International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2021; 9(2): 153-158
© 2021 IJCS
Received: 02-01-2021
Accepted: 27-02-2021

Pruthvi Raj N
Department of Agronomy, University of Agricultural Sciences, Dharwad, Karnataka, India

Chandrashekara CP
Department of Agronomy, University of Agricultural Sciences, Dharwad, Karnataka, India

Corresponding Author:
Pruthvi Raj N
Department of Agronomy, University of Agricultural Sciences, Dharwad, Karnataka, India

Impact of nano zinc oxide application on quality parameters of Bt cotton (*Gossypium hirsutum* L.)

Pruthvi Raj N and Chandrashekara CP

DOI: https://doi.org/10.22271/chemi.2021.v9.i2b.11939

Abstract
A field experiment was conducted at Main Agricultural Research Station, Dharwad, Karnataka, during 2017-18 to evaluate the effect of seed treatment and foliar application of nano ZnO on quality parameters and economics of Bt cotton. The experiment was laid out in split plot design with three main treatments (M_1:seed treatment with chelated $ZnSO_4$ @ 4 g kg^{-1} seeds, M_2: nano ZnO @ 1 g kg^{-1} seeds and M_3:seed priming with 1000 ppm nano zinc solution), four sub plot treatments (Foliar application of nano ZnO @ 500, 750, 1000 and 1250 ppm at square initiation and flowering stage) and three uneven control (C_1: RDF + FYM + 0.5% EDTA $ZnSO_4$ foliar application at square initiation and flowering stage, C_2: C_1 + seed treatment with Fe, Zn, Mg and Mn @ 4g each kg^{-1} seed and C_3: Only RDF + FYM @ 5.0 t ha^{-1}) treatments replicated thrice. Among different seed treatments, significantly higher fibre strength was observed with seed treatment with NZnO (31.5 g tex^{-1}) than other seed treatments. Similarly, among different foliar sprays, foliar application of NZnO @ 1000 ppm recorded higher fibre strength (31.4 g tex^{-1}) than other foliar concentrations. Among different seed treatments, significantly higher gross returns, net returns and B:C ratio were with seed treatment of NZnO @ 1 g kg^{-1} seeds observed (1,37,818 ₹ ha^{-1}, 73568 ₹ ha^{-1} and 2.1, respectively) than other seed treatments. Among different foliar sprays, foliar application of NZnO @ 1000 ppm recorded higher gross returns (₹ 1,31,817 ha^{-1}), net returns (₹ 66,606 ha^{-1}) and B:C ratio (2.0) than other concentrations.

Keywords: Cotton, nano ZnO, fibre strength, economics

Introduction
To sustain benefits of Bt cotton and prevent decline in fertility of soils supporting Bt cotton, a sound nutrient management programme is essential. Therefore, it is the high time to emphasize on usage of efficient forms of zinc to avoid the deficiency of zinc in soil or in crops to enhance the productivity of cotton. In this direction, nanoparticles with small size and large surface area are expected to be the ideal forms for use as zinc fertilizer for cotton. Cotton is a tropical and subtropical crop. All the four cultivable species and their hybrids are grown in India under diverse agro-ecological and farming conditions. Cotton physiology portrays unique indeterminate growth habits with longer crop duration, which make cotton vulnerable to abiotic stress influences from emergence to senescence.

The functional role of Zn includes auxins metabolism, nitrogen metabolism, influence on the activities of enzymes, cytochrome synthesis and stabilization of ribosomal fraction and protection of cell against oxidative stress, poor growth and interveinal chlorosis (Rao and Gupta, 2005). Hence, Zinc plays an important role in increasing yield. High yielding irrigated cotton crops can take up about 260 g Zn ha^{-1}. Of this, 150 g Zn ha^{-1} (13 g Zn bale^{-1}) may be removed in seed cotton and lint. 70 per cent of the zinc is taken up during flowering. Zinc is able to move from leaves and stems to the lint, seed and boll walls (bers) with 60 per cent being removed in the seed (Trinesh, 2006) [11].

The nutrient removal by cotton plant depends on growing conditions and yield potential of the cultivar. On an average rainfed cotton removes 6-7 kg N, 2-2.5 kg P, 7-8 kg K (Venugopalan and Blaise, 2001) [13] and irrigated cotton removes 9-10 kg N, 3-4 kg P, 10-12 kg K (Palaniappan and Annadurai, 1995) [5] 100 kg^{-1} of seed-cotton yield.

Emphasis on present day agriculture is to produce more with lesser land, water and man power. Considering the above factors with a growing world population there has been a growing interest to develop such management practices or tools which alone or in combination with other practices could ensure a good yield.

For this seed treatment and foliar application with micronutrients are the major tools.

Presently seed treatment by using polymer as coating material along with micronutrients are gaining importance. It is done to control a variety of pests, diseases and to ensure uniform stand establishment by protecting against soil borne pathogens and insects.

Foliar fertilization is actually a complement to soil fertilization. It is intended for the correction of micronutrient deficiencies and the recovery of the plant when affected by adverse biotic or abiotic conditions. The need for foliar application of plant nutrients occurs when there is a lack of a particular nutrient in the soil or when plant roots are not able to absorb the required amounts of nutrients needed due to unfavorable conditions. The efficiency of this fertilization method is a function of crop age, foliar area, time of year, application method and mobility of the mineral in question (Pumisacho and Sherwood, 2002) [7].

Nano fertilizers increases the nutrient use efficiency (NUE) by 3 times and it also provides stress tolerating ability. The results of available studies indicate different response of various species of plants to materials in the size of nano. Since these nano fertilizers contain nutrients, growth promoters encapsulated in nano scale polymers, they will have a slow and a targeted efficient release. Solubility and dispersion for mineral micronutrients cause controlled release formulation. Nano sized formulation of mineral micronutrients may improve solubility and dispersion of insoluble nutrients in soil, reduce soil absorption and fixation and increase the bioavailability leads to increased nutrient uptake efficiency (Valadkhan *et al*., 2015) [12].

Two principal factors cause the properties of nano materials to differ significantly from others are materials increased relative surface area and quantum effects. Nanoparticles are atomic or molecular aggregates with at least one dimension between 1 and 100 nm, which can drastically modify their physicochemical properties compared to the bulk material. Owing to its high surface area to volume size ratio, exhibit significantly novel and improved physical, chemical, and biological properties, phenomena, and functions (Lengke *et al*., 2000) [4].

Due to the significance of zinc element in crop growth and production and their positive role in increasing yield and quality due to application of nano form through seed treatment and foliar spray in cotton. The time and speed for the release of elements coincide and match plant nutritional requirements, thus the plant can absorb maximum amount of nutritional elements and, as a consequence, the product yield increases as well.

However, the studies related to seed treatment and foliar application of nano ZnO on cotton in India is very meager or seldom nil. Hence the present investigation was carried out to know the impact of seed treatment and foliar application of nano Zinc fertilisers on yield and quality parameters in Bt cotton.

Materials and methods

A Field experiment was conducted at Main Agricultural Research Station, Dharwad, India, during *kharif* 2017-2018. The experiment was laid out in split plot design with three main treatments (S_1: seed treatment with chelated $ZnSO_4$ @ 4 g kg^{-1} seeds, S_2: nano ZnO @ 1 g kg^{-1} seeds and S_3: seed priming with 1000 ppm nano zinc solution), four sub plot treatments (Foliar application of nano ZnO @ 500, 750, 1000 and 1250 ppm at square initiation and flowering stage) and three uneven control (C_1: RDF + FYM + 0.5% EDTA $ZnSO_4$ foliar application at square initiation and flowering stage, C_2: C_1 + seed treatment with micronutrients Fe, Zn, Mg and Mn @ 4g each kg^{-1} seed and C_3: RDF + FYM @ 5.0 t ha^{-1}) treatments replicated thrice. The hybrid Bt Cotton Superb SP7157 (BG-II) was sown in a plot size of 7.2 × 5.4 m for each treatment. Seeds were dibbled as per the specification on 05th July 2017. Two seeds per hill were dibbled to a depth of 5 cm on flat bed in 90 cm rows at 60 cm distance between plant to plant and Recommended dose of fertilizers (RDF) @ 100:50:50 kg N: P_2O_5: K_2O ha^{-1} + FYM @ 5.0 t ha^{-1} was applied commonly to all treatments.

Treatment details
Design: Split plot
Main plots: Seed treatments (S)

S_1: Seed treatment with chelated $ZnSO_4$ @ 4 g kg^{-1} seeds with 8 ml polymer
S_2: Seed treatment with nano ZnO @ 1 g kg^{-1} seeds with 8 ml polymer
S_3: Seed priming with 1000 ppm nano Zinc solution 8 hours soaking

Sub plots: Foliar application of nano ZnO (F)

F_1: Nano ZnO @ 500 ppm at square initiation and flowering stage
F_2: Nano ZnO @ 750 ppm at square initiation and flowering stage
F_3: Nano ZnO @ 1000 ppm at square initiation and flowering stage
F_4: Nano ZnO @ 1250 ppm at square initiation and flowering stage

Uneven control (C)

C_1: RDF + FYM + 0.5 per cent EDTA $ZnSO_4$ foliar application at square initiation and flowering stage
C_2: RPP: RDF + FYM + seed treatment with micronutrients (Fe, Zn, Mg & Mn @ 4g each kg^{-1} seed) + 0.5% EDTA $ZnSO_4$ foliar application at square initiation and flowering stage
C_3: Only RDF: 100:50:50 kg N: P_2O_5: K_2O ha^{-1}, + FYM @ 5.0 t ha^{-1}

*RDF: Recommended dose of fertilizers @ 100:50:50 kg N: P_2O_5: K_2O ha^{-1}, + FYM @ 5.0 t ha^{-1}, this dose was common for all treatments.

Design and layout

The experiment was laid out in split plot design with three replications.

Location	: Main Agricultural Research Station, Dharwad
Season	: *Kharif* / *rabi* 2017-18
Crop	: Hybrid Bt Cotton
Design of experiment	: Split Plot
Replications	: 3
Gross plot size	: 7.2 m × 5.4 m (38.88 m^{-2})
Net plot size	: 3.6 m × 4.2 m (15.12 m^{-2})
Spacing	: 90 cm × 60 cm
Genotype	: Superb SP7157 (BG-II, Bayer's)

Results

Influence of NZnO seed treatment and foliar application on quality parameters of cotton

The data on quality parameters *viz*., Ginning percentage (%), Upper half mean length (mm), Fibre strength (g tex^{-1}), Fibre fineness (µg inch^{-1}), Uniformity index (%), Fibre elongation (%) and Maturity ratio of cotton fibre were recorded as influenced by NZnO and results are given below

Ginning percentage (%)

Ginning percentage (%) did not show any significant differences among different seed treatment, foliar applications of NZnO at different concentrations and their interactions.

The overall interaction data on ginning percentage revealed that there was no significant difference between all treatment combinations and the three control.

Upper half mean length (mm)

The data on upper half mean length of cotton as influenced by seed treatment and foliar application of NZnO are presented in Table 01. Upper half mean length (mm) did not show any significant difference between seed treatment and foliar application of NZnO at different concentrations and their interactions.

The overall interaction data on upper half mean length revealed that there was no significant difference between all treatment combinations and control.

Fibre strength (g tex^{-1})

Among different seed treatments, significantly higher fibre strength was observed with seed treatment with NZnO (31.5 g tex^{-1}) than other seed treatments. Similarly, among different foliar sprays, foliar application of NZnO @ 1000 ppm recorded higher fibre strength (31.4 g tex^{-1}) than other foliar concentrations.

The data on interaction between seed treatments and foliar sprays were found to be significant. The data on different foliar sprays at same seed treatment was found to be significant. For chelated $ZnSO_4$ seed treatment, foliar application of NZnO @ 1250 ppm recorded higher fibre strength (31.3 g tex^{-1}) than all other lower concentrations. However, for NZnO seed treatment, foliar application of NZnO @ 1000 ppm recorded higher fibre strength (31.9 g tex^{-1}) than other concentrations. Again for NZnO seed priming, foliar application of NZnO @ 1250 ppm recorded higher fibre strength (31.3 g tex^{-1}) than other lower concentrations (Table 02).

The overall interaction data on fibre strength revealed that seed treatment with NZnO along with foliar application of NZnO @ 1000 ppm (S_2F_3) recorded higher fibre strength (31.9 g tex^{-1}) than all other treatment combinations. When compared with recommended practices, the best treatment (S_2F_3) recorded higher fibre strength than all other control treatments. The increase in fibre strength was to the extent of (11.92, 8.87 and 19.47 per cent over C_1, C_2 and C_3, respectively).

Fibre fineness (µg inch^{-1})

Fibre fineness (µg inch^{-1}) did not show any significant difference between seed treatment and foliar application of NZnO at different concentrations and their interactions.

The overall interaction data on fibre fineness revealed that there was no significant difference between all treatment combinations and different controls.

Uniformity index (%)

Uniformity index (%) did not influenced significantly by different seed treatments and foliar applications of NZnO at different concentrations and their interactions (Table 02).

The overall interaction data on uniformity index revealed that there was no significant difference between all treatment combinations and recommended practices.

Fibre elongation (%)

Fibre elongation (%) did not show any significant difference between seed treatment and foliar application of NZnO at different concentrations and their interactions (Table 02).

The overall interaction data on fibre elongation revealed that there was no significant difference between all treatment combinations and recommended practices.

Table 1: Quality parameters of Bt cotton at different growth stages as influenced by nano ZnO seed treatment and foliar application

Treatment	Quality parameters															
	Ginning percentage (%)				Fibre length (mm)				Fibre strength (g tex^{-1})				Fibre fineness (µg inch^{-1})			
Foliar spray of nano ZnO	Seed treatment and priming				Seed treatment and priming				Seed treatment and priming				Seed treatment and priming			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
F_1-500 ppm	32.9	35.1	38.2	35.4	31.0	31.3	30.7	31.0	30.8	31.4	31.1	31.1	3.7	3.7	3.8	3.7
F_2-750 ppm	33.6	36.5	34.5	34.8	30.6	31.1	30.4	30.7	31.0	31.4	31.2	31.2	3.8	3.6	3.7	3.7
F_3-1000 ppm	33.8	36.8	34.5	35.0	30.9	31.1	30.7	30.9	31.1	31.9	31.2	31.4	3.7	3.8	3.6	3.7
F_4-1250 ppm	35.2	35.9	38.1	36.4	30.7	30.6	30.8	30.7	31.3	31.4	31.3	31.3	3.6	3.7	3.7	3.6
Mean	33.9	36.1	36.3	35.4	30.8	31.0	30.7	30.8	31.1	31.5	31.2	31.2	3.7	3.7	3.7	3.7
Control	C_1	C_2	C_3		C_1	C_2	C_3		C_1	C_2	C_3		C_1	C_2	C_3	
	32.2	31.6	30.9		30.6	30.7	30.7		28.5	29.3	26.7		3.6	3.7	3.6	
Source of variation	S. Em±		C.D.(P=0.05)		S. Em±		C.D.(P=0.05)		S. Em±		C.D.(P=0.05)		S. Em±		C.D.(P=0.05)	
Seed treatment (S)	0.99		NS		0.13		NS		0.02		0.06		0.03		NS	
Foliar spray (F)	0.84		NS		0.11		NS		0.01		0.03		0.06		NS	
Between F at same S	1.93		NS		0.19		NS		0.03		0.09		0.11		NS	
Between S at same or diff. F	2.70		NS		0.21		NS		0.04		0.12		0.10		NS	
To compare control with other treatment combinations	3.02		NS		0.2		NS		0.2		0.6		0.1		NS	

DAS –Days after sowing

S_1: Seed treatment with chelated $ZnSO_4$ @ 4 g kg^{-1} seeds in 8 ml polymer

S_2: Seed treatment with nano ZnO @ 1 g kg^{-1} seeds in 8 ml polymer

S_3: Seed priming with nano Zinc solution @ 1000 ppm (8 hours)

C_1: RDF + FYM @ 5.0 t ha^{-1} + 0.5% EDTA $ZnSO_4$ foliar application

C_2: RPP (C_1 + seed treatment with micronutrients (Fe, Zn, Mg & Mn @ 4g each kg^{-1} seed)

C_3: RDF (100:50:50 kg N: P_2O_5: K_2O ha^{-1}) + FYM @ 5.0 t ha^{-1}

Table 2: Quality parameters of Bt cotton at different growth stages as influenced by nano ZnO seed treatment and foliar application

Treatment	Quality parameters											
	Uniformity index				Fibre elongation (%)				Maturity ratio			
Foliar spray of nano ZnO	Seed treatment and priming				Seed treatment and priming				Seed treatment and priming			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
F_1-500 ppm	87.80	87.37	87.93	87.70	5.50	5.50	5.50	5.50	0.59	0.58	0.60	0.59
F_2-750 ppm	86.97	88.60	87.23	87.60	5.50	5.47	5.43	5.47	0.61	0.57	0.59	0.59
F_3-1000 ppm	88.43	87.67	85.50	87.20	5.43	5.50	5.43	5.46	0.58	0.60	0.57	0.59
F_4-1250 ppm	85.43	88.03	87.83	87.10	5.47	5.47	5.50	5.48	0.58	0.58	0.58	0.58
Mean	87.16	87.92	87.13	87.40	5.48	5.48	5.47	5.47	0.59	0.59	0.59	0.59
Control	C_1	C_2	C_3		C_1	C_2	C_3		C_1	C_2	C_3	
	86.13	86.90	86.47		5.50	5.47	5.50		0.57	0.58	0.57	

Source of variation	S. Em±	C.D. (P=0.05)	S. Em±	C.D. (P=0.05)	S. Em±	C.D. (P=0.05)
Seed treatment (S)	0.50	NS	0.02	NS	0.00	NS
Foliar spray (F)	0.43	NS	0.03	NS	0.01	NS
Between F at same S	0.75	NS	0.04	NS	0.02	NS
Between S at same or diff. F	0.82	NS	0.04	NS	0.01	NS
To compare control with other treatment combinations	0.9	NS	0.05	NS	0.05	NS

DAS –Days after sowing

S_1: Seed treatment with chelated $ZnSO_4$ @ 4 g kg^{-1} seeds in 8 ml polymer

S_2: Seed treatment with nano ZnO @ 1 g kg^{-1} seeds in 8 ml polymer

S_3: Seed priming with nano Zinc solution @ 1000 ppm (8 hours)

C_1: RDF + FYM @ 5.0 t ha^{-1} + 0.5% EDTA $ZnSO_4$ foliar application

C_2: RPP (C_1 + seed treatment with micronutrients (Fe, Zn, Mg & Mn @ 4g each kg^{-1} seed)

C_3: RDF (100:50:50 kg N: P_2O_5: K_2O ha^{-1}) + FYM @ 5.0 t ha^{-1}

Economics

The data on economics namely gross returns (₹ ha^{-1}), net returns (₹ ha^{-1}) and benefit cost ratio (B: C) of cotton as as influenced by seed treatment and foliar application of NZnO are presented in Table 03 and Figure 01

Gross returns (GR), Net returns (NR) and Benefit: Cost ratio (B: C ratio) The data of gross returns (₹ ha^{-1}) of cotton as influenced by seed treatment and foliar application of NZnO are presented in Table 03. Among different seed treatments, significantly higher gross returns, net returns and B:C ratio were with seed treatment of NZnO @ 1 g kg^{-1} seeds observed (1,37,818 ₹ ha^{-1}, 73568 ₹ ha^{-1} and 2.1, respectively) than other seed treatments. Among different foliar sprays, foliar application of NZnO @ 1000 ppm recorded higher gross returns (₹1,31,817 ha^{-1}), net returns (₹66,606 ha^{-1}) and B:C ratio (2.0) than other concentrations.

The data on interaction between seed treatments and foliar spray were found to be significant. The data on different foliar sprays at same seed treatment was found to be significant. For chelated $ZnSO_4$ seed treatment, foliar application of NZnO at different concentrations did not influence gross returns, net returns and B:C ratio significantly. For NZnO seed treatment, foliar application of NZnO @ 1000 ppm recorded higher gross returns (₹1,56,241 ha^{-1}), net returns (₹88,128 ha^{-1}) and B:C ratio (2.3) than other concentrations. Similarly, for NZnO seed priming, foliar application of NZnO @ 1000 ppm recorded higher gross returns (₹1,27,191 ha^{-1}), net returns (₹63,254 ha^{-1}) and B:C ratio (2.0) than either 500 or 1250 ppm. However, 750 ppm was on par with 1000 ppm concentration.

The overall interaction data on economics (GR, NR and B:C ratio) revealed that seed treatment with NZnO along with foliar application of NZnO @ 1000 ppm (S_2F_3) recorded higher economics (GR, NR and B:C ratio) than all other treatment combinations. When compared with recommended practices, the best treatment (S_2F_3) recorded higher economics than all other control treatments. The increase in economics was to the extent of (61.34, 53.63 and 66.48 per cent gross returns and 35.29, 27.77 and 35.29 B:C ratio over C_1, C_2 and C_3, respectively).

Table 3: Economics of Bt cotton as influenced by nano ZnO seed treatment and foliar application

Treatment	Economics											
	Gross returns (₹ ha^{-1})				Net returns (₹ ha^{-1})				B:C ratio			
Foliar spray of nano ZnO	Seed treatment and priming				Seed treatment and priming				Seed treatment and priming			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
F_1-500 ppm	1,10,763	1,24,057	1,11,580	1,15,467	52,660	63,043	50,566	55,423	1.8	2.0	1.8	1.9
F_2-750 ppm	1,11,162	1,31,180	1,25,469	1,22,604	49,882	68,704	62,993	60,526	1.8	2.1	2.0	1.9
F_3-1000 ppm	1,12,018	1,56,241	1,27,191	1,31,817	48,437	88,128	63,254	66,606	1.7	2.3	2.0	2.0
F_4-1250 ppm	1,13,935	1,39,794	1,16,568	1,23,433	49,077	74,395	51,169	58,214	1.7	2.1	1.8	1.9
Mean	1,11,970	1,37,818	1,20,202	1,23,330	50,014	73,568	56,996	60,192	1.8	2.1	1.9	1.93
Control	C_1	C_2	C_3		C_1	C_2	C_3		C_1	C_2	C_3	
	96,838	1,01,698	93,847		40,304	45,162	37,661		1.7	1.8	1.7	

Source of variation	S. Em±	C.D. (P=0.05)	S. Em±	C.D. (P=0.05)	S. Em±	C.D. (P=0.05)
Seed treatment (S)	1916.57	6525.37	2209.60	7675.95	0.03	0.09
Foliar spray (F)	1810.10	5430.3	1986.71	5960.13	0.02	0.06
Between F at same S	2320.83	6962.4	2468.1	7404.3	0.05	0.15
Between S at same or diff. F	2568.71	7706.13	2671.3	8013.9	0.06	0.18
To compare control with other treatment combinations	3168.7	9506.1	3721.8	11165.4	0.07	0.21

S_1: Seed treatment with chelated $ZnSO_4$ @ 4 g kg^{-1} seeds in 8 ml polymer

S_2: Seed treatment with nano ZnO @ 1 g kg^{-1} seeds in 8 ml polymer

S_3: Seed priming with nano Zinc solution @ 1000 ppm (8 hours)

C_1: RDF + FYM @ 5.0 t ha^{-1} + 0.5% EDTA $ZnSO_4$ foliar application

C_2: RPP (C_1 + seed treatment with micronutrients (Fe, Zn, Mg & Mn @ 4g each kg^{-1} seed)

C_3: RDF (100:50:50 kg N: P_2O_5: K_2O ha^{-1}) + FYM @ 5.0 t ha^{-1}

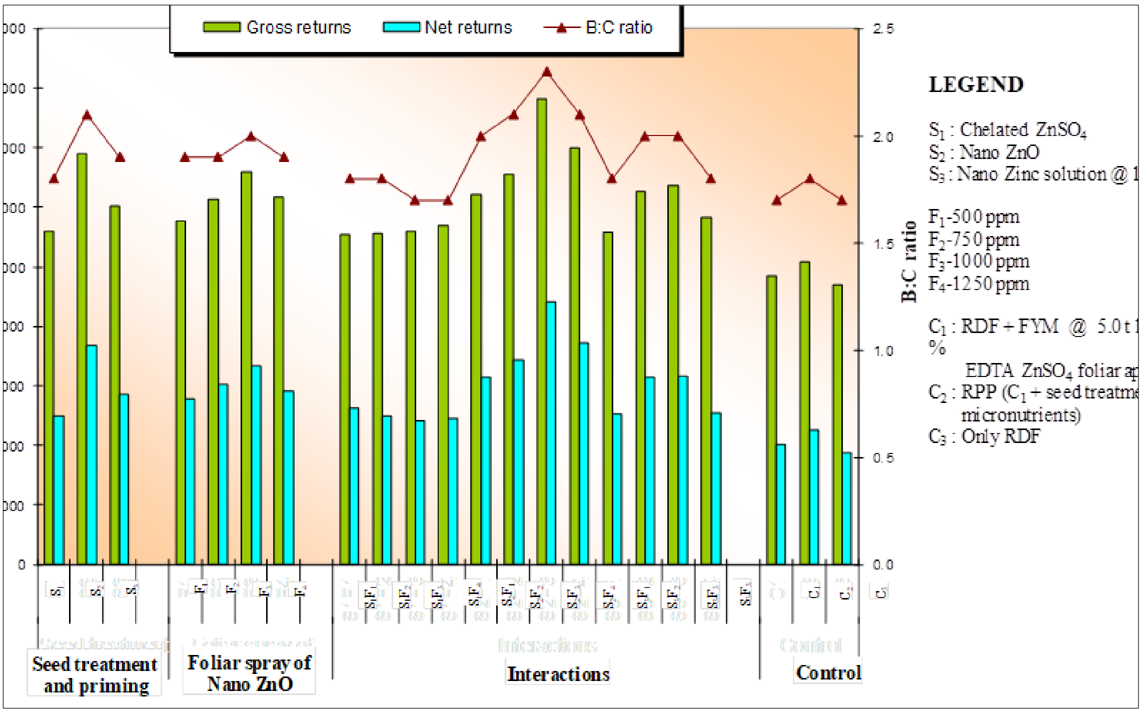

Fig 1: Economics of Bt cotton as influenced by nano ZnO seed treatment and foliar

Discussion

The presence of nanoscale ZnO particles have a significant effect on the plant height of *Phaseolus vulgaris* and *Lolium Perenne* (Doshi *et al*., 2008) [3]. The presence of ZnO nano particles increased nutrient uptake in turn increased yield to the extent of 28.3 percent as compared to chelated $ZnSO_4$, similar trend was reported by Zhu *et al*., (2008) [14].

The quality parameters such as lint index, ginning per cent, seed index, fibre length, strength, colour and oil content in seed etc., are mostly determined by genetic vigor of that crop, variety and environmental factors (Chandra, 1997) [2]. Hence, nano ZnO treatment did not affect the fibre quality parameters except fibre strength. Among all the quality parameters, seed treatment with nano ZnO recorded significantly higher fiber strength (31.5 g tex^{-1}) than seed priming with nano ZnO (31.2 g tex^{-1}) and seed treatment with chelated $ZnSO_4$ (31.1 g tex^{-1}). The increase in fibre strength in seed treatment with nano ZnO was 0.9 percent over seed priming with nano zinc solution and 1.2 per cent over seed treatment with chelated $ZnSO_4$. Rathinavel *et al*., (2015) [8] reported that, the number of sympodial $plant^{-1}$ (30.0%), number of bolls $plant^{-1}$ (39.2%), boll weight (49.8%), seed weight $boll^{-1}$ (36.8%) number of seeds $boll^{-1}$ (10.8%) were significantly higher for cotton plants treated with nano ZnO (2.5 g kg^{-1} seeds). The seed cotton yield and seed yield were 47.1 per cent and 19.2 per cent higher for the same treatment over control. Pratima *et al*., (2015) [6] studied that, seed treatment with nano ZnO (2 g kg^{-1} seeds) significantly increased the seed yield, 100 seeds weight and fibre strength with in cotton and uptake of major nutrients were also increased by nano ZnO. Seed treatment with 5 g kg^{-1} seeds decreased the germination and in turn decreased the yield parameters. Sheteiwy *et al*. (2016) [9] conducted experiment on seed priming with polyethylene glycol induces antioxidative defence and metabolic regulation of cotton under nano ZnO stress. Seed priming with 30 per cent PEG improved α-amylase activities and total soluble sugar contents of cotton under nano ZnO stress. In addition, glutathione reductase (GR) activity, reactive oxygen species (ROS) accumulation, and proline contents decreased after the priming treatments under different nano ZnO concentrations.

Economical returns are an important factor to assess feasibility of the practices in crop production. Among all the treatments, seed treatment with nano ZnO recorded higher gross returns (₹ 1,37,818 ha^{-1}), net returns (₹ 73,568 ha^{-1}) and B: C ratio (2.1) than other seed treatments. The increase in economical returns in seed treatment was 14.6, 29.0 and 10.5 per cent over nano ZnO seed priming and 23.0, 47.0 and 16.6 per cent over seed treatment with chelated $ZnSO_4$, with respect to Gross returns, net returns and B:C ratio, respectively). The higher economical returns was due to higher yield associated with seed treatment with nano ZnO. In the present investigation, between different foliar sprays at same treatment did not influence the economical parameters for chelated $ZnSO_4$ seed treatment. However, the interaction of seed treatment with nano ZnO with foliar application of nano ZnO recorded significantly higher gross returns (₹1,56,241 ha^{-1}), net returns (₹88,128 ha^{-1}) and B:C ratio (2.3) than other combinations. Seed priming with nano ZnO along with foliar application of nano ZnO @ 1000 ppm recorded higher gross returns (₹1,27,191 ha^{-1}). However, 750 ppm was on par with 1000 ppm concentration**.** Among all treatment combinations, seed treatment with nano ZnO with foliar application of nano ZnO recorded significantly higher gross returns, net returns, B:C ratio than recommended practices. The percent increase in Gross returns, net returns and B:C ratio was 53.63, 94.2 and 27.7 per cent over RPP, respectively. This was evidenced by Singh *et al.* (2013) and Singh and Bhati (2013). Even though nano ZnO at higher concentration of 1250 ppm recorded higher yield but recorded lower net returns than 750 ppm. This was attributed to higher cost of cultivation. Among all treatment combinations higher cost of cultivation (₹65,399) was observed in NZnO seed treatment along with 1250 ppm NZnO foliar spray. Though, this treatment needs higher cost of cultivation, the gross returns and net returns were higher due to higher seed cotton yield. (Cost of cultivation in Table 04)

Table 4: Details of cost of cultivation of Bt cotton different treatments of nano ZnO seed treatment and foliar application

Particulars	M-I				M-II				M-III				Control		
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	C-I	C-II	C-III
Ploughing	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Labour	24804	24804	24804	24804	24804	24804	24804	24804	24804	24804	24804	24804	23214	23214	23214
Harrowing	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
Seed cost	4400	4400	4400	4400	4400	4400	4400	4400	4400	4400	4400	4400	4400	4400	4400
FYM	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Nano Zinc Oxide	2520	3780	5040	6300	2,573	3833	5093	6352.5	2573	3833	5093	6353	-	-	-
EDTA $ZnSO_4$	0.45	0.45	0.45	0.45	-	-	-	-	-	-	-	-	300	301.3	-
$FeSO_4$	-	-	-	-	-	-	-	-	-	-	-	-	-	0.51	-
$MnSO_4$	-	-	-	-	-	-	-	-	-	-	-	-	-	0.24	-
$MgSO_4$	-	-	-	-	-	-	-	-	-	-	-	-	-	0.102	-
Urea	522	522	522	522	522	522	522	522	522	522	522	522	522	522	522
SSP	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050
MOP	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
Pesticides	9,850	9,850	9,850	9,850	9,850	9,850	9,850	9,850	9,850	9,850	9,850	9,850	9,850	9,850	9,850
Transportation charges	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Total expenditure	52,547	53,807	55,067	56,327	52,599	53,859	55,119	56,379	52,599	53,859	55,119	56,379	48,736	48,738	48,436
Interest on working capital @ 6%	3153	3228	3304	3380	3156	3232	3307	3383	3156	3232	3307	3383	2924	2924	2906
Supervision charge @ 10%	5255	5381	5507	5633	5260	5386	5512	5638	5260	5386	5512	5638	4874	4874	4844
Total cost of cultivation	60,954	62,415	63,877	65,339	61,014	62,476	63,938	65,399	61,014	62,476	63,937	65,399	56,534	56,536	56,186

Summary and conclusion

In the present investigation, between different foliar spray concentration with chelated $ZnSO_4$ seed treatment, chelated $ZnSO_4$ seed treatment, recorded higher gross returns (₹1,13,935 ha^{-1}) with 1250 ppm foliar spray. However, it was on par with other concentrations similar trend was followed for net returns (₹49,077) and B:C ratio (1.8). The interaction of seed treatment with NZnO with foliar application of NZnO @ 1000 ppm recorded significantly higher gross returns (₹1,56,241 ha^{-1}), net returns (₹88,128 ha^{-1}) and B:C ratio (2.3) than other treatments. Seed priming with NZnO along with foliar application of NZnO @ 1000 ppm recorded higher gross returns (₹1, 27,191 ha^{-1}), net returns (₹63,254 ha^{-1}) and B:C ratio (2.0). However, it was on par with 750 ppm concentration.

Application of micronutrient zinc in the form of nano particles performed better than normal form of fertilizers. Seed treatment and foliar application of nano ZnO had significant influence on economics of cotton. In the present study seed treatment with nano ZnO @ 1g kg^{-1} seeds in 8 ml polymer along with foliar application of nano ZnO @1000 ppm at square initiation and flowering stage was found to be optimum for cotton crop for obtaining better growth, yield, yield components, quality parameters and economical returns.

References

1. Bhati EB, Sahid IB, Jusoh KB. Phytotoxicity Assessment of nano-ZnO on wheat seed germination and growth. *Sains Malaysiana* 2013;45(8):1183-1190.
2. Chandra E, Singh D Kumar A. Investigating long-term effect of nanoparticles on growth of cotton plants: a trans-generational study. Ecotoxicol 1997;27(1):23-31.
3. Doshi A, Biswas AK, Kundu S. Nano-fertiliser-a new dimension in agriculture. Indian J Fertilisers 2008;6(8):22-24.
4. Lengke FM, Fleet EM, Southam G. Biosynthesis of silver nanoparticles by filamentous cyanobacteria a from a silver nitrate complex. Langmuir 2000;23:2694-2699.
5. Palaniappan R, Annadurai. Effect of organic and modern method of cotton cultivation on soil nutrient status. Comm. Soil Sci. Plant Anal 1995;5(9-10):1247-1261.
6. Pratima S, Dube BK Chatterjee C. Nano zinc stress induced changes in cotton. Ann. Agric. Res 2015;22(3):365-370.
7. Pumisacho M, Sherwood S. El cultivo de la papa en Ecuador. Instituto Nacional de Investigaciones Agropecuarias (INAP), 58th Annu. Meet., International Potato Center (CIP), Quito 2002.
8. Rathinavel L, Alan RG, Eruva N Haris LS. Role of superoxide dismutases in controlling oxidative stress in plants. J Bot 2015;53(372):1331-1341.
9. Sheteiwy MS, Fu Y, Hu Q, Nawaz A, Guan Y, Li Z, *et al.* Seed priming with polyethylene glycol induces antioxidative defense and metabolic regulation of cotton under nano-ZnO stress. Environ. Sci. Res 2016;23(19):1989-2002.
10. Singh G, Bhatt SD. Effects of zinc oxide nanoparticles on late sown lentil. Paper presented in: Int. Conf. Environ. Bio-sci., Singapore 2013.
11. Trinesh A. Establishment and management of micronutrient deficiencies in cotton grown soil: A review. Soil Environ 2006;24:1-22.
12. Valadkhan M, Mohammadi K, Nezhad MTK. Effect of priming and foliar application of nanoparticles on agronomic traits of chickpea. Bio. Forum Int. J 2015;7(2):599-602.
13. Venugopalan S, Blaise G. Comparative evaluation of organic and non-organic cotton (*Gossypium hirsutum*) production systems. Indian J Agric. Sci 2001;80(4):287-292.
14. Zhu H, Zhang X, Sun C. Characteristics of micro nutrients uptake by rape plants and methods of B and Zn application. Oil Crops China 2008;18(2):59-61.