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Effect of Pre-harvest Foliar Application of $ZnSO_4$ and ZnO Nanoparticles on the Plat Growth, Fruit Quality and Yield of Strawberry (*Fragaria* × *ananssa* Duch.) cv. Camarosa under Protected Conditions and Assessment of Their Accumulation on Human Health

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Abstract

Strawberry (*Fragaria* × *ananassa* Duch.) is a high value and low volume fruit crop that is highly appreciated worldwide for its good taste, aroma as well as health benefits. The present study was conducted to determine if the pre-harvest foliar application of $ZnSO_4$ and ZnO nanoparticles or their combination influences plant growth, fruit quality, yield as well as fruit and leaves Zn content in strawberry crop variety Camarosa. The study was conducted at Experimental Farm Chhapang, Department of Horticulture, Dr. Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib during 2019-20 and laid out in Randomized Block Design. The treatments consisted of 10 treatment combinations of various concentrations of $ZnSO_4$ and ZnO nanoparticles along with control replicated thrice. Foliar application was given 45 days after transplanting of crop. The observations were recorded in terms of vegetative, quality and yield parameters along with concentrations of Zn present in leaves and fruits. Results indicated that among different treatments applied the combination comprising of $ZnSO_4$ @ 0.3%+ ZnO NPs @ 150 ppm recorded best results in terms of all quantitative and qualitative characters. Also same treatment recorded maximum retention of Zn in fruits as well as leaves. In addition the health risk index for Zn content was less than, which proved that the application of $ZnSO_4$ and ZnO nanoparticles to strawberry does not cause any risk to human health.

Introduction

Strawberry contains 90% water, 1.4% protein, 8% carbohydrates and almost 1.5% crude fibre (Mitra, 1991). Its red fruits has delicate flavor, aroma and becomes one of important table fruit from around the world. The red colour is due to the presence of anthocyanin content. Strawberries contains some minerals, vitamins, flavonoids and phenolic acids that helps in anticancerous, antioxidant, anti-neurodegenerative and anti-inflammatory activities (Seeram et al., 2006). It is a short day plant generally propagated through runners with fruits usually small, firm, non climacteric and red in colour. The edible portion of fruit is called receptacle and achenes i.e. seeds. The short stem is called as crown and crown further produces leaves and flowers during growing season. (Chaturvedi et al., 2005; Kumar and Tripathi, 2009; Arora and Singh, 1970).

Material and Methods

Experimental design and Location: The experiment was laid out in Randomized Block Design with total ten treatment combinations replicated thrice, located at Experimental Farm Chhapang, Department of Horticulture, Dr. Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib, Sirmaur during 2019-20.

Vegetative attributes: Five plants per plot were selected randomly to estimate vegetative parameters. Plant height (cm) and plant spread (cm) were measured by using measuring scale, leaf area (cm^2) by using graph method and number of flowers as well as number of runners by counting manually.

Quality parameters

Yield attributes: Yield parameters of strawberry were also recorded by taking readings from five plants selected from each plot under each treatment. Fruit length and breadth were measured using Digital Vernier Callipers that ultimately results into fruit size (cm). Fruit weight (g) was calculated using Top Pan Balance. Number of fruits per plant was recorded manually from each plot and then working their average. Yield per plant (g) and yield per plot (g) were calculated according to the fruit weight and fruit number recorded under each treatment combination.

Data analysis: The treatments were arranged in Randomized Block Design with 10 treatment combinations and 3 replicates. The data resulted from the experiment were subjected to the statistical analysis of variance and means were compared at 5% level by method suggested by Gomez and Gomez, 1984.

Experimental Results

Vegetative attributes: The foliar application of different concentrations and combinations of $ZnSO_4$ and ZnO nanoparticles resulted in increased vegetative parameters in Strawberry cv. Camarosa. The maximum plant height (27.63 cm), plant spread (34.69 cm), leaf area (85.66 cm^2), number of flowers per plant (12.53) and number of runners per plant (30.66) recorded from treatment comprising of $ZnSO_4$ @ 0.3% + ZnO nanoparticles @ 150 ppm in comparison to control.

Treatment code	*Treatment details*	*Zn content in leaves (mg/100 g)*
T_1	$ZnSO_4$ @ 0.1%	43.90±1.40
T_2	$ZnSO_4$ @ 0.3%	36.54±1.04
T_3	$ZnSO_4$ @ 0.5%	42.14±2.56
T_4	ZnO NPs @ 100 ppm	40.73±2.70
T_5	ZnO NPs @ 150 ppm	36.71±1.58
T_6	ZnO NPs @ 200 ppm	39.69±2.07
T_7	$ZnSO_4$ @ 0.1% + ZnO NPs @ 100 ppm	36.53±2.76
T_8	$ZnSO_4$ @ 0.3%+ ZnO NPs @ 150 ppm	48.49±3.60
T_9	$ZnSO_4$ @ 0.5%+ ZnO NPs @ 200 ppm	36.72±2.40
T_{10}	Control	33.12±1.02

Table 1: Concentration of Zn content in leaves.

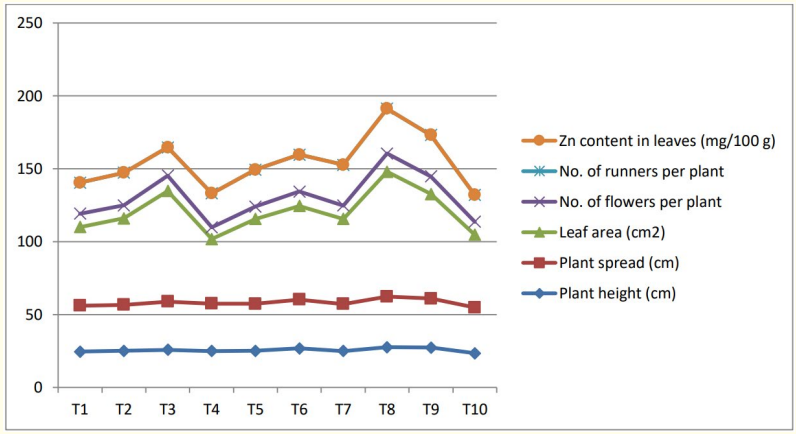

Figure 1: Effect of foliar application of $ZnSO_4$ and ZnO NPs on vegetative parameters and leaves Zn content.

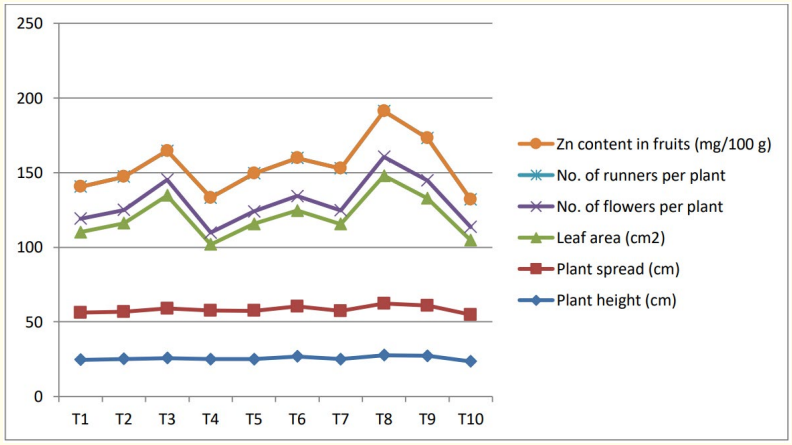

Figure 2: Effect of foliar application of $ZnSO_4$ and ZnO NPs on vegetative parameters and fruit Zn content.

Quality parameters: The results revealed that the maximum values in terms TSS (8.23 °Brix), titratable acidity (0.82%), total sugars (10.88%), non-reducing sugars (0.68%), anthocyanin content (19.73 mg/100g), ascorbic acid content (64.40 mg/100g) and shelf life (5.66 days) was resulted under treatment T_8 ($ZnSO_4$ @ 0.3% + ZnO NPs @ 150 ppm). However, the maximum TSS acid ratio (12.2) and reducing sugars content (10.63%) resulted under treatment T_1 ($ZnSO_4$ @ 0.1%) and T_9 ($ZnSO_4$ @ 0.5% + ZnO NPs @ 200 ppm), respectively.

Treatment code	*Treatment details*	*Zn content in fruits (mg/100 g)*
T_1	$ZnSO_4$ @ 0.1%	17.83±0.75
T_2	$ZnSO_4$ @ 0.3%	16.33±0.91
T_3	$ZnSO_4$ @ 0.5%	15.35±0.99
T_4	ZnO NPs @ 100 ppm	15.69±0.42
T_5	ZnO NPs @ 150 ppm	14.44±0.45
T_6	ZnO NPs @ 200 ppm	15.30±1.35
T_7	$ZnSO_4$ @ 0.1% + ZnO NPs @ 100 ppm	14.80±0.92
T_8	$ZnSO_4$ @ 0.3%+ ZnO NPs @ 150 ppm	16.25±1.41
T_9	$ZnSO_4$ @ 0.5%+ ZnO NPs @ 200 ppm	13.36±0.54
T_{10}	Control	12.32±0.85

Table 2: Concentration of Zn content in fruits.

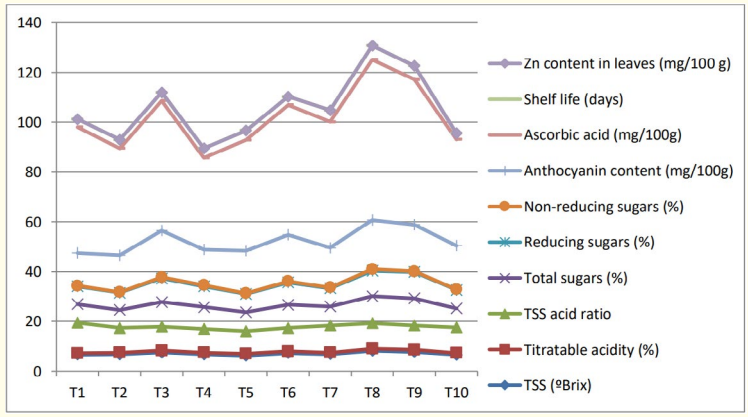

Figure 3: Effect of foliar application of $ZnSO_4$ and ZnO NPs on quality parameters and leaves Zn content.

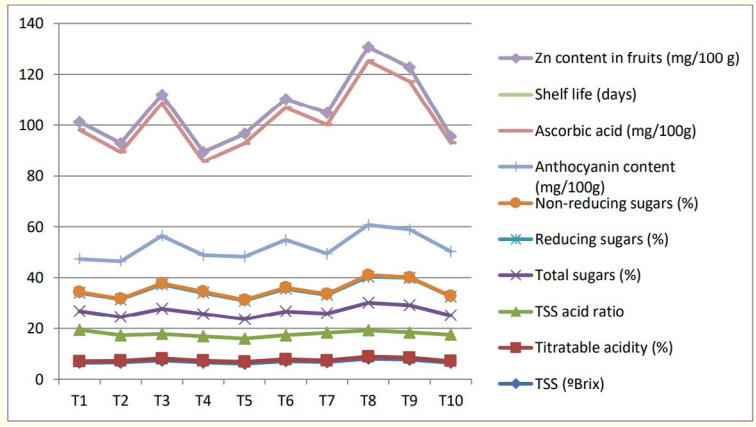

Figure 4: Effect of foliar application of $ZnSO_4$ and ZnO NPs on quality parameters and fruit Zn content.

Yield attributes: With the application of Zn, there is an increase in the yield attributes like fruit size (8.65 cm^2), fruit weight (13.22 g), number of fruits per plant (10.33), yield per plant (136.60 g) and yield per plot (1639.27 g) in present study which was recorded from treatment combination comprising $ZnSO_4$ @ 0.3% + ZnO nanoparticles @ 150 ppm as compared to other treatments as well as control.

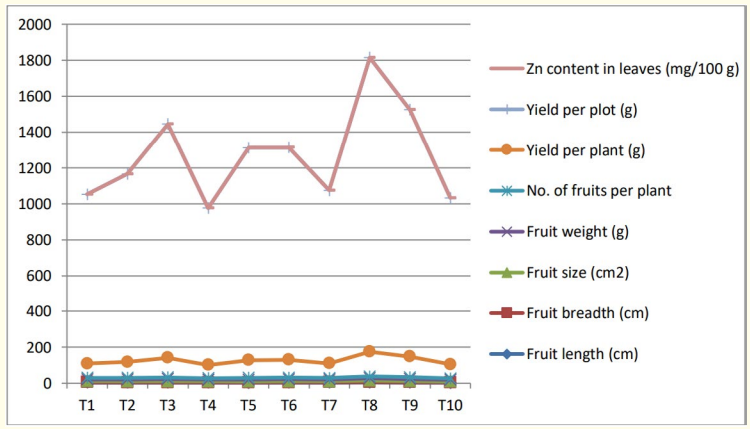

Figure 5: Effect of foliar application of $ZnSO_4$ and ZnO NPs on yield parameters and leaves Zn content.

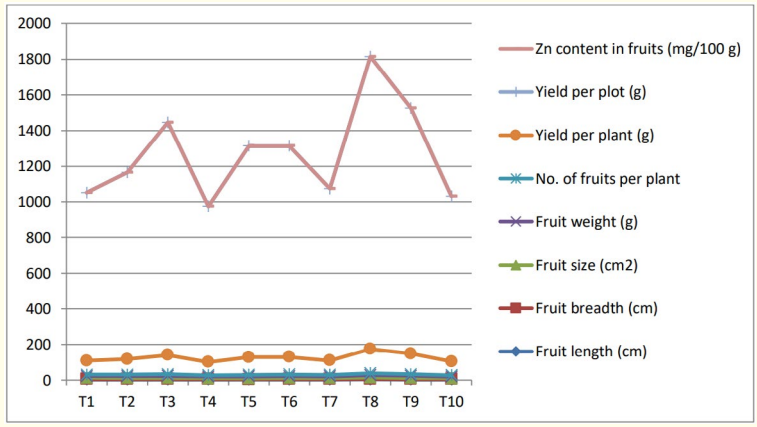

Figure 6: Effect of foliar application of $ZnSO_4$ and ZnO NPs on yield parameters and fruit Zn content.

Discussion

Vegetative attributes: Zinc application as foliar spray increases vegetative growth in many plants as reported by Monjezi et al. 2013. The result in terms of plant height was similar as that of findings Prasad et al. 2012, Lware and Raskar 2014 and Solanki and Laura 2018. Increased plant height could be resulted due to increase in cell elongation (Razzaq et al., 2013). Similar result in terms of plant spread was observed by Kant et al. 2020. Leaf area was found maximum under ZnO application and was closely confined to finding of Elizabath et al. 2017. In case of number of flowers per plant the results are similar to that of Kazemi, 2014 and Daulta et al. 1981. Also, results related to number of runners per plant was close to that of Dawood et al. 2001.

Quality parameters: Mazaherinia et al. 2010 reported that use of any element in nanoscale form lead to change in their catalytic properties resulting into increase in chemical and biological activities thus improving quality of fruits. The Zn spray improves the TSS in strawberry and the obtained results were supported by Bakshi et al. 2013, Razzaq et al. 2013, Monga and Josan 2000, Lakshmi et al. 2018 and Singh et al. 2007. Similar results of titratable acidity were found in the findings of Khorsandi et al. 2019 and Daulta et al. 1981. TSS acid ratio was found maximum under $ZnSO_4$ application as also reported by Dawarpanah et al. 2016 and Daukta et al. 1981. In case of total sugars, results are closely related to that of Singh et al. 2013, El-Khawga, 2007 and Kumar et al. 2020, while Das et al. 2000 and Singh et al. 2015c in terms of reducing sugars and Priyadarshi et al. 2018, Khorsandi et al. 2009 and Singh et al. 2015c in terms of non-reducing sugars suggested the similar results as that of the conducted experiment. The increase in sugar content could be due to the role of Zn in photosynthesis process efficiency at different levels helpful in synthesis of more sugar content inside fruit when applied singly or in combination. Anthocyanin content was found maximum under ZnO nanoparticles application and the results are confined to Hamouda et al. 2016 and El-Said et al. 2019. ZnO nanoparticles application also improves the ascorbic acid content in strawberry and so was observed by Razzaq et al. 2013 and Singh et al. 2007. Shelf life is the major quality contributing character in strawberry and was enhanced by applying ZnO nanoparticles as foliar spray. The findings of Sudha et al. 2018, Kumar et al. 2010, Lakshmi et al. 2018 and Nafady et al. 2019 are more closely related to the results of conducted experiment in strawberry with regard to shelf life of fruits.

Yield parameters: Fruit size in terms of fruit length and fruit breadth was measurd and found maximum under ZnO nanoparticles applications and the observations were closely confined to Sharma et al. 2005, Chaitanya et al. 1997, Dawarpanah et al. 2016, Khayyat et al. 2007 and Swietlik, 2002. Fruit weight is another important factor contributing total yield and results were similar to findings of Bakshi et al. 2013, Sahota and Arora, 1981, Waskela et al. 2013, Kazemi et al. 2013 and Ekka et al. 2018. Production and productivity of plants is greatly influenced by the number of fruits per plant because it is most important factor responsible for higher yields and Zn application proved effective to improve the number of fruits per plant similar to that of Prasad et al. 2012, Hasani et al. 2012 and Dawarpanah et al. 2016. Results with regard to total fruit yield per plant were similar to findings of El Said et al. 2019 and Devi et al. 2019. Total fruit yield per plot is a cost effective parameter in case of polyhouse and is maximized using ZnO nanoparticles as foliar spray. Similar results were found by Cakmak, 2000, Shauky et al. 1990, Ismail, 1994, Verma et al. 2008, Mahmoud et al. 2019 and Kumar et al. 2017.

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