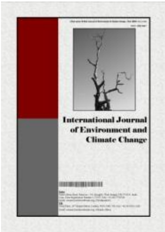

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Effect of Nanochitosan and Biocapsules on Growth, Yield and Quality of Red Okra (*Abelmoschus esculentus L.*) Var. Kashi Lalima

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ABSTRACT

An experiment on okra was conducted throughout August to Nov 2021, in Horticulture Research Field, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, and Technology & Sciences Prayagraj (U.P) India. The results of the investigation, concerning the performance of Nanochitosan and Biocapsule within the 9 treatment of Red Okra i.e. t_0 control (NPK): 100:50:50 Kg/ha, T_1 Biocapsule 250 ppm, T_2 Biocapsule 500 ppm, T_3 Nanochitosan 50 ppm, T_4 Nanochitosan 100 ppm, T_5 Nanochitosan 50 ppm + Biocapsule 250 ppm, T_6 Nanochitosan 50 ppm + Biocapsule 500 ppm, T_7 Nanochitosan 100 ppm + Biocapsule 250 ppm, T_8 Nanochitosan 100 ppm + Biocapsule 500 ppm. The seed was obtained from source of IIVR Varanasi. To find out the best performance in terms of growth, yield and quality the experiment was conducted in randomized block design, where each treatment replicated thrice. The results from the current investigation concluded that the treatment T_6 (Nanochitosan 50ppm + Biocapsule 500 ppm) was recorded with maximum number of fruits (20.37 fruits/plant), with average fruit weight

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(14.22 gm), and also average fruit yield (143.13 q/ha) with Benefit cost ratio of 2.88 whereas in terms of quality the treatment T_8 (Nanochitosan 100ppm and Biocapsule 500 ppm) was recorded with maximum TSS (3.94^0 Bx) and the treatment of T_7 (Nanochitosan 100 ppm and Biocapsule 250 ppm) was recorded with maximum Ascorbic acid (21.38 mg/10 0g).

Keywords: Nanochitosan; biocapsule; kashi lalima.

1. INTRODUCTION

Okra [*Abelmoschus esculentus* L.], is an important vegetable grown in tropical and sub-tropical parts of the world. This crop is appropriate for cultivation as a garden crop as well as on commercial farms. It is grown commercially in India, Turkey, Iran, Western Africa, Croatia, Bangladesh, Afghanistan, Pakistan, Burma and southern regions of the United States. India ranks the first in the world with 3.5 million tonnes (70% of the total world production) of okra produced from over 0.35 Mha land [1].

Okra belongs to the family Malvaceae with 2n=8x=72 or 144 and polyploidy in nature. There are 30 species under genus Abelmoschus in the old world and four in the new world of which the *Abelmoschus esculentus* is the only species noted to be cultivated extensively as a commercial plant. Being it a self pollinated crop, the incidence of outcrossing to an extent of 20% by insects has made an often cross pollinated crop. Being native to the tropical regions of Africa, it is widely cultivated in India. Uttar Pradesh, Assam, Bihar, Orrisa, Maharastra, West Bengal and Karnataka are important okra producing states. Okra is valued for its delicious tender fruits. It is the best source of iron and calcium. Okra accounts for 60% of export of fresh vegetables excluding potato, onion and garlic [2].

The composition of the edible portion of okra is given in previous studies [3]. The biochemical content of the plant is as follows: Moisture 89.6 g, Protein 1.9g, Fat 0.2 g, Fiber 1.2 g, Calories 35, Phosphorous 56 mg, Sodium 6.9 mg, Sulphur 30 mg, Riboflavin 0.1 mg, Oxalic acid 8 mg, Minerals 0.7mg, Carbohydrates 6.4g, Calcium 66 mg, Iron 0.3 5mg, Potassium 103 mg, Thiamine 0.07 mg, Nicotinic acid 0.6mg, Vitamin C 13 mg, Magnesium 53 mg and Copper 0.19 mg.

Red okra (Kashi lalima) have reddish purple fruits which is tolerant to the YVMV and OLCV. It's a medium tall plant and with short internodes Besides it is rich in anthocyanin and phenolics [4].

Nanochitosan are one of the engineered nanomaterials with excellent physicochemical properties; Additionally they are environmentally friendly However, the bioactive distinctive properties of the chitosan biopolymer are often increaed by using it in the form of nanoparticles. Chitosan nanoparticles are presently used to carry ions of fertilizers to be applied to plants. These are used to supply nutrients to plants. They have nano-dimensions ranging from 30 to 40nm and are able to hold varied ions because of their high surface area.

It has distinctive properties like increase in production, ultra high absorption, increase in photosynthesis, and significant expansion in the leaves surface area and also has a broad antimicrobial activity against fungal pathogens.

Biocapsule, a bio-fertilizer technology developed by the IISR (Indian Institute of Spices Research). It uses a selected combination of the beneficial microorganisms such as Trichoderma, Pseudomonas and Bacillus. They form a mutually beneficial microorganism in a gletin capsule for its delivery to the crops for the enhanced soil nutrient solubilization, enhanced growth, and yield. One-gram capsules are very efficient as it contains the microbial population equivalent to what is present in a one-kg pack of powder-based biofertilizer or a one- litre bottle.

2. MATERIALS AND METHODS

An experiment on red okra was conducted throughout August to November 2021, in Horticulture Research Field, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, and Technology and Sciences Prayagraj (U.P) India. The results of the investigation, concerning the performance of the Nanochitosan and Biocapsule in the 9 treatments i.e; t0 control (NPK): 100:50:50 Kg/ha, T_1 Biocapsule 250 ppm, T_2 Biocapsule 50 0ppm, T_3 Nanochitosan 50 ppm, T_4 Nanochitosan 100 ppm, T_5 Nanochitosan

50 ppm + Biocapsule 250 ppm, T_6 Nanochitosan 50 ppm + Biocapsule 500 ppm, T_7 Nanochitosan 100 ppm + Biocapsule 250 ppm, T_8 Nanochitosan 100 ppm + Biocapsule 500 ppm obtained from the source of IIVR VARANASI. To find out the best performance in terms of growth, yield and quality. The experiment was conducted in randomized block design, were each treatment was replicated three times. The mean (maximum and minimum) temperature was 37.98°C and 24.21°C respectively, mean (maximum and minimum) relative humidity was 82.16 percent and 45.26 percent during the crop growing season. The experimental soil was sandy loam in texture, nearly neutral in soil reaction (pH 7.1), low in organic carbon (0.318%), medium in available N (100 Kg/ha), medium available P (50 Kg/ha) and medium available K (50 Kg/ha). Fertilizers were applied in the form of urea, single super phosphate and murate of potash, respectively. The field beds were prepared and the seeds have been directly sown with respective spacing and covered by soil. The observations regarding the yield were recorded after the harvesting of crop.

2.1 Statistical Analysis

The data recorded throughout the course of investigation were subjected to statistical analysis as per methodology of study of variance Fisher (1950). The significance and non-significance of the treatment impact were judged with the assistance of 'f' value (variance ratio) was compared with the table value at 5% level of significance. If calculated value exceeded then the value, the effect of considered to be significant. The significant difference between the means was tested against the critical difference at 5% level of significance.

2.2 Chemical Analysis of Soil

Composite soil samples are collected randomly before the layout of experiment was set so as to determine the soil properties initially. The soil samples are collected from 0-15 cm depth and were dried underneath shade, then fine-grained with the assistance of a wooden pestle and mortar then sieved through a 2 mm sieve and was then subjected to further analysis. The physical properties of soil were evaluated by using the Bouyoucos hydrometer method outlined by Bouyoucos [5] and for organic carbon by wet method Walkely and Black (1956). Available nitrogen was estimated by alkaline permanganate method by Subbiah and Asia (1956), available phosphorus by Clasen's Calorimeter method by Jackson [6], available potassium was determined by use of Flame Photometric method (Perur et al., 1973).

3. RESULTS AND DISCUSSIONS

3.1 Growth Parameters

Data pertaining to growth parameters which are days to first flower emergence, plant height, number of leaves (at last harvesting) were recorded and summarised in Table 1.

3.2 Days to Flower Emergence

The minimum number of days were recorded for first flower emergence in the treatment T6 Nanochitosan 50 ppm and Biocapsule 500 ppm (33.2days) and the maximum number (38.43 days) was found in the treatment T1 Biocapsule 250 ppm. The days to first flower emergence plays an important role in deciding the earliness and lateness of crop in general. Khan et al., [7] concluded that biofertilizer treatment increases days to first flower emergence. It might be due to a higher amount of nitrogen, which ultimately leads to luxurious growth during vegetative phase ultimately delayed flowering. Gonzalez et al., [8] concluded that Nanochitosan treatment decreases time period to first flower emergence. It might be due to the formation of indole acetic acid and enhanced nitrogenase activity that leads to early flowering.

3.3 Plant Height (30DAS)

The maximum height of plant after 30DAS (34.40 cm) in the treatment T7 Nanochitosan 100 ppm & Biocapsule 500 ppm followed by the treatment T8 Nanochitosan 100ppm & Biocapsule 500 ppm (31.21 cm) and minimum height of plant was recorded in the treatment T0 Control NPK(RDF)-100:50:50 Kg/ha (29.27 cm). The improvement in plant height might be due to enhanced photosynthetic and other metabolic activities for the cell division and elongation.

3.4 Plant Height (60DAS)

The maximum height of Plant after 60 DAS (71.00cm) in the treatment T7 Nanochitosan 100 ppm & Biocapsule 250 pm followed by the treatment T8 Nanochitosan 100 ppm & Biocapsule 500 ppm (70.21 cm) and minimum height of plant was recorded in the treatment T0 Control NPK (RDF) – 100:50:50 Kg/ha

(100.31cm). Stepanova et al., 2007 concluded that the application of Nanochitosan caused an increase in average plant height that might be due to an increased level of Giberellic acid (GAs), as GA is responsible for shoot elongation.

3.5 Plant Height (90DAS)

The maximum number of leaves (30.18) was recorded in the treatment T4 Nanochitosan 100ppm followed by the treatment T3 Nanochitosan 50ppm (29.16), T8 Nanochitosan 100 ppm & Biocapsule 5000 ppm (29.1), T5 Nanochitosan 50ppm & Biocapsule 250 ppm (29.02), T7 Nanochitosan 100ppm & Biocapsule 250 ppm (28.56), which were on par with each other and the minimum number of leaves was recorded in the treatment T2 Biocapsule 500 ppm (26.56). Dhawale et al., 2011 concluded that the plant height may also be due to balance C:N ratio, abundant supply of available nutrients from soil with comparatively lesser retention in roots and more translocation to the aerial parts for the protoplasmic proteins and synthesis of other compounds.

3.6 Number of Leaves (at last harvesting)

The maximum height of plant after 90DAS (109.71 cm) was recorded in the treatment T7 Nanochitosan 1000 ppm & Biocapsule 250 ppm and minimum height of plant (1000.31 cm) was recorded in the treatment T0 Control NPK (RDF)-100:50:50 Kg/ha. Leaf number is not affected by the application of Nanochitosan. It is regulated by a complex interaction of various genes whose expression is modulated by growth hormones Gonzalez et al., [8].

3.7 Yield Parameters

Data pertaining to yield parameters which are Average number of fruits/plants, Average Fruit weight (g), Average fruit length (cm), Average fruit diameter, Average fruit yield per plant (g), Average fruit yield (q/ ha) were recorded and summarised in Table 2.

3.7 Average Number of Pod/Plants

The maximum average number of pod per plant (20.37) in the treatment T7 Nanochitosan 100ppm & Biocapsule 250 ppm and minimum average number of pod per plant (15.58) was recorded in the treatment T0 Control NPK (RDF) 100:50:50 Kg/ha. The number of pod per plant was higher in nanochitosan applied plants than control due to increase in the plant height, resulting from increase in the fruit bearing nodes in okra Mondal et al., [9].

Table 1. Performance of nanochitosan and biocapsules on first flower emergence, plant height, No of leaves (at last harvesting) of Okra

Notation	Treatments	Days to 1st flower emergence	Plant Height (30 DAS)	Plant Height (60 DAS)	Plant Height (90 DAS)	No of leaves (at last harvesting)
T0	CONTROL-NPK (RDF) – 100:50:50 Kg/ha	36.7	29.27	64.31	100.31	27.93
T1	Biocapsule 250 ppm	38.43	30.27	65.21	101.57	26.89
T2	Biocapsule 500 ppm	35.7	30.00	65.14	101.21	26.56
T3	Nanochitosan 50 ppm	36.23	30.60	66.54	128.41	29.16
T4	Nanochitosan 100 ppm	35.57	30.39	66.49	102.41	30.18
T5	Nanochitosan 50 ppm & Biocapsule 250 ppm	35.13	30.93	67.11	102.93	29.02
T6	Nanochitosan 50ppm & Biocapsule 500 ppm	33.2	30.67	66.95	102.91	28.12
T7	Nanochitosan 100 ppm & Biocapsule 50 ppm	35.5	34.40	71.00	109.71	28.56
T8	Nanochitosan 100 ppm & Biocapsule 500 ppm	34.87	31.21	70.21	106.45	29.1
	F test	**S**	**S**	**S**	**S**	**S**
	S. Ed (±)	0.76	0.79	0.82	0.80	0.72
	C.V.	1.62	3.14	1.50	0.95	1.55
	C.D at 5%	2.60	1.67	1.73	1.70	3.14

Table 2. Performance of nanochitosan and biocapsules on yield of okra

Notation	Treatment	Average number of pod per plant	Average fruit weight (g)	Average fruit length(cm)	Average fruit diameter (cm)	Average fruit yield per plant (g/plant)	Average fruit yield q/ha
T0	CONTROL-NPK (RDF) – 100:50:50 Kg/ha	15.58	7.87	9.96	1.62	122.65	61.33
T1	Biocapsule 250 ppm	15.73	9.34	10.55	1.62	146.93	73.46
T2	Biocapsule 500 ppm	18.99	12.11	9.78	1.51	229.99	114.99
T3	Nanochitosan 50 ppm	19.08	11.75	8.95	1.99	224.20	112.10
T4	Nanochitosan 100 ppm	18.34	11.39	10.34	2.28	208.95	104.48
T5	Nanochitosan 50 ppm & Biocapsule 250 ppm	19.75	13.18	11.34	1.85	260.44	130.22
T6	Nanochitosan 50 ppm & Biocapsule 500 ppm	20.37	14.22	11.46	1.79	286.27	143.13
T7	Nanochitosan 100 ppm & Biocapsule 250 ppm	20.14	13.03	10.71	1.75	265.39	132.69
T8	Nanochitosan 100 ppm & Biocapsule 500 ppm	20.18	13.89	11.52	1.72	280.21	140.10
	F-Test	**S**	**S**	**S**	**S**	**S**	**S**
	SE.d(±)	0.41	0.25	0.17	0.13	6.65	3.33
	C.V.	0.86	0.54	0.38	0.28	14.10	7.05
	C.D at 5%	2.67	2.63	2.07	9.15	3.62	3.64

3.9 Average Pod Weight (g)

The maximum average pod weight (14.22g) in the treatment T6 Nanochitosan 50ppm & Biocapsule 500 ppm and minimum average pod weight (7.87g) was recorded in the treatment T0 Control NPK (RDF)100:50:50 Kg/ha. The higher pod weight might be due to accelerated mobility of photosynthates from the source to the sink as influenced by the growth hormone, released or synthesized due to biofertilizers Susan et al., 1995.

3.10 Average Fruit Length (cm)

The maximum pod length (11.52 cm) in the treatment T8 Nanochitosan 100 ppm & Biocapsule 500 ppm followed by the treatment T6 Nanochitosan 50 ppm & Biocapsule 500 ppm (11.46 cm), T5 Nanochitosan 50 ppm & Biocapsule 250 ppm (11.34cm), which were on par with each other and the minimum length of pod (8.95 cm). The results were recorded in the treatment T3 Nanochitosan 50 ppm. The biofertilizer treatment increases the pod length. This finding was concluded by Khan et al., [7]. It might be due to the moisture and nutrient absorption from the soil. It is due to the effect of increase in concentration of auxin supply with higher levels of nitrogen brought about increase in the pod length and also due to nitrogen availability.

3.11 Average Fruit Diameter (cm)

The maximum diameter of pod (2.28 cm) in the treatment T4 Nanochitosan 100 ppm and the minimum diameter of pod (1.51 cm) was recorded in the treatment T2 Biocapsule 500 ppm. The pod diameter was higher in chitosan applied plant than control. The pod diameter was higher in chitosan applied plant than control. This finding was concluded by Mondal et al., [9]. The nanochitosan treatment increases might be due to enhanced photosynthesis accumulation of carbohydrates and favourable effect on vegetative growth which increased the pod diameter.

3.12 Average Fruit Yield Per Plant (g)

The maximum yield per plant (286.27g) in the treatment T6 Nanochitosan 50 ppm & Biocapsule 500 ppm and the minimum average yield per plant (122.65 g) was recorded in the treatment T0 Control-NPK (RDF)-100:50:50 Kg/ha. The yield attributes and fruit yield increased significantly with the increasing concentration of chitosan upto a certain level. It might be due to higher production of leaf, leaf area and height of plant, branches, flower and fruits produced per plant. The increased foliage might have resulted in production of more photosynthates enhancing the yield potential [9].

3.13 Average Fruit Yield (q/ ha)

The maximum yield (143.13 q/ha) was recorded in the treatment T6 Nanochitosan 50 ppm & Biocapsule 500 ppm and the minimum average yield per hectare (61.33 q) was recorded in the treatment T0 Control-NPK (RDF)-100:50:50 Kg/ha. Ramakrishnan and Selvakumar 2012 showed that Azotobacter and Azospirillum treated plants had the highest chlorophyll and protein contents. As, N is the chief constituent of Protein, Essential for Protoplasm formation, which leads to cell enlargement, cell division and ultimately resulting in increased plant growth and fruit yield.

3.14 Quality Parameters

Data pertaining to quality parameters which are Total soluble solids and Ascorbic acid were recorded and tabulated in Table 3.

3.15 Total Soluble Solids (^{0} Bx)

The maximum total soluble solids (3.94) in the treatment T8 Nanochitosan 100 ppm & Biocapsule 500 ppm followed by the treatment T1 Biocapsule 250 ppm (3.35) and the minimum total soluble solids (1.81) was recorded in the treatment T4 Nanochitosan 100 ppm. The Nanochitosan treatment increases the TSS this finding was concluded by Lustriance et al., [10]. It might be due to the fact that Nanochitosan is Polysaccharide i.e; sugar which leads to an increment of TSS.

3.16 Ascorbic Acid (mg/100g)

The maximum Ascorbic acid (21.38 mg/100 g) in the treatment T7 Nanochitosan 100 ppm & Biocapsule 250 ppm and the minimum Ascorbic acid was recorded in the treatment T2 Biocapsule 500 ppm (16.50 mg/100 g). The nanochitosan treatment increases the TSS this finding was concluded by Lustriance et al., [10]. The biofertilizer treatment increases the Ascorbic acid this finding was concluded by Amrinder et al., [11]. It might be due to the application of biofertilizer which helps in improving physical, chemical and biological changes in plants that results in increment of ascorbic acid.

Table 3. Performance of nanochitosan and biocapsules on quality of Okra

Notation	Treatments	TSS (Total Soluble Solid)	Ascorbic acid (mg/100 g)
T0	CONTROL-NPK (RDF) – 100:50:50 Kg/ha	2.82	17.42
T1	Biocapsule 250 ppm	3.35	16.75
T2	Biocapsule 500 ppm	3.09	16.50
T3	Nanochitosan 50 ppm	2.87	19.91
T4	Nanochitosan 100 ppm	1.81	19.33
T5	Nanochitosan 50 ppm & Biocapsule 250ppm	2.96	17.62
T6	Nanochitosan 50ppm & Biocapsule 500ppm	3.06	19.50
T7	Nanochitosan 100 ppm & Biocapsule 250ppm	3.01	21.38
T8	Nanochitosan 100 ppm & Biocapsule 50 0ppm	3.94	19.79
	F test	**S**	**S**
	S. Ed (±)	0.23	0.24
	C.V.	0.50	0.52
	C.D at 5%	9.65	1.60

3.17 Seed Parameters

Data pertaining to seed parameters which is seed index was recorded and summarised in Table 4.

3.18 Seed Index (wt of 100 seeds)

The maximum Seed index (6.84 g) in the treatment T6 Nanochitosan 50ppm & Biocapsule 500 ppm and the minimum seed index (5.11 g) was recorded in the treatment T0 Control NPK (RDF)-100:50:50 Kg/ha. The biofertilizer treatment increases the number of seed per pod, seed index and seed yield per plant. Thus, it indicates that the process of application of biofertilizers may be better option for seed growers to achieve seed yield and yield components [7].

Table 4. Performance of nanochitosan and biocapsules on seed parameter of Okra

Notation	Treatments	Seed Index (wt of 100 seeds)
T0	CONTROL-NPK (RDF) – 100:50:50 Kg/ha	5.11
T1	- Biocapsule 250 ppm	5.82
T2	-Biocapsule 500 ppm	6.12
T3	-Nanochitosan 50 ppm	5.94
T4	-Nanochitosan 100 ppm	5.61
T5	-Nanochitosan 50 ppm & -Biocapsule 250 ppm	5.62
T6	-Nanochitosan 50 ppm & -Biocapsule 500 ppm	6.84
T7	-Nanochitosan 100 ppm & -Biocapsule 250 ppm	6.21
T8	-Nanochitosan 100 ppm & -Biocapsule 500 ppm	6.73
	F test	**S**
	S. Ed (±)	0.14
	C.V.	0.31
	C.D at 5%	3.00

4. SUMMARY AND CONCLUSION

The results from the present investigation concluded that the treatment T6 (Nanochitosan 50 ppm & Biocapsules 250 ppm) was recorded with maximum number of fruits (20.37 fruits/plant), with average fruit weight (14.22 g), and also average fruit yield (143.13 q) witth cost Benefit Ratio of 2.88 whereas in terms of quality the treatment T8 (Nanochitosan 100ppm & Biocapsule 500 ppm) was recorded with maximum TSS (3.94^0 Bx) and the treatment T7 (Nanochitosan 100 ppm & Biocapsule 250 ppm) was recorded with maximum ascorbic acid (21.38 mg/100 g).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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