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EVALUATION OF CHITOSAN CONCENTRATIONS FOR IMPROVING CHEMICAL, BIOCHEMICAL AND YIELD CONTRIBUTING PARAMETERS AND YIELD OF CHICKPEA

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ABSTRACT

Growth promoters have previously been documented to enhance chemical, biochemical and yield contributing parameters and yield of plants. This paper documents the effect of chitosan on chemical, biochemical and yield contributing parameters and yield of chickpea plant. Field experiment was carried out at the Botany farm of College of Agriculture, Nagpur during *rabi* 2020-2021 to evaluate the potentiality of chitosan. During investigation chitosan was applied at (0, 10 ppm, 20 ppm, 30 ppm, 40 ppm, 50 ppm, 60 ppm, 70 ppm, 80 ppm, 90 ppm and 100 ppm) 25 and 45 DAS. The results indicate that all foliar concentrations of chitosan showed promising effect on chickpea plant. However, the significantly highest effect on chemical and biochemical parameters *viz.*, total chlorophyll content in leaves (mg g^{-1}), N, P and K content in leaves (%) and protein content in seeds (%) and yield contributing parameters *viz.*,number of seeds pod^{-1},number of pods $plant^{-1}$, 100 seed weight (g) , seed yield $plant^{-1}$(g), ha^{-1}(q) and harvest index (%) were recorded by 60 ppm chitosan when compared with control and different concentrations. It is inferred that chitosan is beneficial and economical and can be implicated to improve chemical, biochemical and yield contributing parameters and yield of chickpea plant in current scenario of high cost of cultivation of crops. Considering the Benefit:Cost ratio 60 ppm chitosan was found more economical and having B:C ratio of 2.74 as compared to 2.08 in control.

(Key words: Chitosan concentrations, chemical, biochemical, yield, parameters, chickpea)

INTRODUCTION

The name *Cicer* is of latin origin, derived from the Greek word 'kikus' meaning force or strength. It is originated in Southeastern Turkey (Ladizinsky, 1975). Chickpea requires cool climate. The somatic chromosome number is 2n=16. *Cicer* contains about 40 species out of which 31 are perennials and 9 are annuals (Ladizinsky and Adler, 1976). Chickpea grains provide about 18% to 22% protein, 4 to 10 % fat and 52 to 70 % carbohydrate and traditionally consumed after processing into various products. The vegetative parts of chickpea are covered with glandular hairs which exudate an acidic liquid which contains 94.2% malic acid, 5.6% oxalic acid and 0.2% acetic acid.

Fragments from chitin and chitosan are known to have eliciting activities leading to a variety of defense responses in host plants in response to microbial infections, including the accumulation of phytolexins, pathogen related (PR) proteins and proteinase inhibitors, lignin synthesis, and cellulose formation**.**

Because of its biopolymer properties, this compound can also form physical barriers around the penetration sites of pathogens, preventing them from spreading to healthy tissues. This bioactive derivatives can activate H+-ATPases and depolarizing biological membranes (Amborabe *et al.,*2008).

In both monocotyledons and dicotyledons chitosan responses include lignification, ion flux variations, cytoplasmic acidification, membrane depolarization and protein phosphorylation, chitinase and glucanase activation, phytoalexin biosynthesis, generation of reactive oxygen species, biosynthesis of jasmonic acid, and the expression of unique early responsive and defense-related genes. Chitosan is also reported to increase the endogenous levels of 2-oxo-phytodeionic and jasmonic acids in many species including rice, leading to the activation of the octadecanoic acid pathway, which ultimately leads synthesis of jasmonic acid.

Chitosan induces programmed-cell death (PCD) and hypersensitive associated responses in plants. It induced chromatin condensation and marginalization followed by a destruction of the nuclei. It did not affect stomatal guard cells but affected epidermal cells.Using a series of inhibitor assays, the same authors demonstrated that chitosan-induced epidermal cell death involves reactive oxygen species generated by the NADPH oxidase of the plasma membrane.Considering the above facts present work was

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undertaken to study the response of chitosan on chemical, biochemical and yield contributing parameters and yield of chickpea.

MATERIALS AND METHODS

Experiment was laid out during *rabi* season of 2020-21 at experimental farm of Agricultural Botany Section, College of Agriculture, Nagpur with the object to know the influence of foliar sprays of chitosan on chemical, biochemical and yield contributing parameters and yield of chickpea cv. JAKI-9218. Plots of the experiment were demarcated in RBD design with three replications. Experiment made in ten treatments along with water spray (control). In this experiment, foliar sprays of chitosan *viz.*, (0, 10 ppm, 20 ppm, 30 ppm, 40 ppm, 50 ppm, 60 ppm, 70 ppm, 80 ppm, 90 ppm and 100 ppm at 25 and 45 DAS were given. The potentiality of chitosan was assessed by observing chemical and biochemical parameters *viz*., total chlorophyll content in leaves (mg g^{-1}) estimated bycolorimetric method as suggested by Bruinsma (1982), N content in leaves determined by micro kjeldahl's method as given by Somichi *et al.* (1972) , P content in leaves determined by vandomoly bdate yellow colour method as given by Jackson (1967) and K content in leaves determined by flame photometer by di-acid extract method given by Jackson (1967) (%) and protein content in seeds determined by micro kjeldahl's method as given by Somichi *et al.* (1972) (%) and yield contributing parameters *viz*., number of the pods $plant^{-1}$, number of seeds pod^{-1}, 100 seed weight (g) , seed yield $plant^{-1}$(g), ha^{-1}(q) and harvest index (%). Five plants were selected randomly from each net plot and tagged. At 25, 45, 65 and 85 DAS all biometric observations were recorded from tagged plants and all yield contributing parameters were recorded at the time of harvest.

RESULTS AND DISCUSSION

Leaf chlorophyll content

Chlorophyll is a pigment directly associated with the photosynthetic activity, which is responsible for the conversion of sunlight into chemical energy in the form of ATP and NADPH (Taiz and Zeiger, 2009), favoring the fixation of atmospheric carbon dioxide and providing thereby the production of plant biomass during the process of Malvin Calvin cycle (Salisbury and Ross, 2012 and Calvino and Messing, 2012).Chlorophyll is green pigment present in chloroplast of all green plant cells and tissues. These are the essentials photosynthetic pigments capable of absorbing light energy for the synthesis of carbohydrates. Chlorophyll content of the plant tissue represents the photosynthetic capacity of plant.

Data regarding leaf chlorophyll content in the leaves of chickpea are given in Table 9 and depicted in Figure 9.

At 45 DAS leaf chlorophyll content was significantly increased by treatment T_7 (60 ppm) and pursued by treatments T_8 (70 ppm), T_9 (80 ppm), T_6 (50 ppm), T_5 (40 ppm) and T_{10} (90 ppm) when correlated with treatment T_1 (control), while treatments T_{11} (100 ppm), T_4 (30 ppm), T_3 (20 ppm) and T_2 (10 ppm) were at par values with treatment T_1 (control) under study.

At 65 DAS, leaf chlorophyll under study found remarkably and significantly increased in the treatment T_7(60 ppm) accompanied by treatments T_8(70 ppm), T_9(80 ppm) and T_6 (50 ppm) when compared with treatment T_1(control). Remaining treatments *viz*., T_5 (40 ppm), T_{10}(90 ppm), T_{11}(100 ppm), T_4(30 ppm), T_3(20 ppm) and T_2(10 ppm) were found at par with treatment T_1(control).

At 85 DAS significantly highest chlorophyll content was noted in the treatment T_7 (60 ppm) with subsequent treatments T_8 (70 ppm), T_9 (80 ppm), T_6 (50 ppm),T_5 (40 ppm) T_{10} (90 ppm) and T_{11} (100 ppm) when compared with treatment T_1 (control). The residual treatments T_4 (30 ppm), T_3 (20 ppm) and T_2 (10 ppm) were found to be at par with treatment T_1 (control).

The chlorophyll reacted positively to the application of chitosan. Chibu and Shibayama (2001) also recorded greater content of chlorophyll in chitosan applied plants. Our outcomes also registered significant increase in amount of both nitrogen and potassium content in plant shoots, which play an important role in increasing the number of chloroplasts $cell^{-1}$, cell size and number $unit^{-1}$ area as well as increased synthesis of chlorophyll (Possingham, 1980). The significant impact of chitosan on plant growth may be credited to an increase of the key enzyme activities of nitrogen metabolism and increased photosynthesis which enhanced plant growth (Gornik *et al.,* 2008; Mondal *et al.,*2012).These might be the reasons for increase in chlorophyll content in the present study.

Farouk and Amany (2012) studied and came to an end that significantly higher chlorophyll content produced when chitosan applied @ 250 ppm under water stress condition in cowpea plant. Rabbi *et al.* (2016) studied effect of foliar application of chitosan on mungbean. The study included different levels of chitosan (0, 25, 50, 75 and 100 ppm) sprayed at 30 and 40 DAS. Analysis concluded that the application of 50 ppm chitosan significantly increased leaf chlorophyll content. Aziz *et al.* (2018) investigated the impact of chitosan/ poly-acrylic acid/ copper nano-composites @ 25, 50 and 75 ppm on onion production. Application of copper-chitosan nano-composites @ 75 ppm attributed to maximum leaf chlorophyll content in onion. Chande (2020) conducted field experiment with the application of different concentrations of chitosan at 25 and 45 DAS and found that foliar spray of 100 ppm chitosan increased chlorophyll content in leaves when compared with control in groundnut.

Leaf nitrogen content

Nitrogen is key component in mineral fertilizers and has more influence on plant growth, appearance and pod production or quality than any other essential elements. Nitrogen is an important constituent of protein and protoplasm and essential for the growth of plants. Its shortage leads to chlorosis and stoppage of growth and its presence in moderate doses is essential for plant growth and fruiting. An abundant supply of essential nitrogenous compound is required in each plant cell for normal cell division, growth and respiration. The nitrogen present mostly as protein is constantly moving and undergoing chemical changes. Increased concentration of nitrogen is found in young, tender plant tissues like tips of shoots, buds and new leaves (Jain, 2010).

The data obtained about the nitrogen content in leaves are given in Table 1.

It is observed from the data that there was significant variation in leaf nitrogen due to foliar sprays at various concentrations of chitosan at 45, 65 and 85 DAS.

At 45 DAS stage of observation, treatment T_7 (60 ppm) significantly superseded in nitrogen content followed by treatments T_8 (70 ppm), T_9 (80 ppm), T_6 (50 ppm) and T_5 (40 ppm) when matched with treatment T_1 (control), while treatments T_{10} (90 ppm) and T_{11} (100 ppm) also exhibited their superiority over the treatment T_1 (control). The left over treatments T_4 (30 ppm), T_3 (20 ppm) and T_2 (10 ppm) were found at parity with treatment T_1 (control).

At 65DAS and 85 DAS results were found same and showed completely different trend as compared to 45 DAS. Treatment with foliar application of 60 ppm chitosan was significantly highest in nitrogen content followed by the application of 70 ppm, 80 ppm, 50 ppm, 40 ppm, 90 ppm, 100 ppm, 30 ppm, 20 ppm and 10 ppm except treatment of control.

From this data and analysis it is observed that nitrogen content in leaves was increased up to 65 DAS and reduced afterwards at 85 DAS. The reduction in nitrogen content might be due to fact that younger leaves and developing organs, such as grains act as strong sink demand and may draw heavily N from leaves (Gardener *et al.,* 1988).

Chitosan enhanced key enzymes activities of nitrogen metabolism and improved the transportation of nitrogen in the functional leaves which enhance plant growth and development**.** Also, it could be attributed to increase the uptake of nitrogen and its associated role in chlorophyll synthesis which enhance process of photo synthesis and carbon dioxide assimilation.

The above findings are consonance with the outcomes of Poonkodi (2003). He specified that decline in N content in leaves might be due to translocation and utilization of nutrients for flower and pod formation in black gram. In the present investigation chitosan was applied as foliar spray. De-acetylation chitosan provides 5-8% nitrogen which is mostly in the form of primary aliphatic amino group which ultimately increases the leaf nitrogen content in the plant tissues. This might be the reasons for increase in leaf nitrogen content in the present study.

Sharifa and Abu-Muriefah (2013) scrutinized the effect of foliar application of chitosan of various concentrations (100, 200 and 400 ppm) and detected that foliar application of 200 ppm chitosan improved nitrogen content in leaves.Meshram *et al.* (2018) studied the effect of foliar application of chitosan (0, 25, 50, 75 and 100 ppm) on soybean plant. Investigation showed that application of chitosan @ 25 ppm significantly elevated the nitrogen content in leaf when sprayed at 30 DAS. Deotale *et al.* (2019) assessed the impact of foliar sprays of chitosan and IBA on chemical, biochemical and yield contributing parameters of pigeonpea by applying chitosan and IBA @ 0, 25, 50, 75, 100 and 125 ppm. They perceived that the 50 ppm chitosan and 25 ppm IBA significantly enhanced leaf nitrogen content in leaves when applied at 45 and 65 DAS. Chande (2020) studied the effect of foliar application of different concentrations of chitosan and observed that foliar application of 100 ppm chitosan at 25 and 45 DAS remarkably and significantly increased nitrogen content in leaves when compared with control in groundnut.

Leaf phosphorus content

Phosphorus (P) is part of the nuclei acid structure of plants which is responsible for the regulation of protein synthesis. Without phosphorus, photosynthesis could not occur. Phosphorus plays a key role in complex energy transformations that are necessary to all life, as a main ingredient in ATP (adenosine triphosphate). It is essential for the formation of seed.

Estimation of phosphorus content in leaves was carried out at three stages of observations i.e. 45, 65 and 85 DAS. Significant results were recorded at all the stages of observations *viz*., 45, 65 and 85 DAS. Data regarding leaf phosphorus content are presented in Table 1.

At 45 DAS, the significant phosphorus content in leaves was found in the treatment T_7 (60 ppm) followed by treatment T_8 (70 ppm), T_9 (80 ppm), T_6 (50 ppm), T_5 (40 ppm), T_{10} (90 ppm), T_{11} (100 ppm) and T_4 (30 ppm) when compared with treatment T_1 (control). Treatment T_3 (20 ppm) was also seen superior and increased phosphorus content significantly over treatment T_1 (control), whereas treatment T_2 (10 ppm) was found at par with treatment T_1 (control).

At 65 DAS, remarkably and significantly highest phosphorus content was shown by treatment T_7 (60 ppm) succeeded by treatments T_8 (70 ppm), T_9 (80 ppm), T_6 (50 ppm), T_5 (40 ppm), T_{10} (90 ppm), T_{11} (100 ppm) and T_4 (30 ppm) when compared with treatment T_1 (control), while treatments T_3 (20 ppm) and T_2 (10 ppm) were at equivalence with treatment T_1 (control).

At 85 DAS, excellent phosphorus content in leaves was depicted by treatment T_7 (60 ppm) followed by treatments T_8 (70 ppm), T_9 (80 ppm), T_6 (50 ppm) T_5 (40 ppm), T_{10} (90 ppm), T_{11} (100 ppm), T_4 (30 ppm) and T_3 (20 ppm) when compared with treatment T_1 (control), whereas treatment T_2 (10 ppm) also showed superiority over treatment T_1 (control).

From the above observations, it is clear that leaf phosphorus content was gradually increased up to 65 DAS and reduced thereafter at 85 DAS. The increase in phosphorus content might be because of translocation of leaf phosphorus and it's utilization for development of food storage organ.

Phosphorus is one of the most important nutrients in the growth and development of plants. It plays a key role in cellular energy transfer, respiration and photosynthesis. The role of chitosan in increasing ionic content may be due to its effects on stabilizing cellular membrane through increasing antioxidants substances, saving cell membranes from oxidative stress and hence, improving plant cell permeability and ultimately enhances nutrient uptake. These might be the reasons for increase in phosphorus content in the present study by the application of chitosan.

Deotale *et al.* (2018) conducted an experiment to study the influence of chitosan and indole-3-butyric acid @ 25, 50, 75, 100 and 125 ppm in improving chemical parameters of soybean. The results revealed that application of chitosan @ 50 ppm significantly enhanced phosphorus content in soybean leaves when applied at 30 DAS. Deotale *et al.* (2019) studied the influence of foliar sprays of chitosan and IBA (@ 25, 50, 75,100 and 125 ppm) on chemical parameters of pigeonpea .They found that 50 ppm chitosan and 25 ppm IBA significantly boosted leaf phosphorus content in pigeonpea leaves significantly when applied at 45 and 65 DAS.Chande (2020) assessed the effect of foliar application of chitosan at various concentrations and found that application of 100 ppm chitosan at 25 and 45 DAS gave the significantly highest phosphorus content in leaves when compared with control in groundnut.

Leaf potassium content

Potassium is an essential macronutrient for the process of respiration, photosynthesis and many physiological processes in plant. It plays important role in stomatal movements and acts as an activator of many enzymes involved in protein synthesis. It is important for crop yield as well as for the quality of edible parts of crops. Although K is not assimilated into organic matter, K deficiency has a strong impact on plant metabolism. Plant responses to low K involve changes in the concentrations of many metabolites as well as alteration in the transcriptional levels of many genes.

Data regarding the leaf potassium content at 45, 65 and 85 DAS stages were found significant and are presented in Table 1.

At 45 DAS, significantly maximum potassium content in leaves was noted by treatment T_7 (60 ppm) followed by treatments T_8 (70 ppm), T_9 (80 ppm), T_6 (50 ppm), T_5 (40 ppm), T_{10} (90 ppm) and T_{11} (100 ppm) when compared with treatment T_1 (control), whereas treatment T_4 (30 ppm) was also seen significantly superior over treatment T_1 (control). Moreover, treatments T_3 (20 ppm) and T_2 (10 ppm) were seen at par with treatment T_1 (control).

At 65 and 85 DAS, potassium content in leaves was significantly highest in the treatment T_7 (60 ppm) followed by the treatments T_8 (70 ppm), T_9 (80 ppm), T_6 (50 ppm), T_5 (40 ppm), T_{10} (90 ppm), T_{11} (100 ppm), T_4 (30 ppm), T_3 (20 ppm) and T_2 (10 ppm) when compared with treatment T_1(control).

Thus, it is found that potassium content in the leaves gradually increased up to 65 DAS and declined at 85 DAS. This might be due to the diversion of the potassium towards developing parts i.e. pods. Foliar application of chitosan especially CH_2 significantly increased nutrient elements and carbohydrate in plant tissue. The high cation exchange capacity of chitosan prevents nutrients from leaching. Chitosan absorbs the nutrients from chemical fertilizers and these exchanged nutrients slowly released to the plants. This might be the reasons for increase in potassium content in leaves.

Farouk and Amany (2012) conducted a study on chitosan as a foliar application on cowpea and concluded that foliar application of 250 ppm chitosan significantly increased inorganic leaf potassium content. Deotale *et al.* (2018) carried out an experiment to study the influence of chitosan @ 25, 50, 75, 100 and 125 ppm on soybean. Results revealed that application of chitosan @ 50 ppm significantly enhanced potassium content in soybean leaves when applied at 30 DAS.Chande (2020) tried foliar application of chitosan @ 0, 25, 50, 75, 100 and 125 ppm on groundnut and found remarkable and significant increase in potassium content by the application of 100 ppm chitosan at 25 and 45 DAS over control in groundnut.

Protein content in seeds

Grain legumes are known to be an important source of protein. The variability in seed protein content among different varieties of legumes is due to the genetic difference and to the interaction with different physiological conditions of the plants. Protein content of the seed is one of the considerable factors for seed quality determination also.

Data regarding protein content in seeds are given in Table 1.

Protein content in seed was significantly high in the treatment T_7 (60 ppm) followed by treatments T_8 (70 ppm), T_9 (80 ppm), T_6 (50 ppm), T_5 (40 ppm), T_{10} (90 ppm) and T_{11} (100 ppm), whereas treatments T_4 (30 ppm), T_3 (20 ppm) and T_2 (10 ppm) were at par with treatment T_1 (control) when calculated.

Chickpea plants have high N requirement for seed production. Protein content of the seed is one of the considerable factors for seed quality determination. Chitosan contain NH_2 group in the basic unit of its formula which is an important constituent of protein, nucleic acid, prophyrins, chloroplast, etc. The stimulating effect of nitrogen on growth characters may be due to the major role of nitrogen on protein and nucleic acids synthesis and protoplast formation. Major part of nitrogen is accumulated in the seed during pod filling stage. It is key component in mineral fertilizers and has more influence on plant growth, appearance and fruit production / quality than any other element. It affects the absorption and distribution of other essential elements. Foliar application of chitosan increases the uptake and availability of nutrients and its further assimilation for biosynthesis of protein. This might be the reasons for increased protein content in seed in the present investigation.

Sharifa and Abu - Muriefah (2013) formulated a field experiment on common bean to study the effect of different concentrations of chitosan (100, 200 and 400 ppm) and observed that foliar application of 200 ppm chitosan increased protein content in seed. Aziz *et al.* (2018) carried out an experiment to study the impact of foliar spraying of chitosan/polyacrylic acid/copper hydrogel nanocomposites (CS/PAA/Cu-HNCs) after 30 and 60 DAS on onion. Results showed that application of 75 ppm CS/PAA/Cu-HNCs increased protein content in seed. Meshram *et al.* (2018) investigated the effect of foliar application of chitosan and IBA (25, 50, 75, 100 and 125 ppm) on chemical and biochemical parameters of soybean. Analysis of data revealed that 25 ppm chitosan and 100 ppm IBA considered as most effective concentration in enhancing the protein content in seeds. Behboudi *et al. (*2019) examined the impact of various concentrations of chitosan (0, 30, 60 and 90 ppm) on wheat crop at the time of tillering, stem elongation and heading and marked significant increase in grain protein content with 90 ppm concentration. Deotale *et al.* (2019) analyzed the performance of foliar sprays of chitosan and IBA on chemical and biochemical parameters of pigeonpea. They applied 25, 50, 75, 100 and 125 ppm chitosan and IBA and found that foliar sprays of 25 ppm IBA and 50 ppm chitosan at 45 and 65 DAS significantly enhanced protein content in seeds.

Yield and yield contributing parameters

Yield is complex character determined by several traits internal plant processes and environmental factors. In general crop yield depends on the accumulation of photo-assimilates during the growing period and the way are partitioned between desired storage organs of plant. In present study data on effect of chitosan on yield and yield contributing parameters *viz*., number of pods plant^{-1}, number of seeds plant^{-1}, 100 seed weight, seed yield plant^{-1}, plot^{-1}, ha^{-1} and harvest index are presented here under.

Number of seeds pod^{-1}

The data with respect to number of seeds pod^{-1} in chickpea are presented in the Table 1.

Number of seeds pod^{-1} were increased significantly with the treatment T_7 (60 ppm) followed by treatments T_8 (70 ppm) and T_9 (80 ppm) when matched with treatment T_1 (control), whereas treatments T_6(50 ppm), T_5 (40 ppm), T_{10} (90 ppm), T_{11} (100 ppm), T_3 (20 ppm), T_4 (30 ppm) and T_3 (20 ppm) were at par with treatment T_1(control).

Meshram *et al.* (2018) examined the effect of foliar application of chitosan (0, 25, 50, 75 and 100 ppm) on yield and yield contributing parameters of soybean. Data revealed that foliar sprays of chitosan @ 25 ppm significantly produced higher number of seeds pod^{-1} in soybean when applied at 30 DAS. Deotale *et al.* (2019) studied the effect of foliar application of chitosan on yield and yield contributing parameters of pigeonpea. Chitosan @ 25, 50, 75,100 and 125 ppm was applied at 45 and 65 DAS. They observed significantly more number of seeds pod^{-1} in pigeonpea. Chande *et al.* (2020) conducted an experiment to study the effect of foliar spray of different concentrations of chitosan at 25 and 45 DAS and depicted that number of seeds pod^{-1} were highest over control in groundnut by the application of 100 ppm chitosan.

Number of pods plant^{-1}

A pod is a case that holds a plant's seeds. In many plants, seeds grow in groups, nestled within a pod. Peas are one such plant, and many other legumes and flowers have seed pods as well. The output of total metabolic activities taking place in plant body is called pod. Pod yield mainly depends upon source sink relation. The economic part will obtain with assimilates synthesized by photosynthesis.

The data with respect to number of pods plant^{-1} are presented in the Table 1.

During the observation it was detected that treatment T_7 (60 ppm) was found significantly at the top followed by treatments T_8 (70 ppm), T_9 (80 ppm) and T_4 (30 ppm) when compared with treatment T_1 (control). Also treatments T_5 (40 ppm), T_{10} (90 ppm) and T_{11} (100 ppm) were found remarkably and significantly superior over treatment T_1 (control). Left over treatments T_4 (30 ppm), T_3 (20 ppm) and T_2 (10 ppm) were at par with the treatment T_1 (control).

Juan *et al.* (2018) researched on the effect of quitomax (liquid formulation of chitosan 4 g l^{-1}) on cowpea plant. Foliar sprays of quitomax having concentrations 200, 400 and 600 mg ha^{-1}. Significantly maximum pods plant^{--1} was observed by the application of quitomax @ 600 mg ha^{-1} in cowpea.Deotale *et al.* (2019) investigated the effect of foliar sprays of chitosan (25, 50, 75, 100 and 125 ppm) on yield and yield contributing parameters of pigeonpea. They noted that 50 ppm chitosan significantly increased number of pods plant^{-1} in pigeonpea when applied at 45 and 65 DAS. Chande (2020) scrutinized the effect of foliar spray of different concentrations of chitosan and found that number of pods plant^{-1} were highest over control by the application of 100 ppm chitosan at 25 and 45 DAS in groundnut.

100 seed weight

Treatment T_7 (60 ppm) was found to be the significantly highest in 100 seed weight followed by treatments T_6 (50 pm), T_5 (40 ppm), T_8 (70 ppm) and T_9 (80 ppm) when compared with treatment T_1 (control). But treatments T_4 (30 ppm), T_{10} (90 ppm), T_{11} (100 ppm), T_3 (20 ppm) and T_2 (10 ppm) were found at par with treatment T_1(control).

Tahawa *et al.* (2006) performed an experiment to study the effect of foliar sprays of lipo-chito oligosaccharides @ 10^{-6} M, chitosan @ 1 mg ml^{-1} and actinomycetes @ at 2.5×10^9 spores ml^{-1} on soybean crop. Results revealed that application of chitosan @ 1 mg ml^{-1} significantly enhanced 100 seed weight in soybean crop. Mondal *et al.* (2013) assessed the effect of foliar application of chitosan on growth and yield contributing parameters of maize. The concentrations of chitosan @ 0 (control), 50, 75, 100 and 125 ppm were sprayed three times at 35, 50 and 65 days after sowing and found that foliar application of chitosan @ 125 ppm improved the 100 seed weight in maize. Meshram *et al.* (2018) checked different concentrations of chitosan (0, 25, 50, 75 and 100 ppm) on yield and yield contributing parameters of soybean and revealed that foliar sprays of chitosan @ 25 ppm significantly increased 100 seed weight in soybean when applied at 30 DAS.Chande (2020) reported that foliar application of 100 ppm chitosan at 25 and 45 DAS significantly increased 100 seed weight as compared to control in ground nut.

Seed yield plant^{-1}and seed yield ha^{-1}

Data regarding seed yield plant^{-1} and ha^{-1} are given in Table 1.

Seed yield plant^{-1} and ha^{-1} are the combined effect of yield attributing characters and physiological efficiency of plant. Source–sink relation contributes to the seed yield. It includes phloem loading at source (leaf) and unloading at sink (seed and pod) by which the economic part will be getting assimilates synthesized by photosynthesis. Partitioning of assimilates in the plant during reproductive development is important for flower, pods and seeds. Thus, crop yield can be increased either by increasing the total dry matter production or by increasing the proportion of economic yield (harvest index) or both (Gardner *et al*., 1988).

In seed yield plant^{-1} treatment T_7 (60 ppm) was found to be the leading one of all the treatments accompanied by T_8 (70 ppm) and T_9 (80 ppm) when compared with treatment T_1 (control) significantly. While, treatments T_6 (50 ppm), T_5 (40 ppm), T_{10} (90 ppm), T_{11} (100 ppm) and T_4 (30 ppm) were also significantly superior over the treatment T_1 (control). Rest of the treatments T_3 (20 ppm) and T_2 (10 ppm) were found at par with the treatment T_1 (control).

In seed yield ha^{-1}, treatment with 60 ppm chitosan gave the significantly highest seed yield followed by treatments with the application of 70 ppm, 80 ppm, 50 ppm, 60 ppm, 90 ppm, 100 ppm and 30 ppm in a descending manner when compared with control treatment. On the other hand, treatments with the application of 20 ppm and 10 ppm chitosan were noted at par with the treatment control.

The increase in chickpea yield due to chitosan application may be due to its effect in stimulating physiological processes, improving vegetative growth, followed by the active translocation of photo assimilates from source to sink tissue (Sharifa, 2013). Chitosan when applied externally was observed to increase crop growth and ultimately the yield. It improves the nutritional status of plant system. Chitosan increases the absorption and translocation of nutrients and ultimately influences the yield.

All the physiological activities of plant significantly contribute to the quantitative trait i.e. seed yield .It is influenced by chemical and biochemical parameters *viz*., chlorophyll, nitrogen, potassium, phosphorus content in the leaves and protein content in seeds. Number of seeds pod^{-1}, number of pods plant^{-1} and 100 seed weight which are considered as yield contributing parameters. The application of different concentrations of chitosan (10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 ppm) remarkably enhanced all the above parameters.Chitosan functions as a carbon source for microbes in the soil, accelerates the process of transforming organic compounds into inorganic compounds and helps root systems in plants to absorb more nutrients from the soil. This is so because chitosan is easily absorbed by the roots after being decomposed by bacteria in the soil .Thus, the administration of chitosan act as an organic fertilizer which plays an important role in supporting plant growth and productivity. This might be the reasons for increase in yield in the present study.

Rabbi *et al.* (2016) formulated an experiment to study the effect of chitosan (0, 25, 50, 75 and 100 ppm) sprayed at 30 and 40 DAS on mungbean. Results showed that application of chitosan @ 50 ppm significantly enhanced seed yield. Deotale *et al.* (2019) studied the effect of foliar sprays of chitosan@ 25, 50, 75, 100 and 125 ppm on yield of pigeonpea. They reported that foliar application of 50 ppm chitosan significantly enhanced seed yield in pigeonpea over control and rest of the treatments when sprayed at 45 and 65 DAS. Chande *et al*. (2020) conducted an experiment on various concentrations of chitosan and found that 100 ppm chitosan at 25 and 40 DAS gave significantly more seed yield over control in groundnut.

Harvest index

Data about the harvest index are given in Table 1.

Significantly maximum harvest index was calculated in treatment T_7 (60 ppm) followed by treatments T_8 (70 ppm) and T_9 (80 ppm) when compared with treatment T_1 (control). Treatments T_6 (50 ppm), T_5 (40 ppm) and T_{10} (90 ppm) also recorded significantly more HI over treatment T_1 (control) and remaining treatments T_{11} (100 ppm), T_4 (30 ppm), T_3 (20 ppm) and T_2 (10 ppm) and witnessed equivalency with the treatment T_1 (control).

Harvest index is the proportion of biological yield represented by economic yield. It is the coefficient of effectiveness or the migration coefficient. Harvest index reflects the proportion of assimilate distribution between the economic and total biomass (Donald and Hamblin, 1976). Increase in harvest index might be the result of coordinated interplay of growth and development characters.

Meshram *et al.* (2018) tried different concentrations of chitosan (0, 25, 50, 75 and 100 ppm) on yield and yield contributing parameters of soybean. Data revealed that foliar spray of chitosan @ 25 ppm significantly increased harvest index in soybean when sprayed at 30 DAS. Chande (2020) noted that foliar application of 100 ppm chitosan at 25 and 45 DAS on groundnut significantly increased harvest index over control.

From the overall results it can be stated that foliar nutrition through chitosan with different concentrations significantly improved chemical, biochemical and yield and yield contributing characters and the highest per cent

Table 1. Effect of chitosan on chemical, biochemical and yield and yield contributing parameters in chickpea

Treatments	Leaf Chlorophyll (%)			Leaf Nitrogen (%)			Leaf phosphorus (%)			Leaf potassium (%)			Protein content in seed (%)	No. of seeds pod^{-1}	No. of pods $plant^{-1}$	100 seed Weight (g)	Seed yield $plant^{-1}$ (g)	Seed yield ha^{-1} (q)	Harvest index (%)
	45 4DAS	65 DAS	85 DAS	45 DAS	65 DAS	85 DAS	45 DAS	65 DAS	85 DAS	45 DAS	65 DAS	85 DAS							
T1(control)	1.40	1.50	1.42	2.35	3.06	3.03	0.61	0.71	0.64	0.91	1.58	1.19	19.50	1.19	26.46	21.20	5.86	19.53	41.84
T2(10 ppm)	1.62	1.68	1.55	2.54	3.31	3.26	0.63	0.84	0.81	0.99	1.68	1.44	20.66	1.20	28.40	21.43	6.35	21.15	43.32
T3(20 ppm)	1.63	1.73	1.71	2.59	3.36	3.35	0.81	0.86	0.83	1.05	1.70	1.49	21.47	1.21	29.13	22.33	6.49	22.20	44.84
T4(30 ppm)	1.71	1.84	1.74	2.73	3.41	3.40	0.81	0.86	0.85	1.31	1.73	1.54	21.83	1.21	31.06	23.03	7.00	23.33	51.32
T5(40 ppm)	1.81	1.94	1.84	3.03	3.56	3.50	0.87	1.08	0.90	1.37	1.85	1.60	23.26	1.23	35.13	23.56	7.50	25.00	55.75
T6(50 ppm)	1.84	2.21	1.91	3.20	3.58	3.51	0.91	1.11	0.94	1.46	1.86	1.65	23.85	1.24	38.66	24.60	7.63	25.44	56.36
T7(60 ppm)	2.14	2.55	2.24	3.43	3.62	3.60	0.95	1.13	0.96	1.56	1.96	1.69	24.53	1.31	41.80	25.03	8.35	27.82	69.67
T8(70 ppm)	2.10	2.48	2.21	3.30	3.61	3.58	0.92	1.13	0.95	1.48	1.96	1.68	24.45	1.29	41.06	23.43	8.02	26.74	68.08
T9(80 ppm)	1.94	2.32	1.94	3.26	3.61	3.58	0.92	1.12	0.94	1.47	1.87	1.67	24.01	1.27	40.93	23.36	7.71	25.70	57.85
T10(90 ppm)	1.79	1.91	1.80	2.85	3.53	3.48	0.86	0.96	0.86	1.34	1.77	1.55	22.64	1.22	33.93	22.70	7.48	24.93	55.44
T11(100 ppm)	1.72	1.86	1.75	2.82	3.42	3.41	0.84	0.95	0.85	1.33	1.75	1.54	22.21	1.22	33.06	22.30	7.37	24.55	51.65
SE (m)±	**0.126**	**0.168**	**0.166**	**0.141**	**0.172**	**0.162**	**0.045**	**0.051**	**0.047**	**0.073**	**0.090**	**0.080**	**0.926**	**0.019**	**2.077**	**0.634**	**0.233**	**1.178**	**4.451**
CD at 5%	**0.373**	**0.496**	**0.492**	**0.415**	**0.510**	**0.48**	**0.130**	**0.151**	**0.139**	**0.215**	**0.266**	**0.236**	**2.732**	**0.056**	**6.128**	**1.871**	**0.689**	**3.475**	**13.130**

increase in yield over control was observed in treatment T_7 (60 ppm chitosan) i.e. 42.43 per cent in chickpea. B: Cratio was also highest in the same treatment (2.74) .

Finally it has been proven through all above observations that the appropriate time and concentration of chitosan used for spraying was 25 and 40 DAS and 60 ppm chitosan respectively for attaining significantly positive results in chemical and biochemical parameters, quality and yield and yield contributing characters of chickpea.

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