Original Research Article

Effects of Nanochitosan and Biocapsule on growth, yield, and quality of Chilli (*Capsicum annuum* L.) in poly-house condition

ABSTRACT

A field experiment was designed in Randomized Block Design with 7 treatments, replicated thrice under polyhouse conditions. The experiment examined the effect of nanochitosan, biocapsule, and NPK on the growth, yield, and quality of chilli. and to work out the economics of various treatments. It was observed that the treatment T_8 (NPK + Nanochitosan 120ppm + Biocapsule 120ppm) was superior over other treatments in terms of growth, yield, and quality of Chilli i.e., plant height (63.73cm), fruit yield per $200m^2$ (3.27q), T.S.S. (9.67^0B) and ascorbic acid (143.96 mg/100g).

Keywords: Nanochitosan, Biocapsule, Chilli, Benefit-cost ratio.

INTRODUCTION

Chilli (*Capsicum annuum* L.) belongs to the family Solanaceae having diploid species with mostly 2n=24 chromosomes but wild species with 2n=2x=26 chromosomes have been reported (Pickersgill, 1991). Chilli was introduced into Europe in 1493 by Christopher Columbus, who discovered it in tropical America. Believed to be a native of Mexico and Peru, it was widely used by the people of Central and South America before Columbus's discovery. It spread so quickly that by 1542, three types of chilli were already introduced into India. India, Mexico, Japan, Ethiopia, Uganda, Nigeria, Thailand, Turkey, Indonesia, China, and Pakistan are the major chili-growi countries. To some extent, it is also grown in Italy, Spain, and the United States. India is the largest producer and consumer of chilli in the world. In India chilli is grown in an area of 7.75 lakh ha with a production of 14.92 lakh tones (Anonymous 2014). Chilli is varieties of the berry-fruit of plants from the genus capsicum. They are cultivated for their pungency (spiciness). Chilli peppers are widely used in many cuisines as a spice to add "heat" to dishes. Capsaicin and related compounds known as capsaicinoids are the substances giving chili peppers their intensity when ingested or applied topically. Other varieties of capsicum include bell peppers (UK: sweet peppers), but while chili peppers are (to varying degrees) pungent or "spicy", bell peppers are generally not and provide additional sweetness and flavor to a meal rather than “heat”. Chilli is one of the most valuable crops in India. The crop is grown largely for its fruits all over India as a principal

ingredient of various curries, and chutneys. It is used for vegetables, spices, condiments, sauces, and pickles. Dry chillies are used for curry powder. The red color in chilli is due to "capsanthin". Pungency in chillies is due to the active constituent "capsaicin", an alkaloid extracted from chillies and used in medicine. Chilli's vitamins include vitamin C (109 mg), vitamin B6 (0.1mg), vitamin A (530 IU), and minerals like iron (0.5mg), copper (0.1mg), potassium (153 mg). It also contains amino acids making it a high nutritional value food. Green chillies are rich in dietary fiber and also contain zero cholesterol. As per studies, 100gms of chilli contains; total fat (0.1g), sodium (3.2mg), magnesium (11.2mg), carbohydrates (1.8g), dietary fibre (0.7g), glucose (0.8g), protein (0.9g), carbohydrate (4.3g), calcium (8.1mg), water content (39.5g) (USDA, 2017).

Polybags are lower-cost alternatives to plastic pots. They are economical and easy to use by the residential greenhouse grower. These heavy-duty re-usable grow bags are made from durable plastic that provides for longer life. The bags have pre-punched drain holes and they are self-standing when filled with media. Widely used in greenhouse drip irrigation applications, they work very well with almost all mediums and are excellent for bedding plants, tree seedlings, tomatoes, bell peppers, cucumbers, etc.

Chitosan is the N-acetyl derivative of chitin obtained by N-deacetylation. Chitosan is widely used in food and bioengineering industries for encapsulation of active food ingredients, enzyme immobilization, as a carrier for controlled drug delivery, and in agriculture as a plant growth promoter. Chitosan is also a defense elicitor and an antimicrobial agent. Chitosan has interesting properties such as biodegradability, biocompatibility, bioactivity, nontoxicity, and polycationic nature (Divya and Jisha, 2017). Nanochitosan has broad antimicrobial activity against fungal pathogens however, the bulk size limits its solubility which affects its antimicrobial property. Chitosan nanoparticles have great potential over their bulk counterparts as size can alter several properties compared to the bulk material. The exclusive properties of these materials, such as a large surface area and greater reactivity, have also raised concerns about adverse effects on environmental health. Recently, IISR-ICAR (Indian Council of Agricultural Research) scientists have developed the technology to pack bio-fertilizers in tiny capsules. This eliminates the need for farmers to carry the sacks of biofertilizers. It consists of a carrier medium rich in live microorganisms. Applying to seed, soil, or living plants increases soil nutrients or makes them biologically available. Easy and reliable technology of storing and delivering PGPR bioagents in hard gelatin capsules termed biocapsule. It uses a select combination of beneficial microorganisms

such as Trichoderma, Pseudomonas, and Bacillus. They form a mutually beneficial or symbiotic relationship with host plants as they grow in the soil.

Nano fertilizers are small particles of different fertilizers that plays an important role in plant growth and productivity. And other bio capsules (PGPR) are soil bacteria that have the potential for direct and indirect effects on plant growth. Chilli plants do much better in good nutrition and controlled nutrient supply in tropical and subtropical regions, and can produce higher yields. Local over-fertilization may decrease groundwater quality, reduce profit margin, induce deficiency of other elements and interfere with metabolic processes, while unsuitable fertilization may restrict chillies yield and quality. Hence, there is a need for a variable rate of Nano fertilizers and Biocapsules application to avoid these problems by having knowledge of the scale of variability of soil and tree characteristics within the field. Soil and leaf analysis can be used to evaluate the nutrition status of the trees and nutrient availability in the soil to supply the trees with nutrients requirement. The objective of this research is to evaluate the nutrients and their relationship with soil properties, so as the use such knowledge as a tool in optimizing fertilizers use for higher yield and quality.

MATERIAL AND METHODS

The experiment was conducted in Randomized Block Design comprising 9 treatments replicated thrice during August 2021- February 2022 at Jacob Institute of Biotechnology and Bio-engineering (JIBB) poly-house, Faculty of Engineering and Technology, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj. The plants were planted with a spacing of 60 cm between the rows and 50 cm between the plants. The observations were recorded on randomly selected five plants on characters. The treatment details have been given in table 1. In general, the soil properties of the experimental site showed a typical alluvial soil of the eastern region of Uttar Pradesh. The soil was sandy loam in texture, slightly acidic in reaction and having low electrical conductivity, very high in organic carbon, low in available nitrogen low in available phosphorus, and moderately high in available potassium given in table 2. Weeding and plant protection measures were followed as and when needed. Observations were recorded at different stages of growth periods. The observations were recorded for characters *viz.* Plant height (cm), No. of branches/plant, Days to first flowering, Days to 50% flowering, No. of flower per plant, No. of fruit per plant, Fruit weight (g), Fruit weight per plant (g/plant), Fruit length (cm), Fruit diameter (cm), Fruit yield per plant, fruit yield per 200m^2 (q), Total soluble solid (TSS),

Acidity (%), Ascorbic acid (mg/100g of fruit). The data were statistically analyzed by the method suggested by **Fisher and Yates, 1936.**

Table 1. Details of Treatments used

Treatment Notation	Treatment Combination
T_0	NPK (RDF)
T_1	Biocapsule (250ppm)
T_2	Biocapsule (500ppm)
T_3	Nanochitosan (60ppm)
T_4	Nanochitosan (120ppm)
T_5	NPK + Biocapsule (500ppm)
T_6	NPK + Nanochitosan (120ppm)
T_7	NPK + Biocapsule (250ppm) + Nanochitosan (60ppm)
T_8	NPK + Biocapsule (500ppm) + Nanochitosan (120ppm)

Table 2. Physical and chemical properties of soil at Horticulture Research field (SHUATS).

Sl. No.	Particulars	Value (0-30 depth)	Method followed
Physical properties (Initial reading)			
1	Sand	58.70	Buoyance Hydrometer (Piper, 1966)
2	Silt	19.46	
3	Clay	21.84	
4	Textural class	Sandy loam	
Chemical properties (Initial reading)			
1	Soil pH	7.3	Potentiometer (Jackson, 1973)
3	Organic carbon (%)	0.56	Walkley and Black's method (Jackson, 1973)
4	Available nitrogen ($Kg\ ha^{-1}$)	49 kg/ha	Alkaline permanganate method (Subbaiah and Asija, 1956)
5	Available phosphorus ($Kg\ ha^{-1}$)	70 kg/ha	Bray's method (Jackson, 1973).
6	Available potash ($kg\ ha^{-1}$)	67 kg/ha	Ammonium acetate method (Jackson, 1973)

Source: Soil analysis was done by KVK (Krishi Vigyan Kendra, Prayagraj, U.P.)

RESULTS AND DISCUSSION

In the present investigation, an attempt has been made to study the effect of different treatment combinations of nano chitosan, biocapusles, and NPK@ RDF on growth, yield, and quality of chilli in Poly-house condition are discussed. The results obtained are presented in relevant Tables as follows.

TREATMENTS	30DAT	60DAT	90DAT

A) Growth Parameters

Growth parameters comprised Plant height (30, 60, 90 DAT), and the number of branches per plant. The data for these characters observed have been listed in Tables 3 and 4.

1. Plant Height (cm) [30, 60, and 90 DAT]

The data about plant height are presented in table 3. At 30 DAT the maximum height was observed in T_8 (31.20cm) followed by T7 (28.53cm). The minimum plant height was observed in T_3 (21.40cm). At 60 DAT the maximum height was observed in T_8 (46.87cm) followed by T_7 (44.60cm). The minimum plant height was observed in T_3 (32.80cm). At 90 DAT the maximum height was observed in T_8 (63.73cm) followed by T_7 (60.80cm). The minimum plant height was observed in T_3 (45.40cm). Treatment T_8 (NPK100% + Biocapsule 500ppm + Nanochitosan 120ppm) was significantly superior and recorded maximum plant height (63.73cm). Biocapsules played an important role in the fixation of nutrients (N&P) in plants. The probable reason for increased plant height is due to more uptake of applied nutrients by the plants, needed for protein and protoplasm synthesis for the higher rate of meiosis, resulting in better photosynthesis and plant growth and ultimately increased plant height. And Nanochitosan prevents the pathogenic attack. A similar result was given by Khati *et al*., (2017).

T_0 - N P K (RDF)	25.00	37.33	54.13
T_1 - Biocapsule (250ppm)	23.05	34.80	47.87
T_2 - Biocapsule (500ppm)	23.67	35.47	51.20
T_3 - Nanochitosan (60ppm)	21.40	32.80	45.40
T_4 - Nanochitosan (120ppm)	22.33	34.07	47.60
T_5 - NPK + Biocapsule (500ppm)	27.27	41.93	58.67
T_6 - NPK + Nanochitosan (120ppm)	25.93	39.00	56.00
T_7 - NPK + Biocapsule (250ppm) + Nanochitosan (60ppm)	28.53	44.60	60.80
T_8 - NPK + Biocapsule (500ppm) + Nanochitosan (120ppm)	31.20	46.87	63.73
F-TEST	S	S	S
SE(d)	2.03	1.75	1.74
C.V.	9.79	5.57	3.95
C.D. AT 5%	4.30	3.72	3.69

Table 3. Effect of Nanochitosan and Biocapsule on different treatment combinations of chilli plant for plant height [30, 60, 90 DAT]

2. Number of branches/plant

3. The data on the number of branches per plant are presented in table 4. Analysis of variance revealed a significant variation in terms of the number of branches per plant due to different treatments. At 30 DAT the maximum branches were observed in T_8 (5.47) followed by T_7 (5.20). The minimum branches were observed in T_3 (3.20). At 60 DAT the maximum branches were observed in T_8 (10.53) followed by T_7 (10.07). The minimum branches were observed in T_3 (7.13). At 90 DAT the maximum branches were observed in T_8 (17.60) followed by T_7 (16.80). The minimum branches were observed in T_3 (12.93). Treatment T_8 (N.P.K. 100 % + Biocapsule 500 ppm + Nanochitosan 120ppm) was significantly superior and recorded a maximum no of branches (17.60). A similar result was given by Jayvanth *et al.*, (2018).

Table 4. Effect of Nanochitosan and Biocapsule on different treatment combinations of

TREATMENTS	30DAT	60DAT	90DAT
T_0 - N P K (RDF)	4.27	9.13	14.80
T_1 - Biocapsule (250ppm)	3.60	7.67	13.73
T_2 - Biocapsule (500ppm)	4.07	8.20	14.47
T_3 - Nanochitosan (60ppm)	3.20	7.13	12.93
T_4 - Nanochitosan (120ppm)	3.33	7.40	13.20
T_5 - NPK + Biocapsule (500ppm)	4.93	9.80	16.47
T_6 - NPK + Nanochitosan (120ppm)	4.53	9.40	16.00
T_7 - NPK + Biocapsule (250ppm) + Nanochitosan (60ppm)	5.20	10.07	16.80
T_8 - NPK + Biocapsule (500ppm) + Nanochitosan (120ppm)	5.47	10.53	17.60
F-TEST	S	S	S
SE(d)	0.24	0.41	0.35
C.V.	6.99	5.64	2.87
C.D. AT 5%	0.52	0.86	0.75

chilli plant for several branches per plant [30, 60, 90 DAT]

B) Flowering Parameter

4. Days to First Flowering, days to 50% flowering, and number of flowers per plant

The data on a day to First Flowering, days to 50% flowering, and the number of flowers per plant influenced by organic manure and bio-fertilizer were recorded and presented in table 5. Days to First Flowering varied significantly due to the effect of different treatments. Early Flowering was observed in T8 (42.17) followed by T7. The maximum day to First Flowering was observed in T3 (50.83). A similar result was given by Turan and Sahin (2008). Early flowering (42.17) was recorded for Treatment T8 (N. P.K. 100 % +Nanochitosan 120 ppm + Biocapsule 500 ppm). Days to 50% flowering varied significantly due to the effect of different treatments. Early Flowering was observed in T8 (52.92) followed by T7 (53.67). The maximum day to 50% Flowering was observed in T3 (62.08). A similar result was given by Turan and Sahin (2008). Early flowering (52.92) was recorded for Treatment T8 (N. P.K. 100 % +Nanochitosan 120 ppm + Biocapsule 500 ppm). Maximum No. of Flowers/Plant was observed in T8 (271.08) followed by T7 (268.92). The minimum No. of Flowers/Plant was observed in T3 (262.58). It is due to the presence of N.P.K, Biocapsule and nano chitosan. Biocapsule can fix the nutrient given by fertilizer in the soil and tends toward plant mechanism. N.P.K. played important role in enhancing the reproductive growth of plants and on the other hand chitosan had the ability of cation exchange capacity in the soil so it made the availability of micronutrients like Zn, B, Fe, and Cl. A similar result was given by Khan *et al.*, (2017). The result was close conformity with Geries *et al*. (2020) for the number of flowers per plant.

Table 5. Effect of Nanochitosan and Biocapsule on different treatment combinations of chilli plant for days to first flowering, days to 50% flowering, and several flowers per plant.

TREATMENTS	Days to First Flower	Days to 50% Flower	No. Of Flowers/Plant
T_0 - N P K (RDF)	46.00	56.50	265.58
T_1 - Biocapsule (250ppm)	48.17	59.50	264.00
T_2 - Biocapsule (500ppm)	47.33	58.00	264.50
T_3 - Nanochitosan (60ppm)	50.83	62.08	262.58
T_4 - Nanochitosan (120ppm)	49.08	61.00	263.42
T_5 - NPK + Biocapsule (500ppm)	43.58	54.17	267.83
T_6 - NPK + Nanochitosan (120ppm)	44.67	55.50	267.42
T_7 - NPK + Biocapsule (250ppm) + Nanochitosan (60ppm)	43.00	53.67	268.92
T_8 - NPK + Biocapsule (500ppm) + Nanochitosan (120ppm)	42.17	52.92	271.08
F-TEST	S	S	S
SE(d)	1.07	1.09	2.00
C.V.	2.85	2.35	0.92
C.D. AT 5%	2.28	2.32	4.24

C) Yield parameters

5. Number of fruits per plant

Results of the present study indicated that with the progression of growth stages there was a statistically significant increase in No. of Fruit/Plant (Table 6). A Higher No. of Fruit/Plants was observed in T8 (148.67) followed by T7 (146.83). The minimum No. of Fruit/Plants was observed in T3 (138.42). It is evident from the data that treatment T8 (N. P.K. 100 % +Nanochitosan 120 ppm + Biocapsule 500 ppm) showed the best result among the other treatment which is at par with each other whereas treatment T3 (Nanochitosan 60 ppm). This result was in close conformity with Geries *et al*. (2020).

6. Fruit weight (g), Fruit yield per plant (g/plant), Fruit yield per 200m^2 (q)

The fruit weight of chilli showed differences among the different. Results of the present study indicated a statistically significant increase in Fruit weight (g), fruit yield per plant (kg/plant), and fruit yield per hectare (q) (Table 6). Maximum Fruit weight (g) was observed in T8 (7.28g) followed by T7 (6.59g). The minimum Fruit weight (g) was observed in T3 (3.49g). The maximum fruit weight (7.28g), was recorded for Treatment T8 (N.P.K. 100 % +Nanochitosan 120 ppm + Biocapsule 500 ppm). Maximum Fruit yield (g/plant) was observed in T8 (1082.31g) followed by T7 (967.24g). The minimum Fruit yield (kg/plant) was observed in T3 (483.57g). Higher Fruit yield per hectare (q) was observed in T8 (7.24 q) followed by T7 (6.48q). The minimum Fruit yield per hectare (q) was observed in T3 (3.27q). The increase in fruit weight may be due to the combination of N.P.K. fertilizer and Biocapsule and Nanochitosan which promoted vegetative growth and development and have been associated with the acceleration of a higher rate of photosynthesis and their accumulation in the economic part of the plant. Nanochitosan accumulates micronutrient availability to plants and Biocapsule fixed nutrient given through the N.P.K for plants' reproductive phase resulting in increased fruit weight. This result was in close conformity with Sharif *et al*. (2018), for fruit yield by Mondal *et al*. (2012).

Table 6. Effect of Nanochitosan and Biocapsule on different treatment combinations of

TREATMENTS	No. of Fruits/Plant	Fruit Weight (g)	Fruit Weight/Plant (g/plant)	Fruit Yield Quintal/200m^2
T_0 - N P K (RDF)	142.58	4.70	670.11	4.50
T_1 - Biocapsule (250ppm)	139.58	3.95	550.65	3.70
T_2 - Biocapsule (500ppm)	141.67	4.28	606.34	4.07
T_3 - Nanochitosan (60ppm)	138.42	3.49	483.57	3.27
T_4 - Nanochitosan (120ppm)	139.08	3.67	510.99	3.44
T_5 - NPK + Biocapsule (500ppm)	146.00	5.91	862.18	5.78
T_6 - NPK + Nanochitosan (120ppm)	144.08	5.29	762.73	5.11
T_7 - NPK + Biocapsule (250ppm) + Nanochitosan (60ppm)	146.83	6.59	967.24	6.48
T_8 - NPK + Biocapsule (500ppm) + Nanochitosan (120ppm)	148.67	7.28	1082.31	7.24
F-TEST	S	S	S	S
SE(d)	1.73	0.09	14.30	0.10
C.V.	1.48	2.14	2.43	2.49
C.D. AT 5%	3.67	0.18	30.31	0.21

chilli plant for fruit weight, fruit yield per plant, fruit yield per 200m^2.

7. Fruit length(cm) and Fruit diameter (cm)

8. Results of the present study indicated that with the progression of growth stages there was a statistically significant increase in fruit length (cm) and fruit diameter (cm) (Table 7). Maximum fruit length (cm) was observed in T8 (10.13cm) followed by T7 (9.27cm. The minimum fruit length (cm) was observed in T3 (6.27cm). Maximum fruit Diameter (cm) was observed in T8 (1.21cm) followed by T7 (1.13cm), T5 (1,06cm), T6 (0.99cm), T0 (0.93cm), T2 (0.92cm), T1 (0.84cm), T4 (0.84cm) and T3. The minimum fruit Diameter (cm) was observed in T3 (0.81cm). It is confirmed from the data that treatment T8 (N. P.K. 100 % +Nanochitosan 120 ppm + Biocapsule 500 ppm) showed the best result among the other treatment which is at par with each other whereas treatment T4 (Nanochitosan 60 ppm). Similar findings were observed by Rafique *et al.* (2018) for fruit length and Duhana *et al.* for fruit diameter.

Table 7. Effect of Nanochitosan and Biocapsule on different treatment combinations of chilli plant for fruit length and diameter (cm)

TREATMENTS	Fruit Length (cm)	Fruit Diameter (cm)
T_0 - N P K (RDF)	7.57	0.93
T_1 - Biocapsule (250ppm)	6.87	0.84
T_2 - Biocapsule (500ppm)	7.20	0.92
T_3 - Nanochitosan (60ppm)	6.27	0.81
T_4 - Nanochitosan (120ppm)	6.43	0.84
T_5 - NPK + Biocapsule (500ppm)	8.80	1.06
T_6 - NPK + Nanochitosan (120ppm)	8.03	0.99
T_7 - NPK + Biocapsule (250ppm) + Nanochitosan (60ppm)	9.27	1.13
T_8 - NPK + Biocapsule (500ppm) + Nanochitosan (120ppm)	10.13	1.21
F-TEST	S	S
SE(d)	0.32	0.04
C.V.	5.01	5.55
C.D. AT 5%	0.68	0.09

9. TSS (^{0}Brix), acidity, Vitamin C content (mg/100g)

The total Soluble Solid, acidity, and Vitamin C content of Chilli showed significant variation among different treatments which is presented in table 8. The maximum value of total Soluble Solid was observed in T8 (9.67^{o}B) followed by T7 (9.46^{o}B). The minimum total Soluble Solid was observed in T3 (6.97^{o}B). The highest TSS (9.67oB) value was observed for T8 (N.P.K. 100 % +Nanochitosan 120 ppm + Biocapsule 500 ppm). Based on the data it is found that in nine treatment combination, T8 (NPK % + Biocapsule 500ppm + Nanochitosan 120ppm) recorded minimum (0.172%) for acidity followed by T7 (NPK % + Biocapsule 250ppm + Nanochitosan 60ppm) with (0.182%). The maximum vitamin C content was observed in T8 (NPK % + Biocapsule 500ppm + Nanochitosan 120ppm) (143.96 mg) followed by T7 (NPK % + Biocapsule 250ppm + Nanochitosan 60ppm) with (140.02 mg). The minimum Vitamin C was observed in T3 (Nanochitosan 60ppm) with (117.10 mg). When the nutrient supply became insufficient, the limited synthesized carbohydrates meet the requirements of only vegetative parts. Contrary to this, a combination of N.P.K. with Biocapsule supplied an adequate level of nutrients because Biocapsule prevent the leaching of nutrients and fixed the nutrient for plant growth. Thus, synthesized carbohydrates translocated to the fruits, which ultimately increased the total soluble solids of the fruit. A similar finding was given by Duhana *et al*. (2018) for TSS, acidity, and Vitamin C content.

Table 8. Effect of Nanochitosan and Biocapsule on different treatment combinations of chilli plant for TSS, acidity, and Vitamin C content.

CONCLUSION

Based on the present investigation, it is concluded that the various treatments applied to enhance the vegetative growth of chilli, where treatment T8 (NPK (RDF) + Nanochitosan 120 ppm + Biocapsule 500ppm) is found superior among others, followed by T7 (NPK (RDF) + Nanochitosan 60ppm + Biocapsule 250ppm) and the lowest was T3 (Nanochitosan 60 ppm) in every aspect of growth, yield, quality

TREATMENTS	T.S.S. (^{0}Brix)	Acidity %	Vitamin C mg/100g
T_0 - N P K (RDF)	8.57	0.219	131.41
T_1 - Biocapsule (250ppm)	7.92	0.234	125.74
T_2 - Biocapsule (500ppm)	8.39	0.227	127.05
T_3 - Nanochitosan (60ppm)	6.97	0.252	117.10
T_4 - Nanochitosan (120ppm)	7.26	0.247	124.82
T_5 - NPK + Biocapsule (500ppm)	9.21	0.196	136.87
T_6 - NPK + Nanochitosan (120ppm)	8.85	0.216	134.01
T_7 - NPK + Biocapsule (250ppm) + Nanochitosan (60ppm)	9.46	0.182	140.02
T_8 - NPK + Biocapsule (500ppm) + Nanochitosan (120ppm)	9.67	0.172	143.96
F-TEST	S	S	S
SE(d)	0.22	0.01	3.98
C.V.	3.18	7.98	3.71
C.D. AT 5%	0.47	0.03	8.43

REFERENCES

Almaliotis, D., Bladenopoulou, S., Chatzissavvidis, C.H. and Karagiannidis, N. (2007). Broccoli (Brassica oleracia L. Var. Italica) yield as affected by soil fertility parameters in northern Greece. *Acta Hortic.* 729, 409-413

Ayoola, O. T., & Adeniyan, O. N. (2006). Influence of poultry manure and NPK fertilizer on yield and yield components of crops under different cropping systems in southwest Nigeria. *African journal of biotechnology*, *5*(15).

Bosland, P. W. (1996). Capsicums: Innovative uses of an ancient crop. *Progress in new crops. ASHS Press, Arlington, VA*, 479-487.

Baris, O., Sahin, F., Turan, M., Orhan, F., & Gulluce, M. (2014). Use of plant-growth-promoting rhizobacteria (PGPR) seed inoculation as alternative fertilizer inputs in wheat and barley production. *Communications in Soil Science and Plant Analysis*, *45*(18), 2457-2467.

Bakshi, M., Wali, V. K., Bakshi, P., Sharma, A., Sharma, D., & Shah, R. A. (2017). Integrated nutrient management induced changes in nutrient uptake, fruit yield, and quality of Kinnow mandarin. *Indian Journal of Agricultural Sciences*, *87*(3), 414-8.

Chiou, K. L., & Hastorf, C. A. (2014). A systematic approach to species–level identification of chile pepper (Capsicum spp.) seeds: Establishing the groundwork for tracking the domestication and movement of chile peppers through the Americas and beyond. *Economic botany*, *68*(3), 316-336.

Carrizo García, C., Barfuss, M. H., Sehr, E. M., Barboza, G. E., Samuel, R., Moscone, E. A., & Ehrendorfer, F. (2016). Phylogenetic relationships, diversification, and expansion of chilli peppers (Capsicum, Solanaceae). *Annals of Botany*, *118*(1), 35-51.

Choudhary, R. C., Kumari, S., Kumaraswamy, R. V., Sharma, G., Kumar, A., Budhwar, S., & Saharan, V. (2019). Chitosan nanomaterials for smart delivery of bioactive compounds in agriculture. In *Nanoscale engineering in agricultural management* (pp. 124-139). CRC Press.

Duhan, J. S., Kumar, R., Kumar, N., Kaur, P., Nehra, K., & Duhan, S. (2017). Nanotechnology: the new perspective in precision agriculture. Biotechnol Rep 15: 11–23.

Gadalla, M. B. (2020). Knowledge, Attitude, and Practice about Health Benefits of Chilli Pepper among Students of the University of Science and Technology.

Geries, L., Omnia, H. S., & Marey, R. A. (2020). Soaking and foliar application with chitosan and nano chitosan to enhance growth, productivity, and quality of onion crop. *Plant Arch*, *20*(2), 3584-3591.

Hidangmayum, A., Dwivedi, P., Katiyar, D., & Hemantaranjan, A. (2019). Application of chitosan on plant responses with special reference to abiotic stress. *Physiology and molecular biology of plants*, *25*(2), 313-326.

Islam S, Akanda AM, Prova A, Sultana F, and Hossain MM (2015) Isolation and identification of plant growth promoting rhizobacteria from cucumber rhizosphere and their effect on plant growth promotion and disease suppression. Front. Microbiol. 6:1360. doi:10.3389/fmicb.2015.0136

Kraft, K. H., Brown, C. H., Nabhan, G. P., Luedeling, E., Luna Ruiz, J. D. J., Coppens d'Eeckenbrugge, G., ... & Gepts, P. (2014). Multiple lines of evidence for the origin of domesticated chilli pepper, Capsicum annuum, in Mexico. *Proceedings of the National Academy of Sciences*, *111*(17), 6165-6170.

Khan, Insaf, Singh, Devendra and Jat, Bhanwar Lal (2017). Effects of biofertilizers on plant growth and yield characters of Pisum sativum L. *Adv. Res. J. Crop Improv.,* **8 (1)**: 99-108,

Khati, P., Chaudhary, P., Gangola, S., Bhatt, P., & Sharma, A. (2017). Nanochitosan supports Zea mays' growth and maintains soil health following growth. *3 Biotech*, *7*(1), 1-9.

Kumar, U. J., Bahadur, V., Prasad, V. M., Mishra, S., & Shukla, P. K. (2017). Effect of different concentrations of iron oxide and zinc oxide nanoparticles on growth and yield of strawberry (Fragaria x ananassa Duch) cv. Chandler. *International Journal of Current Microbiology and Applied Sciences*, *6*(8), 2440-2445.

Khalifa, N. S., & Hasaneen, M. N. (2018). The effect of chitosan–PMAA–NPK nanofertilizer on Pisum sativum plants. *3 Biotech*, *8*(4), 1-12.

Kocięcka, J., & Liberacki, D. (2021). The potential of using chitosan on cereal crops in the face of climate change. *Plants*, *10*(6), 1160.

Makinde, E. A., Ayoola, O. T., & Akande, M. O. (2007). Effects of organo-mineral fertilizer application on the growth and yield of egusi melon. *Australian Journal of Basic and applied sciences*, *1*(1), 15-19.

Mondal, M. M., Malek, M. A., Puteh, A. B., Ismail, M. R., Ashrafuzzaman, M., & Naher, L. (2012). Effect of foliar application of chitosan on growth and yield in okra. *Australian Journal of Crop Science*, *6*(5), 918-921.

Malerba, M., & Cerana, R. (2016). Chitosan effects on plant systems. *International journal of molecular sciences*, *17*(7), 996.

Munazza Rafique, Aneela Riaz, Ashfaq Anjum, M. Amjad Qureshi, Fakhar Mujeeb (2018). Role of Bioinoculants for Improving Growth and Yield of Okra (*Abelmoschus esculentus*). *Universal Journal of Agricultural Research* 6(3): 105-112,2018.

Maluin, F. N., & Hussein, M. Z. (2020). Chitosan-based agronanochemicals as a sustainable alternative in crop protection. *Molecules*, *25*(7), 1611.

Orzali, L., Corsi, B., Forni, C., & Riccioni, L. (2017). Chitosan in agriculture: a new challenge for managing plant disease. *Biological activities and application of marine polysaccharides*, 87-96.

Pickersgill, B. (1971). Relationships between weedy and cultivated forms in some species of chilli peppers (genus Capsicum). *Evolution*, *25*(4), 683-691.

Pickersgill, B. A. R. B. A. R. A. (1991). Cytogenetics and evolution of Capsicum L. *Chromosome engineering in plants: genetics, breeding, evolution, part B. Elsevier, Amsterdam*, 139-160.

Singh, A., & Singh, J. N. (2009). Effect of biofertilizers and bioregulators on growth, yield, and nutrient status of strawberry cv. Sweet Charlie. *Indian Journal of Horticulture*, *66*(2), 220-224.

Sharif, R., Mujtaba, M., Ur Rahman, M., Shalmani, A., Ahmad, H., Anwar, T., ... & Wang, X. (2018). The multifunctional role of chitosan in horticultural crops; a review. *Molecules*, *23*(4), 872.

Turan, M., Gulluce, M., Cakmakci, R., Oztas, T., Sahin, F., Gilkes, R. J., & Prakongkep, N. (2010, August). The effect of PGPR strain on wheat yield and

quality parameters. In *Proceedings of the 19th World Congress of Soil Science: Soil solutions for a changing world, Brisbane, Australia* (Vol. 209, p. 212).

Zayed, M. M., Elkafafi, S. H., Zedan, A. M., & Dawoud, S. F. (2017). Effect of nano chitosan on growth, physiological and biochemical parameters of Phaseolus vulgaris under salt stress. *Journal of Plant Production*, *8*(5), 577-585.