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Effect of foliar application of zinc oxide nanoparticles on biochemical characteristics of guava (*Psidium guajava* L.) cv. VNR Bihi

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Abstract
An experiment was conducted in 2021-22 to evaluate the biochemical characteristics of guava cv. VNR Bihi in different seasons (winter and rainy) by the spray of different concentrations of ZnO NPs (0, 50 100, 150 and 200 ppm). The results indicated that applying zinc oxide nanoparticles at 150 ppm via spraying led to the highest levels of Total Soluble Solids (TSS) at 11.10 ºB, ascorbic acid at 157.65 mg/100g, and sugars content at 7.98%, while keeping titratable acidity at its lowest at 0.45%, consistent in both seasons. Among the seasons all the qualitative characteristics were found better in the winter season crop as compared to the rainy season. The study suggested that foliar application of ZnO nanoparticles significantly enhanced the biochemical characteristics of guava in both seasons. Consequently, ZnO nanoparticles have the potential to serve as an alternative to conventional bulk zinc fertilizers.

Keywords: Foliar application, zinc oxide nanoparticles, biochemical characteristics, *Psidium guajava* L.

Introduction
Guava is the hardest among tropical fruit trees and excels most other fruit crops in productivity and adaptability. It provides a rich supply of ascorbic acid, dietary fiber, pectin and minerals. The composition of guava fruits varies with cultivars, stage of maturity and season (Das *et al.*, 1995) [4]. Guava fruits have a wide range of applications in commercial products such as jelly, fruit butter, and juice. It is also highly suitable for use in fruit salad. Careful management is required to produce a profitable crop which includes cultural practices and obviously the nutrition of an orchard. Nutrient management in guava involves maintaining soil fertility and providing essential plant nutrients at an optimal level to sustain desired fruit quality. Previously, in the Tarai region, farmers predominantly favored guava cultivars like L-49, Allahabad Safeda, and Pant Prabhat due to their reputation and adaptability in that area. But nowadays people have started adopting cv. VNR Bihi because it performs extremely well under drip fertigation and mulching (Preet *et al.*, 2021) [12]. A considerable advance in tree nutrition was the introduction of the nutrient balance concept. Zine deficiency is common in the Tarai region of Uttarakhand and symptoms of its deficiency have been observed in many crops i. e. paddy, wheat and soybean (Rajkumar *et al.*, 2014) [13]. Zinc is one of the essential micronutrients for plants, and Zn deficiency is common in many crops (Marschner, 2012; Ojeda-Barrios *et al.*, 2014) [9, 11]. Fernández *et al*. (2013) [6] demonstrated that utilizing foliar sprays containing fertilizers that incorporate microelements like Zn, B, copper (Cu), manganese (Mn), and iron (Fe) offers a practical solution for field applications. These sprays exhibit notable efficacy and lead to swift responses in plants. Additionally, the use of foliar fertilizers helps prevent potential toxicity manifestations that could arise when the same microelements are applied to the soil (Obreza *et al.*, 2010) [10]. On the other hand, nano-technologies, which are currently used for the manufacturing, processing, and application of nano-scale complexes, have been used to tackle many difficulties in various domains of research and industry (Scott and Chen, 2013) [15]. Materials that possess dimensions below 100 nm in at least one direction, generally falling under the category of nano-materials. Among these, zinc oxide nanoparticles (ZnO NPs) serve as micro-nutrients at the nano scale, with applications at low concentrations that significantly impact plant functions. These nanoparticles alter the impact of auxin by overseeing tryptophan synthesis and exerting an influence on fruit quality (García-López *et al.*, 2019) [7].

The goal of this work was to evaluate the influence of ZnO NPs as a foliar spray on qualitative characteristics including TSS, acidity, ascorbic acid and sugars of the VNR Bihi cultivar of guava.

Materials and Methods

The current study was conducted at the Horticulture Research Centre, Patharchatta, G. B. Pant University of Agriculture and Technology, Pantnagar, spanning from August 2021 to August 2022 over two consecutive seasons. The research focused on seven-year-old guava trees of the VNR Bihi cultivar, which were planted in a square system with a spacing of 5 x 3 m². The experimental design employed a two-factor randomized block design. Each treatment was replicated three times, with an individual tree representing a treatment unit in each replication. The plants underwent foliar spraying with varying concentrations of zinc oxide nanoparticles (50, 100, 150, and 200 ppm) along with a control treatment involving water spraying. Treatments were applied in the last week of September for the winter season in 2021 and for the rainy season, treatment was applied during the last week of May in 2022, with the help of a foot sprayer to different sets of trees. Total soluble solids (TSS) were calculated in degrees brix using a hand refractometer (MSW 503, Make-Macro Scientific Works) at room temperature. In guava, the% titratable acidity (as citric acids), total sugars, and reducing sugars were calculated using the method outlined by (Ranganna, 2001) [14]. The ascorbic acid concentration of fruit pulp was determined using the visual titration method described by (Ranganna, 2001) [14].

Results and Discussion

Total soluble solids

The data presented in Table 1. clearly indicated that the highest TSS (11.10 ºB) was recorded in the treatment T_4 (ZnO NPs @ 150 ppm) which was nonsignificant with the treatment T_3 (ZnO NPs @ 100 ppm). However, the lowest TSS (8.80 ºB) was found in control. On the basis of season, the highest TSS (12.00 ºB) was found in the winter season crop as compared to the rainy season. The interaction effect of zinc oxide nanoparticles treatment and seasons was found non-significant. A comparable finding has also been noted in apples, as Zn plays a direct role in processes such as carbohydrate synthesis, metabolism, and movement within the plant described by (Davarpanah *et al.*, 2016) [5].

Acidity

Foliar application of zinc oxide nanoparticles significantly decreases the acidity level of guava in both seasons presented in Table 1. The minimum acidity (0.45%) was recorded in treatment T_4 (ZnO NPs @ 150 ppm) which was statistically at par with treatment T_3 (ZnO NPs @ 100 ppm). Conversely, the control group exhibited the highest acidity value of 0.61%. When considering the seasons, the winter season crop showed the minimum acidity (0.47%) compared to the rainy season crop. The combined effect of zinc oxide nanoparticle treatment and seasons did not show any significant interaction. Hasani *et al.* (2012) [8] reported that a foliar spray of zinc decreased titratable acidity in pomegranate.

Table 1: Effect of zinc oxide nanoparticles and seasons on total soluble solids (ºB) and acidity per cent of guava cv. VNR Bihi

	TSS (ºB)			Acidity (%)		
Treatments	**Winter (S_1)**	**Rainy (S_2)**	**Mean (A)**	**Winter (S_1)**	**Rainy (S_2)**	**Mean (A)**
T_1 (Control)	10.60	7.00	8.80	0.57	0.64	0.61
T_2 (ZnO 50 ppm)	11.70	8.20	9.95	0.49	0.56	0.53
T_3 (ZnO 100 ppm)	12.60	9.10	10.85	0.43	0.49	0.46
T_4 (ZnO 150 ppm)	12.90	9.30	11.10	0.42	0.48	0.45
T_5 (ZnO 200 ppm)	12.20	8.70	10.45	0.45	0.52	0.49
Mean (B)	12.00	8.46		0.47	0.54	
Factor	CD (5%)	S.Em ±		CD (5%)	S.Em ±	
Factor (A)	0.378	0.127		0.017	0.006	
Factor (B)	0.239	0.081		0.011	0.004	
Factor (A x B)	NS	0.180		NS	0.008	

Ascorbic acid

Data presented in Table 2 revealed that ascorbic acid (157.65 mg/100 g) was found to be maximum in treatment T_4 (ZnO NPs @ 150 ppm) followed by treatment T_3 (ZnO NPs @ 150 ppm) where the minimum ascorbic acid (132.73 mg/100 g) was recorded in the treatment T_1 (control). Among the seasons maximum ascorbic acid (162.42 mg/100) was found in the winter season as compared to the rainy season and the interaction effect between zinc oxide nanoparticles and season was nonsignificant. Zn nanoparticles could have limited the movement of oxygen within the fruits, consequently slowing down the oxidation of ascorbic acid in the samples. Comparable findings were also documented in strawberry (Carlesso *et al.*, 2018) [2] and pomegranate (Davarpanah *et al.*, 2016) [5].

Total sugars

The data presented in Table 2. revealed that the highest total sugars (7.98%) were observed in the treatment T_4 (ZnO NPs @ 150 ppm) which was nonsignificant with the treatment T_3 (ZnO NPs @ 100 ppm). However, the minimum total sugars (6.80%) were found in control. On the basis of season, the highest total sugars (8.55%) were found in the winter season crop as compared to the rainy season. The combination of zinc oxide nanoparticle treatment and different seasons did not show a significant interaction effect. The impact of Zn on overall sugar content could stem from its involvement in processes like starch and nucleic acid metabolism, as well as its influence on the functioning of diverse enzymes engaged in these biochemical processes (Alloway, 2008) [1].

Table 2: Effect of zinc oxide nanoparticles and seasons on ascorbic acid (mg/100 g) and Total sugars per cent of guava cv. VNR Bihi

	Ascorbic acid (mg/100 g)			Total sugars (%)		
Treatments	**Winter (S_1)**	**Rainy (S_2)**	**Mean (A)**	**Winter (S_1)**	**Rainy (S_2)**	**Mean (A)**
T_1 (Control)	147.60	117.87	132.73	7.83	5.76	6.80
T_2 (ZnO 50 ppm)	156.00	126.13	141.07	8.32	6.29	7.31
T_3 (ZnO 100 ppm)	170.67	139.20	154.93	8.92	6.81	7.87
T_4 (ZnO 150 ppm)	172.79	142.51	157.65	9.04	6.92	7.98
T_5 (ZnO 200 ppm)	165.07	132.53	148.80	8.66	6.57	7.62
Mean (B)	162.42	131.65		8.55	6.47	
Factor	CD (5%)	S.Em ±		CD (5%)	S.Em ±	
Factor (A)	4.976	1.675		0.192	0.065	
Factor (B)	3.147	1.059		0.122	0.041	
Factor (A x B)	NS	2.368		NS	0.092	

Conclusion
According to the findings of this study, foliar spraying of ZnO nanoparticles at 100 ppm and 150 ppm showed to be the most efficient Zn nutrient source for increasing the biochemical quality of guava fruits in both the rainy and winter seasons.

Future Scope
We can extend the biochemical attributes of guava fruits as well as other fruit crops in the future by using ZnO NPs. Formers that use these techniques also earn the highest return on their crops.

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