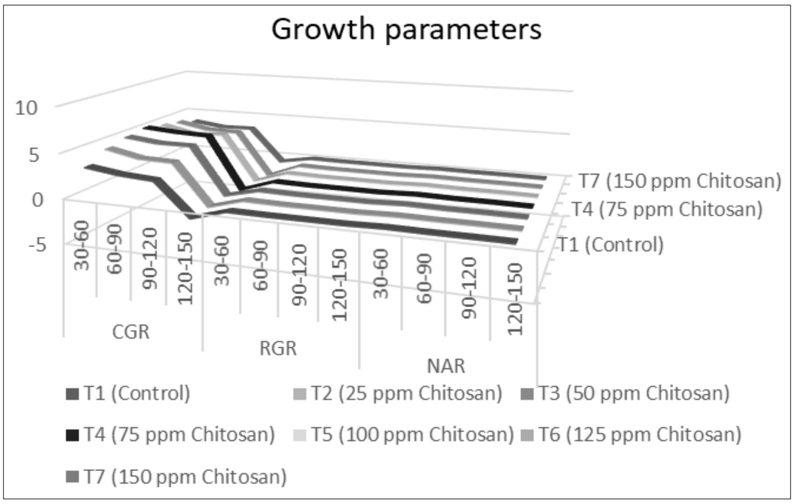


**Fig 3:** Influence of chitosan on growth parameters

However, the significantly minimum dry matter was found in treatment $T_1$ (control) followed by treatment $T_7$ when compared with other treatments. Treatment $T_1$ and $T_7$ were at par with each other. At 150 DAS, significantly maximum dry matter production was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$ and $T_5$. Treatments $T_4$, $T_3$, and $T_5$ were at par with each other. However, significantly minimum dry matter was found in treatment $T_1$ followed by treatments $T_7$ and $T_2$ when compared with other treatments. Treatments $T_1$, $T_7$, and $T_2$ were at par with each other.

The stimulating influence of chitosan on plant development can be linked to an increase in water and vital nutrient availability and uptake by modifying the cell osmotic pressure and minimizing the formation of damaging free radicals by enhancing antioxidants and enzyme activities (Guan *et al*., 2009). Total dry matter was greater in chitosan applied plants might be due to an increase in leaf area (Islam *et al*., 2016) [10]. Application of carboxymethyl chitosan increased key enzyme activities of nitrogen metabolism (nitrate reductase, glutamine synthetase, and protease) which enhanced plant growth development, thereby increasing total dry matter in rice (Ke *et al*., 2001; Islam *et al*., 2016) [11, 10]. Mondal *et al.* (2013, b) [18] evaluated the effect of foliar application of chitosan in five different concentrations i.e. 0, 25, 50, 75, and 100 ppm at 25 and 35 DAS on mungbean plant. Results showed that 50 ppm chitosan increased the physiological parameter like the dry weight of plant of mungbean plants. Rabbi *et al.* (2016) [21] experimented with different concentrations of chitosan *viz*., 0 (control), 25, 50, 75, and 100 ppm at 30 and 40 DAS were applied on mungbean plants. Results showed that foliar application of chitosan @ 50 ppm significantly enhanced total dry mass (TDM) over control.

**Relative Water Content (%)**

Data on relative water content were recorded at 30, 60, 90, 120, and 150 DAS. At 30 DAS, the data on relative water content was found non-significant. At 60 DAS, significantly maximum relative water content was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$ and $T_5$. Treatments $T_4$, $T_3$, and $T_5$ were at par with each other. However, significantly minimum relative water content was found in treatment $T_1$ followed by treatment $T_7$ when compared with other treatments. Treatments $T_1$ and $T_7$ were at par with each other. At 90 DAS, significantly maximum relative water content was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$ and $T_5$. Treatments $T_4$, $T_3$, and $T_5$ were at par with each other. However, significantly minimum relative water content was found in treatment $T_1$ (control) followed by the treatment $T_7$ when compared with other treatments. Treatments $T_1$ and $T_7$ were at par with each other. At 120 DAS, significantly maximum relative water content was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$ and $T_5$. Treatments $T_4$, $T_3$, and $T_5$ were at par with each other. However, significantly minimum relative water content was found in treatment $T_1$ (control) followed by the treatment $T_7$ when compared with other treatments. Treatments $T_1$ and $T_7$ were at par with each other. At 150 DAS, significantly maximum relative water content was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$ and $T_5$. Treatments $T_4$, $T_3$, and $T_5$ were at par with each other. However, significantly minimum relative water content was found in treatment $T_1$ (control) followed by treatment $T_7$ when compared with other treatments. Treatment $T_1$ and $T_7$ were at par with each other.

It was reported that a higher molecular mass of chitosan caused partial closure of stomata. They suggested that it might be due to the production of $H_2O_2$ (hydrogen peroxide) (Lee *et al*., 1999; Khan *et al*., 2002) [13] which may lead to more relative water content. The stimulating influence of chitosan on plant development can be linked to an increase in water and vital nutrient availability and uptake by modifying the cell osmotic pressure and minimizing the formation of damaging free radicals by enhancing antioxidants and enzyme activities (Guan *et al*., 2009). Also, foliar application of chitosan reduced the water use of pepper plants by 26-43% while maintaining biomass production and yield (Bittelli *et al*., 2001; Limpanavech, 2008) [3, 14] which may lead to an increase in relative water content.

**Growth parameters**

**Crop Growth Rate (CGR) (g m$^{-2}$ day$^{-1}$)**

At 30-60 DAS, a significantly maximum crop growth rate was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$ and $T_5$. Treatments $T_4$, $T_3$, and $T_5$ were at par with each other. However, a significantly minimum crop growth rate was found in treatment $T_1$ (control) followed by treatment $T_7$ when compared with other treatments. Treatments $T_1$ and $T_7$ were at par with each other. At 60-90 DAS, a significantly maximum crop growth rate was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$. Treatments $T_4$ and $T_3$ were at par with each other. However, a significantly minimum crop growth rate was found in treatment $T_1$ (control) followed by the treatments $T_7$ and $T_2$ when compared with other treatments. Treatments $T_1$, $T_7$, and $T_2$ were at par with each other. At 90-120 DAS, a significantly maximum crop growth rate was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$ and $T_5$. Treatments $T_4$, $T_3$, and $T_5$ were at par with each other. However, a significantly minimum crop growth rate was found in treatment $T_1$ (control) followed by $T_7$ when compared with other treatments. Treatments $T_1$ and $T_7$ were at par with each other. At 120-150 DAS the mean values of crop growth rate were not significantly influenced by different chitosan concentrations.

Mondal *et al.* (2012) [19] conducted an experiment comprising of different concentrations of chitosan *viz*., 0, 50, 75, 100, and 125 ppm on okra. Three sprays were carried out at 25, 40, 55 DAS. Results revealed that spraying of chitosan @ 125 ppm has significantly increased the growth rate of Okra.

**Relative growth rate (g g$^{-1}$ day$^{-1}$)**

At 30-60 DAS, a significantly maximum relative growth rate was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$ and $T_5$. Treatments $T_4$, $T_3$, and $T_5$ were at par with each other. However, a significantly minimum relative growth rate was found in treatment $T_1$ (control) followed by treatment $T_7$ when compared with other treatments. Treatments $T_1$ and $T_7$ were at par with each other. At 60-90 DAS, a significantly maximum relative growth rate was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$ and $T_5$. Treatments $T_4$, $T_3$, and $T_5$ were at par with each other. However, a

significantly minimum relative growth rate was found in treatment $T_1$ followed by treatment $T_7$ and $T_2$. Treatments $T_1$, $T_7$, and $T_2$ were at par with each other. At 90-120 DAS, a significantly maximum relative growth rate was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except treatment $T_3$ and $T_5$. Treatments $T_4$, $T_3$, and $T_5$ were at par with each other. However, a significantly minimum relative growth rate was found in treatment $T_1$ followed by treatment $T_7$ when compared with other treatments. Treatments $T_1$ and $T_7$ were at par with each other. At 120-150 DAS the mean values of relative growth rate were not significantly influenced by different chitosan concentrations.
Deotale *et al.* (2018) [4] revealed the response of soybean to treatment with chitosan and IBA @ 25, 50, 75, 100, 125 ppm. The foliar spray was given at 30 DAS on soybean. The increase in relative growth rate was recorded at a 25 ppm concentration of chitosan.

**Net assimilation rate (g dm$^{-2}$ day$^{-1}$)**
At 30-60 DAS, a significantly maximum net assimilation rate was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except treatment $T_3$. Treatments $T_4$ and $T_3$ were at par with each other. However, a significantly minimum net assimilation rate was found in treatment $T_1$ followed by treatment $T_7$ when compared with other treatments. Treatments $T_1$ and $T_7$ were at par with each other. At 60-90 DAS, a significantly maximum net assimilation rate was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all treatments under study except $T_3$ and $T_5$. Treatment $T_4$, $T_3$, and $T_5$ were at par with each other. However, a significantly minimum net assimilation rate was found in treatment $T_1$ followed by treatment $T_7$ and $T_2$ when compared with other treatments. Treatments $T_1$, $T_7$, and $T_2$ were at par with each other. At 90-120 DAS, a significantly maximum net assimilation rate was recorded in treatment $T_4$ (75 ppm chitosan) to the rest of all the treatments under study except $T_3$. Treatment $T_3$ and $T_4$ were at par with each other. However, a significantly minimum net assimilation rate was found in treatment $T_1$ (control) and was followed by treatment $T_7$. At 120-150 DAS the mean values of net assimilation rate were not significantly influenced by different chitosan concentrations.
Deotale *et al.* (2018) [4] did an experiment that revealed the response of soybean to treatment with chitosan and IBA @ 25, 50, 75, 100, 125 ppm. The foliar spray was given at 30 DAS on soybean. The increase in net assimilation rate was recorded at a 25 ppm concentration of chitosan.

**Conclusion**
Cotton responded to the application of chitosan and also gave significant variation among different parameters studied. With respect to morphological parameters *viz*, plant height, leaf area and leaf area index were recorded maximum with chitosan @ 75 ppm spray. The significantly maximum physiological parameters *viz*, dry matter production, relative water content and growth parameters (crop growth rate, relative growth rate and net assimilation rate) were recorded with chitosan @ 75 ppm spray.

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