R-2448
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RESEARCH ARTICLE Agricultural Reviews, Volume Issue : ()

Influence of Zn, Fe and Ag Nanoparticles on Growth, Yield Attributes and Profitability in Tomato (*Solanum lycopersicum mill*)

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10.18805/ag.R-2448

ABSTRACT

Background: The ambition of nanoparticles in agriculture is to reduce the amount of spread chemicals, minimize nutrient losses in fertilization and increased yield through pest and nutrient management. The recent advances in nanotechnology and its use in the field of agriculture are astonishingly increasing therefore it is tempting to evaluate the effect of different nanoparticles on growth and yield contributing characters in tomato.

Methods: A field experiment was conducted at College of Horticulture and Forestry, Jhalawar during *Rabi* season 2019-2020 which consisted of 13 treatments of three nanoparticles, *viz*. Zn, Fe and Ag at four different concentrations.

Result: The results revealed that among different concentration of nanoparticles, seed treated with 800 ppm Zn NPs solution for 4 hours significantly improved the growth and yield characteristics in comparison to control. Similarly, Fe and Ag NPs also significantly influenced the growth and yield attributes but at increasing concentration showed decreasing trend for these characters. Thus, it can be inferred that employing Zn nanoparticles as seed treatment could increase in growth and yield contributing attributes at higher concentration in tomato.

Key words: Growth, Nanoparticles, Tomato, Yield, Zinc.

INTRODUCTION

Tomato is one of the most popular and widely grown vegetable in the world, has second position in importance after potato in many countries. In India, the estimated area and production of tomato is 0.81 mha and 20.57 mt respectively (NHB, 2019-20). Fresh fruits are the good source of potassium, folate, soluble and insoluble dietary fibers and minerals. Tomatoes are major contributors of antioxidants such as carotenoids (especially, Lycopene and β-carotene), phenolics, ascorbic acid (vitamin C) and small amounts of vitamin E in daily diets. Tomato is considered as an important protective food.

Despite all the technological, varietal and mechanization interventions in tomato cultivation, its productivity in the country is very low. The major constraints for low productivity include: climatic variations resulting in drought or excess water; increased pressure of diseases and pests; low adoption of hybrid; small farm holdings and limited resource availability; limited adoption of improved production-protection technologies; which deprives crop from proper nutrients, especially micronutrients availability. Unsustainable intensification accompanied by imbalanced soil nutrient management is one of the major causes of declining productivity of crops in the country. An increase in the productivity of a crop can be achieved either by increasing the area under cultivation or by increasing the productivity per unit area. Since the area is limited, yield level per unit area needs to be augmented to ensure food and nutrition security of nation. Micronutrients play a significant role in plant growth and metabolic processes associated with photosynthesis, chlorophyll formation, cell wall development, respiration, water absorption and resistance to plant diseases, enzyme activities involved in the synthesis of primary and secondary metabolites.

Innovation in development of new fertilizers and pesticides are required to provide sustainable agri-inputs for higher production of agricultural crops. Currently, Nanotechnology is working with the smallest possible particles which increase hopes for improving agricultural productivity through encountering problems unsolved conventionally and have the potential to change agricultural production by allowing better management and conservation of inputs of plant. It provide a great scope of novel applications in the plant nutrition fields to achieve the future request of the rising population because nanoparticles have exclusive physicochemical characters *i.e.* high surface area, high reactivity and tunable pore size. The ambition of nanoparticles in agriculture is to reduce the amount of spread chemicals, minimize nutrient losses in fertilization

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How to cite this article: Sharma, R.K., Meena, S.K., Kavita, A., Singh, B., Chhipa, H. and Maurya, I.B. (2022). Influence of Zn, Fe and Ag Nanoparticles on Growth, Yield Attributes and Profitability in Tomato (*Solanum lycopersicum mill*). Agricultural Reviews. DOI: 10.18805/ag.R-2448.

Submitted: 20-12-2021 **Accepted:** 06-06-2022 **Online:** 05-07-2022

and increased yield through pest and nutrient management. The recent advances in nanotechnology and its use in the field of agriculture are astonishingly increasing therefore it is tempting to understand the role of Zn, Fe and Ag nanoparticles on growth and yield of tomato.

MATERIALS AND METHODS

A field experiment was carried out during *Rabi* 2018-19 at the Protected Cultivation Unit of Department of Vegetable Science, College of Horticulture and Forestry, Jhalawar (Rajasthan). The tomato cv. Arka Rakshak was used as an experimental material for this study. Three nanoparticles *viz.* Zn, Fe and Ag NPs were used at four different concentrations (200, 400, 600, 800 ppm for Zn and Fe NPs) and (25, 50, 75, 100 ppm for Ag NPs) in the experiment. Synthesized different nanoparticles at different concentrations were suspended directly in deionized water and dispersed ultrasonic vibration (100 W, 40 KHz) for 30 minutes. Small magnetic bar was placed in the suspension for stirring through Ultrasonicator to avoid aggregation of the particles. Several suspensions of concentration range up to maximum possible limit were tried for uniform particle dispersion, stability and clear suspension (trial and error method). Tomato seeds were treated with mentioned concentrations of Zn, Fe and Ag NPs for 4 hour as well as control. After soaking, seeds were dried to near original moisture content and sown in pro-trays for raising seedling in nursery.

Field was ploughed by mould board plough twice and then levelled properly with heavy wooden planker to bring the field to a good tilth. Raised beds of 20 cm height and 1 m width were prepared with the space of 50 cm between the beds. Well decomposed vermicompost @ 5 kg/m^2 was uniformly mixed in the soil a fortnight before transplanting. The recommended dose of NPK fertilizers (150:100:120 kg/ha) were applied as basal dose. Nitrogen was given into two split doses, first as basal dose and another was given after one month of transplanting to each treatment plot. After that, 25 days old vigorous and uniform seedlings were transplanted on the raised beds according to treatment at the spacing of 60 × 45 cm in three replications. All the recommended package of practices was uniformly followed in all treatments. The necessary plant protection measures were adopted to raise healthy crop.

The observations on growth attributes *viz.* plant height (cm), number of leaves per plant, intermodal length (cm), shoot diameter (cm), number of flower/plant, days to 50 percent flowering, total chlorophyll content at 45 and 90 DAT and yield contributing characters *i.e.* number of fruit set/ plant, number of fruits/plant, fruit weight (g), fruit weight/ plant (g), fruit yield/ha (Kg), seed yield/plant (g) were recorded at maturity from randomly selected 10 plants from each treatment plots. B: C ratio was also computed by dividing gross returns with cost of cultivation for each treatment. The data on quantity observations recorded during the course of investigation for various characters were subjected to statistical analysis by adopting randomized block design (RBD) with three replications as per the technique suggested by Panse and Sukhatme (1995). Significance of difference in the treatment effect was tested through 'F' test at 5 percent level of significance.

RESULTS AND DISCUSSION

Performance of growth attributes

Application of nanoparticles as seed treatment significantly influenced growth attributes in tomato (Table 1). Plant height was significantly increased with Zn NPs treated seeds (800 ppm) and treatments, *viz*. T4, T3, T2 and T1 registered higher plant height (144.2, 135.84, 133.2 and 129.78, respectively). The increased in plant height in Zn NPs treatment might be due to the enhanced biosynthesis of auxins (IAA) and better nutrient uptake activity, which lead to increase in plant height (Faizan and Hayat, 2019). The results are in conformity with the reports of Velasco *et al*. (2020) in tomato, siddiqui *et al*. (2014) in summer squash. Significantly higher number of leaves/plant (161.88), intermodal length (7.10 cm) and shoot diameter (1.98 cm) were reported in Zn NPs 800 ppm treatments than control (129.12, 4.34 cm and 1.21 cm, respectively). The significant increase in these attributes with application of Zn NPs could be due to enhanced photosynthesis and related attributes along with the CA activity. Moreover, ZnO-NPs enhanced the assimilatory rate of CO_2, increasing metabolism and enzymatic action which leads the increased cell division and ultimately enhanced growth and development of plant. These results are in conformity with the finding of Burman *et al*. (2013) in chick pea, Elizabath *et al.* (2016) in carrot, Mahdieh *et al.* (2017) in bean, Sarkar *et al.* (2017) in water spinach, Salama *et al.* (2019) in bean, Lopez *et al.* (2018) in pepper, Faizan and Hayat (2019) in tomato. NPs seed treatment particularly Zn NPs significantly increased the number of flowers/plant (Table 2). The significantly higher number of flowers was recorded in T4 (129.42) followed by T3 (121.29) and T2 (116.65) than control (T0) (80.12). This may be due to use of Zn nanoparticles helped in chlorophyll synthesis which increases in photosynthetic rate resulting more accumulation of carbohydrates leading to profuse flowering (Dhruve *et al.,* 2018). The results are in conformity with the finding of Laware and Raskar (2014) in onion and Lopez *et al.* (2018) in pepper. Nanoparticles application changes the days taken to 50% flowering. Significantly lesser days taken to 50% flowering was observed in T4 (38.87) followed by T3 (39.84) and T2 (40.18). However, Zn NPs application significantly reduced the days taken to 50% flowering which might be due to ZnNPs provided essential plant growth promoting substance which promoted reproductive phase resulting in lesser time required for 50 percent flowering (Laware and Raskar 2014). The results are in agreement with the finding of Sarkar *et al.* (2017) in spinach and Kumar *et al*. (2017) in strawberry.

Significantly higher value of chlorophyll content (1.71 and 2.01 mg/100 g) in T_4 treatment (ZnNPs at 800 ppm)

Table 1: Effect of different nanoparticles on growth attributes of tomato.

Treatment	Plant height (cm)	Number of leaves	Internodal length (cm)	Shoot diameter (cm)	No. of flowers	Days to 50% flowering	Chlorophyll content	
							45 DAT	90 DAT
T_0	118.59	129.12	4.34	1.21	80.12	46.84	1.11	1.23
T_1	129.78	144.62	6.20	1.51	110.45	42.46	1.54	1.73
T_2	133.20	146.91	6.37	1.59	116.65	40.18	1.56	1.78
T_3	135.84	149.16	6.61	1.84	121.19	39.84	1.68	1.88
T_4	144.22	161.88	7.10	1.98	129.42	38.87	1.71	2.01
T_5	125.55	142.25	4.97	1.43	98.81	45.84	1.40	1.50
T_6	124.47	138.16	4.87	1.40	93.44	44.84	1.34	1.46
T_7	121.61	133.32	4.85	1.31	88.80	45.84	1.28	1.42
T_8	119.20	131.10	4.80	1.28	85.11	42.85	1.23	1.39
T_9	127.90	143.35	5.69	1.69	103.64	42.85	1.51	1.67
T_{10}	125.62	141.30	5.60	1.66	99.30	43.85	1.46	1.61
T_{11}	124.88	137.72	5.20	1.51	96.47	45.84	1.42	1.58
T_{12}	122.27	133.66	5.12	1.39	91.72	44.84	1.39	1.53
S.Em (±)	2.13	3.62	0.14	0.03	2.50	0.40	0.05	0.05
CD (5%)	6.08	10.36	0.41	0.09	7.14	1.15	0.13	0.15

T_0: Control, T_1: Seed treatment with Zn NP suspension at 200 ppm, T_2: Seed treatment with Zn NP suspension at 400 ppm, T_3: Seed treatment with Zn NP suspension at 600 ppm, T_4: Seed treatment with Zn NP suspension at 800 ppm, T_5: Seed treatment with Fe NP suspension at 200 ppm, T_6: Seed treatment with Fe NP suspension at 400 ppm, T_7: Seed treatment with Fe NP suspension at 600 ppm, T_8: Seed treatment with Fe NP suspension at 800 ppm, T_9: Seed treatment with Ag NP suspension at 25 ppm, T_{10}: Seed treatment with Ag NP suspension at 50 ppm, T_{11}: Seed treatment with Ag NP suspension at 75 ppm, T_{12}: Seed treatment with Ag NP suspension at 100 ppm,

Table 2: Effect of different nanoparticles on yield contributing characters of tomato

Treatment	Fruit set per plant	Number of fruit per plant	Fruit weight (g)	Fruit weight per plant (kg)	Fruit yield per hectare (q)	Seed yield per plant (g)
T_0	68.73	55.10	61.79	3.39	125.00	26.35
T_1	94.71	80.23	79.73	6.37	233.41	47.17
T_2	103.16	86.33	82.72	7.12	268.81	52.48
T_3	107.83	91.31	84.71	7.70	277.29	56.42
T_4	117.99	99.62	87.70	8.70	322.54	65.52
T_5	85.79	70.24	72.75	5.08	172.13	39.20
T_6	78.98	65.78	69.76	4.53	168.14	34.74
T_7	74.78	61.28	67.77	4.13	154.87	31.14
T_8	69.68	57.92	66.77	3.85	152.29	28.28
T_9	88.81	76.32	73.75	5.60	200.96	43.35
T_{10}	83.78	71.40	71.76	5.10	179.95	39.14
T_{11}	77.93	65.78	70.76	4.64	178.10	35.40
T_{12}	72.60	60.88	68.76	4.17	157.82	31.54
S.Em (±)	1.38	1.68	1.03	0.10	2.34	0.73
CD (5%)	3.95	4.81	2.95	0.29	6.71	2.09

while, the lesser value of chlorophyll content (1.11 and 1.23 mg/100 g) was recorded in T_0 (control) at 45 and 90 DAT respectively. However, the treatment T_3 (Zn NPs suspension 600ppm) with 1.68 and 1.88 mg/100 g were found at par with treatment T_4 at 45 and 90 DAT respectively. The observed increases in the chlorophyll content are attributed to the fact that Zn plays an essential role in the activity of carbonic anhydrase enzyme that catalyzes the hydration of CO_2 that facilitates the diffusion of carbon dioxide to the carboxylation sites in plant. The similar results were also reported by Pullagurala *et al*. (2013) in coriander and Raliya and Tarafdar (2013) in cluster bean.

Yield contributing characters

The data presented in Table 2 showed that application of nanoparticles as seed treatment significantly influenced yield and yield contributing attributes in tomato. Yield contributing attributes *i.e.* number of fruit set/plant (117.99), number of fruit/plant (99.62), fruit weight (87.7 g), fruit weight/plant (8.7 kg), fruit yield (322.54 q/ha) and seed yield per plant (65.52g)

Table 3: Economics of different treatments of tomato cultivation with the application of nanoparticles.

Treatment	Tomato yield (q. /ha)	Cost of cultivation including the cost of treatment	Gross return ha^{-1} @ Rs.1000 q^{-1}	Net returns (Rs ha^{-1})	B:C ratio
T_0	125.00	62522	125000	62478	1.99
T_1	233.41	62547	233410	170863	3.73
T_2	268.81	62572	268810	206238	4.29
T_3	277.29	62597	277290	214693	4.42
T_4	322.54	62622	322540	259918	5.15
T_5	200.96	62547	200960	138413	3.21
T_6	179.95	62572	179950	117378	2.87
T_7	178.10	62597	178100	115503	2.84
T_8	157.82	62622	157820	95198	2.52
T_9	154.87	62539.5	154870	92330.5	2.47
T_{10}	152.29	62557	152290	89733	2.43
T_{11}	168.14	62574.5	168140	105565.5	2.68
T_{12}	172.13	62592	172130	109538	2.75

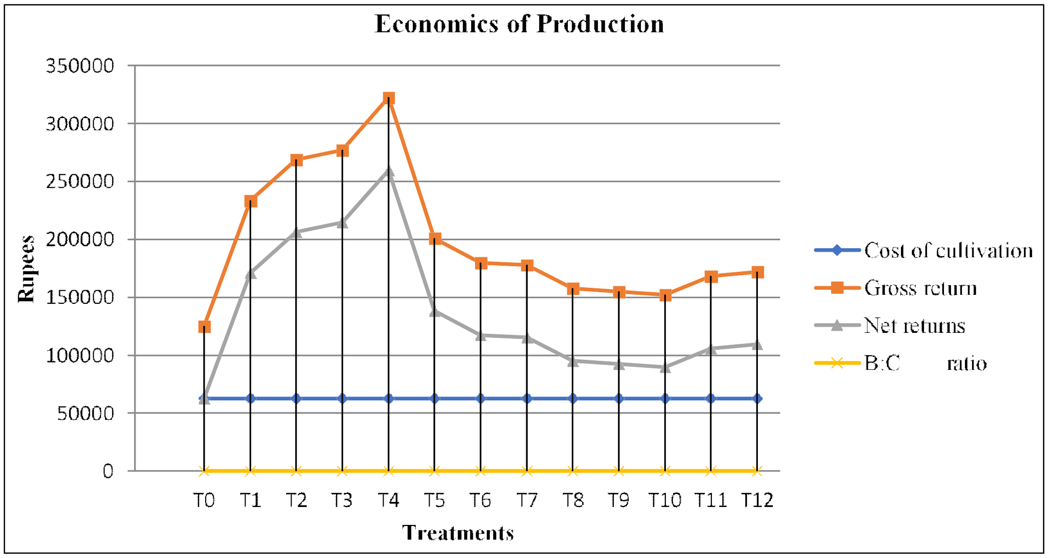

Fig 1: Profitability of seed treatment with different nanoparticles concentration in tomato.

were recorded significantly high under treatment T_4 (Zn NPs 800ppm) and the minimum value for yield parameters *i.e.* number of fruit set/plant (68.73), number of fruit/plant (55.10), fruit weight (61.79 g), fruit weight/plant (3.39 kg), fruit yield (125.00 q/ha) and seed yield per plant (26.35 g) were recorded under treatment T_0. This might be due to better absorption of Zn NPs which ultimately increase more accumulation of photosynthates which were synthesized in the leaf and translocated towards the fruit and provide better environment for growth and developmental processes, thus, better results were obtained due to the availability of favorable conditions and more number of fruit set and development per plant. The similar results were also obtained by Kole *et al.* (2013) in bitter melon, Laware *et al.* (2014) in onion, Lopez *et al.* (2019) in pepper, Osman *et al.* (2019), Faizan and Hayat (2019) in tomato.

Seed yield per plant was significantly higher in treatment T_4 (Seed treated with ZnNPs at 800 ppm). The highest (65.52 gm) seed yield per plant was recorded under treatment T_4 while minimum seed yield (26.35) was recorded in T_0. It might be due to ZnNPs play a decisive role in improving the productivity of the crop. In fact zinc is recognized as key element in protein synthesis and also involved in various types of enzyme activity, carbohydrate metabolism nitrogen fixation that lead the higher number of seed per plant (Elham *et al.* 2020).The results are in conformity with the finding of Laware and Raskar (2014) in onion and Masuthi *et al.* (2009) in cowpea.

Cost of economics

The data regarding to net return and B: C ratio is presented in Table 3 and Fig 1 and showed that increase in net return and B: C ratio was obtained with application of nanoparticles. Treatment T_4 (Zn NPs 800 ppm) resulted maximum net profit of Rs. 259918.00 with B: C ratio (5.15), followed by Rs. 214693 net return and 4.42 B: C ratio under treatment T_3 (Zn NPs 600ppm) than control (Rs. 62478.00 and 1.99, respectively).

CONCLUSION

From the study it was concluded that application of nanoparticles specially Zn NPs @ 800 ppm as seed treatment significantly increased growth and yield contributing characters as well as profitability in tomato cultivation.

Conflict of interest: None.

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