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Influence of nitrogen, copper and zinc nanofertilizers on growth characteristics of chilli (*Capsicum annuum* var. *annuum* L.)

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Abstract
To study the efficacy of nanofertilizers in chilli, an experiment was carried out during the year 2020 and 2021. The experiment was conducted at the experimental field of division of vegetable science, SKUAST- Kashmir, Shalimar Srinagar during Kharif 2020 and Kharif 2021 with an objective of assessing the effectiveness of nanofertilizers (Nitrogen, Zinc and Copper) for enhancing growth attributes of chilli (*Capsicum annuum* L.), variety Kashmir Long-1. The experiment was carried out in randomized block design with twenty seven treatments and three replications. Foliar application of the nanofertilizers was done thrice at three different stages of crop growth. Out of the 27 treatment combinations T_{19} (N @ 4 ml/l + Cu @ 2 ml/l + Zn @ 2ml/l) was found best with regard to growth parameters of chilli. The results under such treatment were significantly higher for plant height (73.77cm), plant spread (63.11cm), number of branches (10.45) and leaf area (41.07 cm^2).

Keywords: Efficacy, nanofertilizers, chilli, growth, foliar application

1. Introduction

Chilli also known as hot pepper (*Capsicum annuum* var. annuum L.) is an important vegetable as well as cash crop in India. It belongs to family Solanaceae and originated in the tropics and subtropics of America (Dhaliwal, 2015) [9]. Chilli is famous for its nutritional value, medicinal effects and therapeutic uses; in addition it is being used as an organic coloring and flavoring agent in food industry. The fresh green chilli fruits are outstanding source of vitamin A and C (292 IU /100 g and 67 mg / 100 g) due to several carotenoid *viz-* chlorophyll, provitamin a, carotene and oxygenated carotenoids such as capsanthin and cryptocapsin (Deepa *et al.,* 2007) [8]. The green chilli contain moisture, protein, mineral, fiber, fat, carbohydrate, energy, Ca, P, Fe, thiamine, carotene, capsaicin, niacin, riboflavin, nordihydrocapsaicin and dihydrocapsaicin as well as large number of polyphenolic compounds or flavonoids. Chilli accounts for 17% of the annual trade of the world and hence is considered most important spice crop of the world (Ahmed *et al.*, 2000) [2]. Sustainable agriculture with a high productivity is crucial to alleviate the perils of hunger and ensure food security. Food production and distribution are under an increased and continuous stress at a global scale due to climate change, an increased human population, decreased fertile lands and freshwater resources. This challenge could be addressed with technological advancements coupled with significant modifications to existing global food production systems (Achiri *et al*., 2017) [1]. Currently, modern agriculture is heavily supported by the use of high rates of agrochemicals. Synthetic chemical fertilizers are used for the optimal growth and productivity of crops, but they are not successful to enhance plant nutrient use efficiency (NUE) and crop productivity (Alemayehu and Shewarega, 2015) [3]. The NUE values of the three most basic macronutrients i.e., nitrogen, phosphorus and potassium are low at 30–35%, 18–20% and 35–40%, respectively (Zhang *et al*., 2015) [16], which shows that more than half of the broadcasted fertilizers in the fields are lost and do not reach their targeted sites due to different factors such as photolysis, hydrolysis, leaching and microbial immobilization and degradation. The direct application of fertilizers to the soil will result in loss of nutrients owing to different factors such as photolysis, hydrolysis, leaching and degradation, as such the applied fertilizers are unable to reach the targeted sites in the plant system which had the bearing on the growth and productivity of crops. Hence an attempt was made to increase the efficiency of applied fertilizer in the form of nanofertilizer through foliar spray to the crop.

Compared with commercial chemical fertilizers, nanofertilizers has larger specific surface area, which makes nutrients more easily absorbed by plants hence significantly improves its fertilizer use efficiency and economic benefits. The application of nanofertilizer can improve the physical and chemical properties of soil and improve the ability of water and fertilizer conservation (Yu and Ren, 2014) [15]. Therefore in the present investigation, the role of different nanofertilizers such as nano nitrogen, nano copper and nano zinc on the growth components of chilli variety Kashmir Long-1 was studied.

2. Materials and Methods

The experiment was conducted at the experimental field of division of vegetable science, SKUAST- Kashmir, Shalimar Srinagar during Kharif 2020 and Kharif 2021. The variety of the chilli used was Kashmir Long-1. The seed of chilli cv. Kashmir Long-1 were provided by the Division of Vegetable Science, SKUAST-Kashmir, Shalimar, whereas the nanofertilizers used in this study were procured from IFFCO (Indian Farmers Fertilizer Cooperative Limited). Raised beds were prepared by working the soil thoroughly into fine tilth. The seeds were sown on raised beds. 81 plots of 3.15 m x 2.25 m size were prepared as per layout specifications two sub irrigation channels were prepared to irrigate the crop. FYM at the rate of 25 t ha^{-1} was uniformly applied to each plot 3-4 days before transplanting and well incorporated into the soil. Half dose of nitrogen and full dose of phosphorous at the rate of 120 and 85 kg P_2O_5 ha^{-1} through urea and diammonium phosphate, respectively was uniformly applied to each plot as basal dose just before transplanting of seedlings. Remaining half dose of nitrogen was top dressed at 45 days after transplanting. The nursery beds were irrigated before uprooting of seedlings vigorous and healthy seedlings of uniform size were transplanted in well prepared and fertilized plots at spacing of 60 cm × 45 cm. The nanofertilizers were sprayed at three growth stages of the crop (vegetative stage, flowering stage and fruiting stage) each time with the same dose of Nano-N, Cu and Zn or combination as mentioned in result tables.

3. Results

3.1. Plant height

Plant height is an important parameter depicting the health of the plant. The data pertaining to the effect of different treatments on plant height of chilli is presented in table 1. The application of nitrogen, zinc and copper proved effective for enhancing plant height. Among all the treatments plant height of 72.37 cm in the year 2020, 75.16 cm during 2021 and 73.77 cm in pooled data was recorded maximum with the treatment T_{19} (N @ 4 ml/l + Cu @ 2 ml/l + Zn @ 2 ml/l), while the minimum plant height of 43.41 cm in the year 2020, 44.19 cm in 2021 and 43.80 cm in pooled data was observed in treatment T_{27} (control).

3.2 Plant spread (cm)

The data pertaining to plant spread presented in table 1 revealed significant influence of various treatments over the years 2020 and 2021. The application of nitrogen, zinc and copper proved effective for enhancing plant spread. Among all the treatments plant spread of 62.51 cm in the year 2020, 63.70 cm during 2021 and 63.10 cm in pooled data was recorded maximum with the treatment T_{19} (N @ 4 ml/l + Cu @ 2 ml/l + Zn @ 2 ml/l), while the minimum plant spread of 34.43 cm in the year 2020, 36.13 cm in 2021 and 35.78 cm in pooled data was observed in treatment T_{27} (control).

3.3 Number of branches $plant^{-1}$

The data pertaining to number of branches $plant^{-1}$ presented in table 2 revealed significant influence of various treatments over the years (2020 and 2021). The application of nitrogen, zinc and copper proved effective for enhancing number of branches $plant^{-1}$. Among all the treatments number of branches $plant^{-1}$ of 10.32 in the year 2020, 10.59 during 2021 and 10.45 in pooled data was recorded maximum with the treatment T_{19} (N @4ml/l + Cu @ 2 ml/l + Zn @ 2 ml/l), while the minimum number of branches $plant^{-1}$ of 5.38 in the year 2020, 5.41 in 2021 and 5.39 in pooled data was observed in treatment T_{27} (control).

3.4 Leaf area (cm^2)

The data pertaining to leaf area presented in table 2 revealed significant influence of various treatments over the years 2020 and 2021. The application of nitrogen, zinc and copper proved effective for enhancing leaf area. Among all the treatments the leaf area of 40.27 cm^2 in the year 2020, 41.86 cm^2 during 2021 and 41.07 cm^2 in pooled data was recorded maximum with the treatment T_{19} (N @ 4 ml/l + Cu @ 2 ml/l + Zn @ 2 ml/l), while the minimum leaf area of 25.92 cm^2 in the year 2020, 26.57 cm^2 in 2021 and 26.25 cm^2 in pooled data was observed in treatment T_{27} (control).

Table 1: Effect of nanofertilizers on plant height and plant spread of chilli (*Capsicum annuum* L.), variety Kashmir Long-1

Treatment	Plant Height (cm)			Plant Spread (cm)		
	2020	2021	Mean	2020	2021	Mean
N @ 4 ml/l	53.40	54.20	53.80	45.48	46.54	46.01
N @ 5 ml/l	49.58	50.20	49.89	41.64	42.67	42.15
Cu @ 2 ml/l	45.61	46.38	45.99	37.42	38.46	37.94
Cu @ 2.5 ml/l	44.25	45.13	44.69	36.45	37.02	36.74
Zn @ 2 ml/l	47.47	48.30	47.89	39.44	40.49	39.96
Zn @ 2.5 ml/l	46.41	47.22	46.82	38.29	38.99	38.64
N @ 4ml/l + Cu @ 2 ml/l	59.43	61.08	60.26	51.50	52.22	51.86
N @ 4ml/l + Cu @ 2.5 ml/l	58.69	60.03	59.36	50.45	51.12	50.79
N @ 5ml/l + Cu @ 2 ml/l	55.34	56.24	55.79	47.77	48.58	48.17
N @ 5 ml/l + Cu @ 2.5 ml/l	54.50	55.13	54.82	46.45	47.12	46.78
N @ 4 ml/l + Zn @ 2 ml/l	61.61	63.80	62.71	53.40	54.02	53.71
N @ 4 ml/l + Zn @ 2.5 ml/l	60.10	62.51	61.30	52.37	53.31	52.84
N @ 5 ml/l + Zn @ 2ml/l	57.35	58.85	58.10	49.55	50.24	49.89
N @ 5 ml/l + Zn @ 2.5 ml/l	56.34	57.25	56.80	48.68	49.45	49.07

Cu @ 2 ml/l + Zn @ 2ml/l	52.11	53.38	52.75	44.57	45.67	45.12
Cu @ 2 ml/l + Zn @ 2.5ml/l	50.40	51.24	50.82	42.59	43.41	43.00
Cu @ 2.5 ml/l + Zn @ 2ml/l	51.51	52.12	51.82	43.58	44.65	44.12
Cu @ 2.5 ml/l + Zn @ 2.5ml/l	48.48	49.14	48.81	40.40	41.54	40.97
N @ 4 ml/l + Cu @ 2 ml/l + Zn @ 2ml/l	72.37	75.16	73.77	62.51	63.70	63.11
N @ 4 ml/l + Cu @ 2 ml/l + Zn @ 2.5ml/l	68.21	71.14	69.68	59.04	59.82	59.43
N @ 4 ml/l + Cu @ 2.5 ml/l + Zn @ 2ml/l	70.11	73.30	71.71	60.06	61.03	60.55
N @ 4 ml/l + Cu @ 2.5 ml/l + Zn @ 2ml/l	63.56	65.51	64.54	55.32	56.05	55.69
N @ 5 ml/l + Cu @ 2 ml/l + Zn @ 2ml/l	67.14	69.44	68.29	58.32	59.01	58.67
N @ 5 ml/l + Cu @ 2 ml/l + Zn @ 2.5ml/l	64.61	67.10	65.85	56.45	57.31	56.88
N @ 5 ml/l + Cu @ 2.5 ml/l + Zn @ 2ml/l	66.55	68.25	67.40	57.54	58.66	58.10
N @ 5 ml/l + Cu @ 2.5 ml/l + Zn @ 2.5 ml/l	62.32	64.21	63.27	54.45	55.13	54.79
Control	43.41	44.19	43.80	35.43	36.13	35.78
C.D	0.72	0.90	1.07	0.89	1.04	1.26

Table 2: Effect of nanofertilizers on number of branches and leaf area (cm^2) of chilli (*Capsicum annuum* L.), variety Kashmir Long-1

Treatment	Number of branches			Leaf area (cm^2)		
	2020	2021	Mean	2020	2021	Mean
N @ 4 ml/l	7.30	7.29	7.30	37.89	38.47	38.18
N @ 5 ml/l	6.91	6.92	6.92	32.45	33.08	32.77
Cu @ 2 ml/l	5.81	5.78	5.79	31.35	31.98	31.66
Cu @ 2.5 ml/l	5.53	5.50	5.52	30.53	31.15	30.84
Zn @ 2 ml/l	6.74	6.79	6.77	33.21	33.83	33.52
Zn @ 2.5 ml/l	6.60	6.54	6.57	32.16	32.77	32.47
N @ 4 ml/l + Cu @ 2 ml/l	7.71	7.68	7.70	42.26	42.87	42.57
N @ 4 ml/l + Cu @ 2.5 ml/l	7.65	7.60	7.62	41.23	41.79	41.51
N @ 5 ml/l + Cu @ 2 ml/l	7.41	7.37	7.39	38.95	39.56	39.26
N @ 5 ml/l + Cu @ 2.5 ml/l	7.34	7.37	7.35	38.15	38.81	38.48
N @ 4 ml/l + Zn @ 2ml/l	8.03	8.17	8.10	43.89	44.55	44.22
N @ 4 ml/l + Zn @ 2.5 ml/l	7.86	7.97	7.92	43.19	43.81	43.50
N @ 5 ml/l + Zn @ 2 ml/l	7.53	7.54	7.53	40.21	40.77	40.49
N @ 5 ml/l + Zn @ 2.5 ml/l	7.47	7.40	7.44	39.21	39.83	39.52
Cu @ 2 ml/l + Zn @ 2 ml/l	7.22	7.26	7.24	36.72	37.33	37.03
Cu @ 2 ml/l + Zn @ 2.5 ml/l	7.02	6.99	7.00	34.51	35.07	34.79
Cu @ 2.5 ml/l + Zn @ 2 ml/l	7.12	7.09	7.10	35.55	36.12	35.84
Cu @ 2.5 ml/l + Zn @ 2.5 ml/l	6.83	6.87	6.85	33.34	33.90	33.62
N @ 4 ml/l + Cu @ 2ml/l + Zn @ 2 ml/l	10.32	10.59	10.45	50.79	51.35	51.07
N @ 4 ml/l + Cu @ 2ml/l + Zn @ 2.5 ml/l	8.68	8.79	8.74	48.58	49.09	48.84
N @ 4 ml/l + Cu @ 2.5ml/l + Zn @ 2 ml/l	9.82	9.95	9.88	49.64	50.20	49.92
N @ 4 ml/l + Cu @ 2.5ml/l + Zn @ 2 ml/l	8.21	8.34	8.28	44.89	45.50	45.20
N @ 5 ml/l + Cu @ 2ml/l + Zn @ 2 ml/l	8.52	8.61	8.57	47.52	48.18	47.85
N @ 5 ml/l + Cu @ 2 ml/l + Zn @ 2.5 ml/l	8.30	8.44	8.37	45.09	45.70	45.40
N @ 5 ml/l + Cu @ 2.5 ml/l + Zn @ 2 ml/l	8.38	8.51	8.45	46.47	47.09	46.78
N @ 5 ml/l + Cu @ 2.5 ml/l + Zn @ 2.5 ml/l	8.14	8.26	8.20	44.23	44.90	44.56
Control	5.38	5.41	5.39	29.65	30.32	29.98
C.D	0.35	0.22	0.18	0.27	0.26	0.56

4. Discussion

The foliar application of nanofertilizers increases crop growth to optimum under low concentrations. However, the increased concentration may inhibit the crop growth due to the toxicity of nutrient (Al-juthery *et al.,* 2018) [5]. All nutrients in the nanofertilizers are at nano scale making it easier for it to penetrate into the plant leaves (Jyothi and Hebsur, 2017; Ali and Al-juthery, 2017) [11, 4]. Nanofertilzers or nano-encapsulated nutrients have properties that are effective to crops, release the nutrients on-demand, controlled release of chemicals fertilizers that regulate plant growth and enhanced target activity (De Rosa *et al.,* 2010; Nair *et al.,* 2010) [7, 13]. The results of the present investigation are in close conformity with Amin (2011) [6], who observed that the increase in plant height with nitrogen can be attributed to the fact that it promotes plant growth, increases the number and length of the internodes which results in progressive increase in plant height. This might also be due to the effect of nano-N that enhanced the formation of chlorophyll, the rate of photosynthesis, dry matter production, consequently the overall plant growth (Morales-Díaz *et al.,* 2017) [12]. The physiological mechanisms through which nano nitrogen in combination with nano zinc and nano copper exerts their effects may depend on enzymes for hormone synthesis. Vegetative growth enhancement may also be attributed to the role of nano micronutrient stimulatory effects on the production of chlorophyll, photosynthesis, mitochondrial respiration, and hormone biosynthesis, e.g. ethylene, gibberellic acid and jasmonic acid (Hansch and Mendel 2009) [10]. In addition to this zinc is involved in synthesis of tryptophan which is a precursor of IAA (indole acetic acid) (Spiegel-Roy and Goldschmidt, 2008) [14] hence may cause the stimulative influence on growth due to increased IAA synthesis which in an important growth promoting hormone.

5. Conclusion

Foliar application of nanofertilizers (nano nitrogen, nano copper, nano zinc), as an alternative to soil application of fertilizers, in combination with synthetic fertilizers through soil application for chilli var. Kashmir Long-1, was very effective in enhancing the growth attributing parameters. To conclude, the foliar application of nitrogen, copper and zinc nanofertilizers (N @4ml/l + Cu @2ml/l + Zn @2ml/l) alongwith recommended dose of fertilizers proved to be beneficial in all aspects of growth characteristics. This study clearly suggests that, soil application of fertilizer can be replaced by nanofertilizer through foliar application which enhanced the growth attributes of the crop. In addition the foliar application of nanofertilizer will also reduce soil pollution and enhance soil fertility by improving the physical and chemical properties of the soil.

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