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EFFECT OF FOLIAR SPRAY WITH ZINC AND BORON ON GROWTH, YIELD AND FRUIT QUALITY OF STRAWBERRY *(Fragaria × ananassa Duch cv. Camarosa)* PLANTS GROWN IN SANDY SOIL

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ABSTRACT

This experiment was carried out during the two successive summer seasons of 2009/2010 and 2010/2011 at EL-Kassasien Horticultural Research Station, Ismailia Governorate, Egypt, to study the effect of foliar application with $ZnSO_4$ at rates of 0,150 and 200 mg/ l as and boric acid H_3BO_3 (17 % boron)at rates 0, 100 and 150 mg/l on vegetative growth, photosynthetic pigments, chemical constituents in branches and fruit, yield productivity, fruit quality at harvest time Strawberry plants (Fragaria × ananassa Duch cv. Camarosa) grown under sandy soil conditions with drip irrigation system.

Result showed that *spraying strawberry plant with 150 mg/ l $ZnSO_4$ or 150 mg/l H_3BO_3 significantly increased all studied parameters, such as vegetative plant growth, early and total yield as well as fruit quality in both seasons as compared to control treatment (0 mg/ l), which recorded the lowest values of all studied parameters. In generally, spraying plants with 150 mg/ l $ZnSO_4$+ 150 mg/ l H_3BO_3 gave the best results for increasing plant growth , yield and its components as well as fruit quality, i.e., Vit. C, TSS and total sugar in both seasons as compared other interaction treatments.*

Conclusively*, application of $ZnSO_4$ or H_3BO_3 at 150 mg/l of each alone or mixture improved vegetative growth in the tested plants and increased yield and fruit quality.*

Keywords: Strawberry, zinc, boron, $ZnSO_4$, H_3BO_3, early & total yield, and fruit quality.

INTRODUCTION

Strawberries are ideal model for nutrient interaction studies in perennial crops. Since, they are relatively precocious in producing their first crop within months of planting, and also, they can easily be excavated and divided into vegetative and reproductive components, allowing for detailed evaluation of observed growth or responses (May and Pritts, 1993).

The total area devoted for production in the year of 2010 in Egypt was about 5245 ha. Which produced 238432 ton with average 45.458 ton/ha . The export quantity of strawberry in Egypt was about 66992 tons in the year of 2009 (Faostat, 2010).

Balanced nutrient at proper time is one of the means to reach a commercial fruit production, and improved yield and fruit quality. Foliar program at key stages can have a marked positive effect on fruit yield and quality. Micronutrients have considerable significant effect, as limiting factors, on the productivity of strawberry. While, their deficiencies are more frequent in many soil types such as sandy soil. Micronutrients such as Zn and B are elements with specific and essential physiological functions in plant metabolism and they are required for normal development and growth of plants in minute quantities. Micronutrients are very efficient and minute quantities produced optimum effects, even a light deficiency or excess, on the other hand, are harmful to the plant (Reddy and Reddi,1998).

Zinc is a component of many enzymes such as dehydrogenase , proteinase, peptidases and phosphohydrolass important for (metabolism of carbohydrate, protein and phosphate). (Kabata and Pendias, 1992; Srivastava and Gupta, 1996).

Among nutrient elements, zinc and boron have important role on pollination, fruit set and total yield (Motesharezade *et al.*, 2001). Zinc is known to have an important role either as a metal component of enzymes or as a functional, structural or regulatory factor of a large number of enzymes (Bowler *et al.,* 1994). Zinc induces pollen tube growth through, its role on tryptophan as an auxin precursor biosynthesis (Chaplin and Westwood, 1980). Growth of the receptacle is controlled primarily by auxin, which is synthesized in achene's (Archbold and Dennid, 1984), therefore ZnSO4 is applied to increase number of leaves/ plant , fruit number, size and quality. Zinc sulphate permits normal development of new leaves (Barker and Pilbeam, 2006) and Abdollah et al. (2012). Zinc has also shown to have an important role in photosynthesis and related enzymes, resulting in increasing sugar and decreasing acidity (Abedy, 2001).

Another nutrient which also has an important role in fruit quality is boron. Boron has an effect on cell wall structure and also has a major effect on cell elongation (pollen tube) and root growth (Barker and Pilbeam, 2006). Boron is also involved in transport of sugars and in synthesis of cell wall materials, cell division and differentiation, carbohydrate metabolism , formation and synthesis of protein (Marschner,1995).

Zuhair *et al*. (2010) found that, the highest increases in leaf area , percentage of flower set and average weight of fruit recorded by foliar application of 20 mg/l of boron, but the highest yield per plant and total yield obtained by application 0 mg/L boron on Hapil cultivars plants. While application of 30 mg/l of boron on Kaiser's samling plants gave the best result in percentage of leaf dry weight and total soluble solids in fruits of strawberry. Abdollah *et al*., (2010 and 2012) found that the highest number of fruit clusters, TSS and vitamin C in fruit of strawberry was obtained through application of a combination of $ZnSO_4$200 mg/ l $\times H_3BO_3$ at 300 mg/l .

So, the present work aimed to maximize the productivity of Strawberries through application of some micro-elements under sandy soil conditions.

MATERIALS AND METHODS

This experiment was carried out during the two successive summer seasons of 2009/2010 and 2010/2011 at EL-Kassasien Horticultural Research Station, Ismailia Governorate, Egypt, to study the effect of foliar spray of three concentration of $ZnSO_4$ (0,100 and 150 mg/ l) and three boric acid (17 % boron) concentration (0 , 150 and 200 mg/ l) as on vegetative growth ,yield and fruit quality of strawberry (*Fragaria x ananassa* Duch. cv. Camarosa). The physical and chemical analysis of the soil are presented in Table 1.

Table 1: The physical and chemical properties of the experimental soil

Physical properties			Chemical properties		
	2009	**2010**		**2009**	**2010**
Sand %	94.6	95.5	**Organic matter(%)**	0.08	0.03
Silt %	2.6	3.7	**Available N (%)**	6.2	5.8
Clay %	2.8	1.8	**Available P (ppm)**	5.9	5.3
Texture	sandy	sandy	**Available K (ppm)**	64	51
Available Zn (ppm)	3.25	3.22	**Calcium carbonate(%)**	0.29	0.23

This experiment included 9 treatments, which were the combination between three concentration of zinc sulfate at 0,100 and 150 mg/l and three concentration boric acid (17 % boron) at 0 , 150 and 200 mg/l.

These treatments were arranged in a split plot design with three replications. Zinc sulphate concentrations were assigned at random in the main plots, while, sub plots were devoted to boric acid concentrations.

Frigo transplants of strawberry Camarosa cultivar were obtained from local nurseries**.** The transplants were dipped for 10 minutes at doses of 1g/ L Benlet+1g/L Rizolex.. The transplants were planted on one side of row at 13 and 12^{th} Sept. in 2009 and 2010, respectively. Plants were sprayed three times at age 30, 45 and 60 days after planting, The experimental unit area was 21 m^2 and each unit contained six rows with 5 m length for each and 70 cm width of them, four inner rows were possessed for yield determination, whereas the two outer rows were devoted to plant growth parameter. The distance between seedlings was 15cm. One row was left between two experimental units to avoid the overlapping.

The ammonium nitrate (33.5 % N) at rates of 200 kg N/fed. was added through the drip irrigation system during the growing season. Calcium super phosphate (15.5 % P_2O_5) at the rate of 46.5 kg/fed. and potassium sulphate (48 % K_2O) at the rate of 80 kg /fed. were added once during soil preparation. While during the entire growing season, phosphorus and potassium fertilizers were also added through the drip irrigation system four times per week, at the rate of 75 kg P_2O_5 /fed. in the form of phosphoric aid (80 % P_2O_5) and 120 kg K_2O as soluble potassium sulphate (48 % K_2O). The normal agricultural practices of strawberry production under drip irrigation system of this area were followed according to the recommendations of Agriculture Ministry.

Data recorded

1. Plant growth characters

A random sample of three plants from each experimental units was taken at flower initiation stage 100 days after transplanting in the two growing seasons to measure the following parameters**:** Number of leaves/plant, leaf area/plant, fresh weight/plant (gm). Fresh weight /plant were dried at 70 C^o till constant weight and dry weight/plant was calculated.

2. Photosynthetic pigments.

In this experiment a disc sample from the fourth upper leaf on the main vine was randomly taken from every plot at 100 after transplanting and determine chlorophyll a, b, (a+b) and carotenoids according to the method described by Wettestein (1957).

3. Contents of N, P and K (%) : In branches and fruits

The dry weight of branches and fruits at harvesting time were finely ground and wet digested for N, P and K Contents in branches and fruits: Total nitrogen, phosphorus and potassium percentages in shoots and fruits were determined in dry matter according to the both methods described by A.O.A.C. (1995).

4. Early yield and its components:

An average berry weight(gm), berry yield/plant (gm), No. of berry/ plant, berry yield/fed (ton) were calculated (as fresh weight of harvested fruits from the first four pickings).

5. Total yield and its components:

An average berry weight (gm), berry yield/ plant (gm), No. of berry / plant, berry yield/ fed. (ton) were calculated as fresh weight of all harvested fruit all over growing seasons.

6. Fruit Quality:

Random samples of ten fresh fruits were taken from each plot at the peak of harvesting period to determine :

a-Total soluble sugars (%): It was determined according to the both method described by Forsee (1938).

b - Total soluble solid (T.S.S): It was determined with the help of hand refract meter,

c- The acidity: It was estimated by titrating known volume of juice against 0.1 N NaOH using phenolphthalein as an indicator,

d- Ascorbic acid (vitamin C): It was determined by volumetric method through standard dye solution (Sadasivam and Thymoli 1987).

Statistical analysis:

Recorded data were subjected to the statistical analysis of variance according to Snedecor and Cochran (1980), and means separation were done according to LSD at 5 % level.

RESULTS AND DISCUSSION

Plant growth characters:

Results given in Table 2 show the effect of spraying plants with 0 , 150 and 200 mg/ l as $ZnSO_4$ and boron at rates of 0 , 100 and 150 mg/ l as boric acid (17 % boron) and different combination treatments among them as well as water spray (control) on growth aspects (number of leaves/plant, leaf area, fresh and dry weight/plant). It is obvious that vegetative growth was promoted with all spraying materials as compared to control.

Spraying plants with 150 mg/ l $ZnSO_4$ recorded the uppermost values of number of leaves/plant, leaf area, fresh and dry weight/plant than control treatments. Spraying with zinc had a positive effect on vegetative growth, this

may be due to that Zn deficiency was a significant decrease in ^{14}C fixed in the primary photosynthetic process (Srivastava and Gupta 1996), so spraying plants with Zn increased photosynthetic efficiency, which reflected a simulative effect on vegetative growth of pepper plant, and also zinc is a component of a variety of enzymes such as dehydrogenase, proteinase, peptidase and phosphohydrases (metabolism of carbohydrates, protein and phosphate), and Zn is known to stimulate plant resistance to dry and hot weather (Kabata and Pendias, 1992)

Spraying plants with 150 mg/ l boric acid (17.8%) significantly increased number of leaves/plant, leaf area, fresh and dry weight/plant than other treatments. Boron have considerable significant effect, as limiting factor, on the productivity of strawberry. Boron has an effect on cell wall structure and also has a major effect on cell elongation (pollen tube) and root growth (Barker and Pilbeam, 2006). Also, boron is element with specific and essential physiological functions in plant metabolism and they are required for normal development and growth of plants in minute quantities (Reddy and Reddi, 1998).

The best treatment for increasing number of leaves/plant, leaf area, fresh and dry weight/plant was spraying plants with 150 mg/ l Zn SO4+150 mg/l boric acid as compared to other treatments (Table 3). The obtained results are in accordance with those reported (Kabata and Pendias, 1992; Srivastava and Gupta, 1996 and Motesharezade *et al.*, 2001).

Photosynthetic pigments

Concerning the effect of spraying plants with 150 and 200 mg/ l $ZnSO_4$ and 100 and 150 mg/ l boric acid (17 % B) and different combination treatments among them as well as water spray (control) on chlorophyll a , b, total (a+b) and carotenoids in strawberry leaves in both seasons, it is obvious form Table 4 that all spraying treatments had a significantly increments in yield and its components as compared to control.

The obtained results in Table 4 show that, spraying of strawberry plants with $ZnSO_4$ concentration of 150 mg/l had a significant effect on the concentration of chlorophyll a , b, total (a+b) and carotenoids in both seasons. It is clear from data that foliar spray with concentration of 150 mg/l recorded the highest values of chlorophyll a , b, total (a+b) and carotenoids in both seasons. These results are in harmony with those reported by Ahmad (2002) and Abedy (2001) who found that chlorophyll a, b, and carotenoids in leaf tissue of garlic increased with increasing foliar spray with zinc.

In the same of data in Table 4 showed that the foliar spray with boric acid at rates150 mg/ l marked significant effect of photosynthetic pigments of strawberry leaves as compared to other treatments.

It is obvious from data in Table 5 that the interaction between zinc and boron application had significant effect on chlorophyll a, b and total (a+b) as well as carotenoids in the leaf tissues of Strawberry plants. Foliar spray with 150 mg l $ZnSO_4$ + 150 mg/l boric acid (17 % B) recorded the highest values of chlorophyll a, b, total (a+b) and carotenoids in the leaf tissues in both seasons , whereas, application (0 %) gave the lost values in both seasons.

NPK contents in branches and fruits:

The effect of foliar application with 150 and 200 mg/ l $ZnSO_4$, 100 and 150 mg/ l boric acid (17%B) and different combination treatments among them as well as water spray (control) on mineral contents (NPK) in branches and fruits of strawberry plants. It is obvious from the data that foliar application of Zn and B at all concentrations reflect significant effect on all mineral contents (NPK) in plants as compared to control (water spray).

It is clear from data in Table 6 that the foliar spray with $ZnSO_4$ at rates 150 mg/ l a marked significant effect of NPK contents in their branches and fruits as compared to other treatments. These results agreed with those reported by Abedy (2001).

According to Table 6 that the foliar spray with boric acid at rates 150 mg/l a marked significant effect of NPK contents in their branches and fruits. These results are in harmony with those reported by Mohamed and Helal (1999) found that spraying broad bean plants with B at a rate of 50 gm/fed increased N and P leaves content.

In the present study according to Table 7 shows that the interaction between zinc and boron had a significant effect on NPK contents in their branches and fruits of strawberry plants. foliar spray with 150 mg/ l $ZnSO_4$ + 150 mg/l boric acid recorded the highest values of N, P and K contents in their shoots and fruits except N content in branches in both seasons. These results agreed with those reported by This may be attributed to plants were health (Table 2) and fruits were good (Table 8), which reflected on enhancing minerals uptake by plants to maximum values, and resulting in maximum accumulation of minerals in plants.

Early and total yield.

As for the effect of $ZnSO_4$ rates 0, 150 and 200 mg/ l and as boric acid rates 0, 100 and 150 mg/ l on fruit weight (gm), number of fruit per plant , fruit

yield per plant(gm) and fruit yield per fed (ton) both early yield and total yield are presented in Tables 8 and 10. These results show that there were a significant effect to zinc rates and boron rates on fruit weight (gm), number of fruit per plant , fruit yield per plant(gm) and fruit yield per fed (ton) both early yield and total yield.

Concerning the effect of $ZnSO_4$ the obtained results in Tables 8 and 10 indicate that, foliar spray of $ZnSO_4$ at rates (150 mg/l as) recorded the maximum values of average fruit weight (gm), number of fruit per plant, fruit yield per plant (gm) and fruit yield per fed (ton) both early yield and total yield except average fruit weight (gm) un significant between foliar spray of $ZnSO_4$ at rates (150 and 200 mg/l) in both seasons. While, Foliar spray of $ZnSO_4$ at rate (0 mg/l) gave the lost values in both seasons.

Zinc ($ZnSO_4$) has an important role either as a metal component of enzymes or as a functional, structural or regulatory cofactor of a large number of enzymes (Bowler *et al.*, 1994). Zinc sulphate induces pollen tube growth through its role on tryptophan biosynthesis, as an auxin precursor (Chaplin and Westwood, 1980). Growth of the receptacle is controlled primarily by auxin, which is synthesized in the achene's, so an application of $ZnSO_4$, a prerequisite of auxin, is potentially useful in increasing fruit size as well as its quality. Therefore ZnSO4 is applied to increase fruit number, size and quality. These results are in harmony with those reported by Barker and Pilbeam (2006).

Respecting the effect of B, the obtained results in Tables 8 and 10 indicate that, foliar spray of boric acid (17 % B) at rate 150 mg/l recorded the maximum values of average fruit weight (gm), number of fruit yield per plant (gm), fruit yield per fed (ton) both early yield and total yield except average fruit weight (gm) un significant between foliar spray of boric acid at rates 100 and 150 mg/l in both seasons as well as number of fruit yield per plant (gm) in first season only. While, foliar Spray of boric acid at rate (0 mg/l) gave the lowest values in both seasons. These results are in harmony with those reported by Jana *et al*.(1987), Padma *et al*. (1989)

With regard to the interaction, data in Tables (9 and 11) show that the interactions between $ZnSO_4$ and boric acid as foliar spray had significant effect on average fruit weight (gm), number of fruit per plant, fruit yield per fed (ton) both early and total yield of Strawberry plants. foliar spray with 150 mg/l $ZnSO_4$ + 150 mg/l boric acid recorded the highest values of average fruit weight (gm), fruit yield per plant (gm), fruit yield per fed (ton) in both early and total yield except, number of fruit per plant early yield un significant in both seasons. As well as number of fruit per plant total yield in first season.

Among nutrients, zinc and boron play an important role in pollination, fruit set, and total yield (Motesharezade *et al.*, 2001). Boron (H_3BO_3) is an essential element required for optimal growth and development in higher plants (Marschner, 1995). Increased fruit yields in pear and sour cherry have been reported using B fertilization (Wojcik and Wojcik, 2003).

Fruit quality:

Data in Table 12 represent the effect of $ZnSO_4$ rates 0, 150 and 200 mg/l and boric acid rates 0, 100 and 150 mg/l on fruit quality (vit. C, TSS, reducing sugar, total sugar and total acid in fruit) of strawberry, it is evident that all treatments had a positive effect on Vit. C, TSS, reducing sugar, total sugar and total acid in fruit under study in two growing seasons. Concerning the effect of zinc rates, there were a significant difference between the effect of zinc rates, and plants sprayed with 150 mg/l $ZnSO_4$ gave the highest values of Vit. C, TSS, reducing sugar, total sugar and total acid in fruit as compared to other treatments. ZnSO4 claimed that a foliar spray application of $ZnSO_4$ on March and April increased size, TSS and juice of oranges. Zinc has also shown to have an important role in photosynthesis and related enzymes, resulting in increasing sugar and decreasing acidity (Abedy, 2001). These results agree with reported with Rath *et al.,* (1980) who reported that foliar application of zinc sulfate (0.8 %) increased vitamin C.

The effect of boric acid rates at 0, 100 and 150 mg/l on fruit quality (Vit. C, TSS, reducing sugar, total sugar and total acid in fruit) of strawberry are illustrated in the same Table. Results revealed that spraying plants with 150 mg/l boric acid significantly improved on fruit quality.

These results could be attributed to the effect of Zn and boron on the increase of nutrient absorption and photosynthesis process that lead to more accumulation of metabolism in reproductive organs, which in turn improve fruits quality of strawberry (Hagreaves *et al*., 2009). Adding boron as foliar spraying plays a key role in improve size of fruits and stimulates fruits color. It is necessary for the translocation sugar and formation of carbohydrates consequence increase fruits quality

Data in Table 13 showed that significant differences were observed among treatments as far as vitamin C, is concerned and highest vitamin C, TSS and total sugar was observed in concentrations of $ZnSO_4$ at 150 mg/ l + boric acid at 150 mg/l .Whereas , the interaction between Zn and B have non significantly on reducing sugar in both seasons.

Conclusively, result showed that spraying strawberry plant with 150 mg/l $ZnSO_4$ or 150 mg/l H_3BO_3 significantly increased all studied parameters, such as vegetative plant growth, early and total yield, as well as, fruit quality in both seasons as compared to control treatment (0 mg/ l), which recorded the lowest values of all studied parameters. In generally, spraying plants with 150 mg/ l $ZnSO_4$+150 mg/l H_3BO_3 gave the best results for increasing plant growth, yield and its components, as well as, fruit quality, *i.e*., Vit. C, TSS and total sugar in both seasons as compared other interaction treatments.

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تأثير الرش الو رقى بالزنك والبورن على النمو والمحصول وجودة ثمار الفراولة صنف كماروزا النامية فى ارض رملية

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أجرى البحث خلال عامي ٢٠٠٩ ، ٢٠١٠ بمحطة بحوث البساتين بالقصاصين ، محافظة الإسماعيلية، مصر، لدراسة تأثير الرش بالزنك في صورة سلفات زنك بمعدلات ٠، ١٥٠، ٢٠٠ مجم/لتر والبورن في صورة حامض البوريك بمعدلات ٠، ١٠٠ ، ١٥٠ مجم/لتر على النمو الخضري وصبغات البناء الضوئي والمحتوى الكيماوي بالأفرع والثمار والإنتاجية لمحصول الفراولة النامي تحت ظروف الاراضى الرملية مع نظام الري بالتنقيط.

أوضحت النتائج أن رش النباتات بـ ١٥٠ مجم/لتر من الزنك فى صورة سلفات الزنك ، أو الرش بمعدل ١٥٠ مجم/لتر من البورن فى صورة حمض البوريك (١٧ % بورون) قد أدت إلى زيادة معنوية في كل الصفات المدروسة المتمثلة فى صفات النمو الخضرى والمحصول المبكر والكلى كذلك جودة الثمار مقارنة بمعاملة الكنترول (الرش بالماء). وعموما رش النباتات بـ ١٥٠ مجم/لتر من سلفات الزنك مخلوطا مع ١٥٠ مجم/لتر من حمض البوريك أعطى كانت أفضل المعاملات لزيادة لصفات المحصول ومكوناته وكذلك جوده الثمار مثل فيتامين ج ، تركيز المواد الصلبة الذائبة ، والسكريات الكلية في الموسمين مقارنة بباقي معاملات التفاعل.

التوصية : أدى رش الزنك فى صورة سلفات الزنك بتركيز ١٥٠ مليجرام / لتر والبورون فى صورة حمض البوريك بتركيز ١٥٠ مليجرام/ لتر الى نباتات الفراولة منفردا أو فى مخلوط الى تحسن صفات النمو الخضرى والمحصول وجودة الثمار عند الحصاد.