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Impact of various nutrition sources and ZnO (nanoparticles) treatment on the fruit parameters of capsicum (*Capsicum annuum* L.)

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Abstract
This study focuses on the effect of ZnO nanoparticles on fruit parameters of capsicum (*Capsicum annuum* L.) and was performed under net house conditions using a completely randomized design with thirteen treatments along with seed treatment and foliar application of ZnO nanoparticles @ 50, 100 and 150 ppm concentration which was further replicated three times during the year 2020. The effect of seed treatment and foliar application of ZnO nanoparticles at the rate of 50, 100 and 150 ppm along with different nutrient sources on fruit shape index and pericarp thickness of capsicum was evaluated and it was observed that, the fruit shape index and pericarp thickness did not vary significantly by the seed treatment as well as foliar application of ZnO nanoparticles.

Keywords: ZnO, nanoparticles, capsicum, nutrient sources

Introduction
Capsicum belongs to genus capsicum and Solanaceae family and is grown throughout the year in India [1]. It is grown as vegetable, spice and cash crop [2]. In world, capsicum is grown over 1.7-million-hectare area with production of 7.18 million tons [3]. Capsicum is cultivated in Himachal Pradesh, Karnataka, hilly areas of U.P and Tamil Nadu and Maharashtra states of India. Capsicum is grown sub-tropical and temperate regions of the world. Bell pepper is a rich source of flavonoids antioxidants, vitamins and essential nutrients [4]. Capsicum can be consumed as raw or cooked as vegetable, also the antioxidants present in it aids in prevention of cataracts and cardiovascular diseases etc. [5].

Nanotechnology is widely used in agricultural research area [6]. It is emerged as innovative technology which provides opportunity for better environment conditions and best nutrient delivery [7]. Nanoparticles are the particle with size 1 to 100 nanometers [8]. The effectiveness of macro and micronutrients and pesticides can be enhanced with the modern technologies like nanotechnology [9]. Micronutrients are needed in small amounts and play an outstanding role in plant metabolic processes. Zinc is essential micronutrient and its deficiency is very common in various crops. Zinc is involved in Dehydrogenase, Aldolase, Isomerase, Transphosphorylase activities and is requird for tryptophan synthesis, cell division and other regulatory functions [10]. ZnO nanoparticles are mostly studied due to its less cost, toxicity and environmental hazards [11]. Zinc oxide nanoparticles also involved in defense mechanism of plant which ultimately affects the morphology, physiology and histology of plant [12]. ZnO is useful in the agricultural research area due to importance of Zinc as micronutrient for growth and development in plants [13]. In this context, the present studies were conducted to check the effect of ZnO nanoparticles on fruit parameters of capsicum.

Materials and Methods
The given pot experiments were conducted in net house of Department of Soil Science and Water Management, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh) in the year 2020. May-June months are moderate hot in summers, and December-January are the cold months in winters. Rainfall is highest in the month of June to September in this area with average of about 1100 mm. There were three replications and 13 treatment combinations i.e., T_1- control and treatments T_2 to T_{13} consist of 100% RDN (through vermicompost) and 50-50% RDN (through vermicompost and chemical fertilizers) along with seed treatment and foliar spray of 50, 100 and 150 ppm ZnO nanoparticles.

Fruit shape index**:** Polar and equatorial diameter of five randomly picked fruit was measured with digital vernier caliper after cutting the fruit from stem end to blossom end. Ratio of polar diameter to equatorial diameter was worked out to calculate fruit shape index.

Pericarp thickness: Mean value of pericarp thickness five randomly picked fruit from each plot was worked out after cutting the fruits transversely. Measurement was taken with digital vernier caliper in millimeters.

Table 1: Effect of different nutrient sources along with ZnO (nanoparticles) application on fruit shape index and pericarp thickness of capsicum.

Treatments	Fruit Shape Index	Pericarp Thickness
T_1	0.91	3.11
T_2	0.92	3.28
T_3	0.95	2.69
T_4	1.03	3.28
T_5	0.99	3.65
T_6	1.10	3.43
T_7	1.00	3.58
T_8	0.92	3.52
T_9	0.95	3.45
T_{10}	0.92	3.57
T_{11}	0.96	3.76
T_{12}	0.95	3.86
T_{13}	0.94	3.82
Mean	0.97	3.46
CD $_{(0.05)}$	*NS*	*NS*

Results and Discussions

The data presented in Table 1 revealed that the fruit shape index did not significantly affect by the application of ZnO nanoparticles along with different nutrient sources in capsicum. However, the maximum fruit shape index (1.10) was recorded under treatment T_6 i.e., 100% vermicompost + 100 ppm ZnO (seed treatment) whereas the minimum fruit shape index was recorded under treatment T_1 (control). Similar results were also obtained by Zhao *et al*. (2021) [14], they observed that fruit shape index did not affect significantly by the application of ZnO nanoparticles in tomato plant. The pericarp thickness also remained non significant by the application of ZnO nanoparticles along with different nutrient source in capsicum as given in Table 1. The maximum value of pericarp thickness (3.86 mm) was reported in treatment T_{12} (100% vermicompost + 150 ppm ZnO through foliar) whereas minimum value (3.11 mm) was obtained under treatment T_1 (control).

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