Effect of Iron (Fe - EDDHA), Calcium Chloride and Zinc Sulphate on Vegetative Growth, Yield and Fruit Quality of Strawberry (Fragaria × Ananassa Duch. Cv. Pajaro)

Mohsen Kazemi*

ABSTRACT

In this study, effect of foliar application of Iron, calcium chloride and zinc on vegetative and reproductive growth, yield and some quality characteristics of strawberry "Pajaro" fruit were investigated. The treatments included zinc sulfate at three levels (50, 100 and 150 mg l^{-1}), Iron (Fe - EDDHA) at three levels (250, 500 and 1000 mg l^{-1}), calcium chloride at two levels (5 and 10 mM) and distilled water as a control. Iron (500 mg l^{-1}) and zinc sulfate (150 mg l^{-1}) increased number of runners, plant dry weigh and length of roots of plant. Sprays of zinc sulfate at 150 mg l^{-1}, Iron at 1000 mg l^{-1} and calcium chloride at 10 mM increased significantly length of flowering period, number of flowers, weight of primary and secondary fruit and number of achenes of primary and secondary fruit . The highest percentage of total soluble solids, titratable acidity and ascorbic acid were attained in fruits treated with zinc sulfate at 150 mg l^{-1} and calcium chloride at 10 mM and the lowest was achieved in the control. In general, spraying zinc sulfate at 150 mg and calcium at 10 mM is recommended for increasing the strawberry yield.

Keywords: Foliar Application, Strawberry, Iron, Zinc Sulfate, Calcium.

Abbreviations: TSS, total soluble solids; TA, titratable acidity; Zn, Zinc Sulfate; Ca, Calcium; Fe, Iron

INTRODUCTION

Strawberry (Fragaria ×ananassa Duch. Cv. Pajaro) is one of the most delicious fruits of the world. Strawberry is a very rich source of bioactive compounds including vitamin C, E, b-carotene and phenolic compounds (phenol acids, flavan-3-ols, flavonols, and anthocyanins) (Oszmianski and Wojdylo, 2009). Parameters like total acids (TA), total soluble solids (TSS) and their ratio (TSS/TA) are very important in determining strawberry fruit quality (Sturm *et al.,*2003; Laugale and Bite, 2006; Rutkowski *et al.,*2006; Testoni *et al.,*2006).

The foliar nutrition of micro-nutrients have very important role in improving fruit set, productivity and quality of fruits. Foliar nutrition at proper time improved quality and quantity strawberry (Abdollahi *et al.,* 2010).

Iron has an important role as a micronutrient element in crop production. Iron chlorosis is a common nutritional disorder, mainly associated with high pH or calcareous soils also it is a limiting factor for fruit production in many areas of the world (Abadia *et al.* 2011; Borowski and Michalek, 2011; Fernandez *et al.,* 2006).

Since Zn is a component of many enzymes and proteins, it is an essential metal for normal plant growth

*Department of Horticultural Science, Faculty of Agricultural Science and Natural Resources, Science and Research Branch, Islamic Azad University, Tehran, Iran
✉kazemimohsen85@gmail.com
Received on 15/8/2013 and Accepted for Publication on 24/7/2014.

and development (Nasiri *et al.*2010). It is also, required for the synthesis of tryptophan, a precursor of IAA which acts as a growth promoting substance. It was reported that flower yield, essential oil percentage and essential oil yield of chamomile (*Matricaria chamomilla*) increased by foliar application of Fe and Zn compared with control (Nasiri *et al.*2010).

It is well known that calcium plays an important role in maintaining quality of fruits and vegetables. Calcium treatment helps to retain fruit firmness, increase vitamin C content, decreased storage breakdown rotting and browning in apple. The beneficial effects of Ca on maintaining fruit quality are well documented by many researchers (Na Phun *et al.,*1997; Kazemi *et al.,* 2011). Pre and postharvest application of Ca is effective on, fruit quality, delayed senescence, reduced postharvest decay and controlling the physiological disorder in many fruits and vegetables (Na Phun *et al.,*1997). Calcium application usually leads to an increase in apoplastic Ca concentration that may affect the structure and functions of cell walls, membranes and certain aspects of cell metabolism, also it delays leaf senescence and fruit ripening (Poovaiah and Leopold, 1973; Poovaiah, 1979; Dreher and Poovaiah, 1982; Paliyath *et al.,*1984; Glenn *et al.,*1988). The aim of this research was to evaluate the effects of the foliar application of Iron, calcium and zinc on vegetative growth and reproductive characteristics of strawberry cv. Pajaro.

MATERIALS AND METHODS

Plant Growth Conditions and Treatments

The experiment was conducted during 2011 and 2012 on strawberry plants at the experimental greenhouse, Ilam (Elevation 1339 m, Latitude 33° 38′ 18.71″ N, Longitude 46° 25′ 21.53″ E), Iran. Strawberry plants (*Fragaria* × *ananassa* Duch. cv. Pajaro) were grown under natural day light conditions. The temperature conditions were 24 ± 5°C and 15 ± 4°C, during days and nights respectively; with relative humidity of 70%. Induced and rooted daughter plants of Pajaro cultivar were potted in 3 l plastic pots filled with 2:1 sandy loam soil and compost, after 2 weeks of establishment, in the beginning of November, the treatments, included: zinc sulfate at three levels (50, 100 and 150 mg l^{-1}), Iron at three levels (250, 500 and 1000mg^{-1}) Iron (Fe - EDDHA) , calcium as $CaCl_2$ at two levels (5 and 10 mM) and distilled water as control. During the experimental period the plants were fertilized with Hoagland solution. Spray materials were used as follows: after plant establishment, at the beginning of flowering (November), and 15 days after the second time.

Measurements

At the end of the experiment, plants were carefully taken out of their pots, roots were washed with distilled water, and the whole plants were oven dried for 72 hours at 70° c .

We recorded: dry weight, number of runners, leaf area, number of flowers, length of the roots, length of flowering period, weight of primary and secondary fruits and number of their achenes, TSS, TA and vitamin C of 'Pajaro' strawberry. Dry weights were expressed as gram. Length of roots was measured using a ruler and was expressed in cms. Number of runners and flowers were counted throughout the experimental period. Leaf area was measured using a ΔT^- leaf area meter and expressed as cm^2. Length of flowering period was recorded and expressed as days between the first appearing of flowers till end of experiment. Primary and secondary fruits were weighed in order to measure their weight as gram. Number of their achenes were counted afterwards.

Ascorbic acid content

Ascorbic Acid content of strawberry was determined by the 2,6-dichlorophenolindophenol method (Tefera *et al.,*2007). An aliquot of 10 mL strawberry fruit juice was extracted and diluted to 50 mL with 3% metaphosphoric acid in a 50 mL volumetric flask. The aliquot was filtered and titrated with the standard dye to a pink endpoint (persisting for 15 sec).

Total soluble solids and titratable acidity

To characterize the maturity and quality of the fruit total soluble solids (TSS), titratable acidity (TA) were determined. A sample of 15 Strawberry fruits was randomly harvested for quality measurements from each replicate of each treatment. TSS, expressed as Brix, was measured with a portable refractometer (Moraes *et al.*,2012). Titratable acid (TA) was determined by diluting each 5 ml aliquot of strawberry juice to 100 ml with distilled water, then titrating to pH 8.2 by using 0.1 N NaOH. Acidity was expressed as mg citric acid/100 ml juice.

Statistical Analysis

The experiment was conducted as a factorial experiment in a completely randomized design with 4 replications, each consisting of 3 pots with each pot containing one plant. Data were analyzed by SAS 9.2 software and comparing averages was done by LSD test and a probability value of %5.

RESULTS AND DISCUSSION

Effect of Zinc Sulfate on Vegetative Growth, Yield and Fruit Quality of Strawberry

Application of zinc sulfate at 150 mg l^{-1} significantly influenced plant dry weight ($p \leq 0.05$) (Table 1). The highest dry weight, leaf area and length of roots were obtained at 150 mg l^{-1} zinc sulfate. Table 2 show zinc sulfate increased umber of flowers, length of flowering period, weight of primary and secondary fruits and number of their achenes (Table 1-2). Application of zinc sulfate at 150 mg l^{-1} significantly influenced T.S.S, TA and ascorbic acid ($p \leq 0.05$) (Table 3). The highest T.S.S, TA and ascorbic acid were obtained at 150 mg l^{-1} zinc sulfate. Norvell and Welch (1993) reported that adequate supply of Zn is important in controlling root uptake, shoot accumulation of Na and vegetative growth. Positive effect of $ZnSO_4$ on fruit number is well documented (Chaplin and Westwood, 1980). Zinc is an essential element for plant that act as a metal component of various enzymes,a functional structural, regulatory cofactor protein synthesis, photosynthesis, synthesis of auxin, cell division, maintenance of membrane structure, function, and sexual fertilization (Marschner, 1995). Nazarpur (2005) reported that $ZnSO_4$ increased strawberry leaf number cultivar Camarosa and Armore, respectively. Sing *et al.*2002, found that the application of Zn as foliar spray not only increased the number of leaves but also reduced the leaf drop and hastened the flowering in papaya plant. Growth of the receptacle is controlled primarily by auxin, which is synthesized in achenes (Archbold and Dennid, 1984), Therefore, $ZnSO_4$ is applied to increase fruit number, size and quality. Application of zinc sulfate can increase TSS in fruit of guava (Dobroluybsikii *et al.*,1982). Since zinc has an important role in photosynthesis and enzymes responsible for plant metabolism, the increased TSS could be attributed to $ZnSO_4$. Rath *et al.*,(1980) reported, foliar application of zinc sulfate (0.8 %) increased vitamin C. Dixi and Gamdagin (1978) claimed that a foliar spray application of $ZnSO_4$ on March and April increased size, TSS and juice of oranges.

Effect of Iron and Calcium chloride on Vegetative Growth, Yield and Fruit Quality of Strawberry

Iron resulted significant change in dry weight, number of runners and length of roots (Table 1). Iron at 500 mg l^{-1} significantly increased leaf area, plant dry weight, number of runners and Length of roots ($p \leq 0.05$). Table 1 and 2 show Iron at 1000 mg l^{-1} and Ca at 10 mM increased number of flowers, length of flowering period, weight of primary and secondary fruits and number of their achenes.

Application of Iron at 1000 mg l^{-1} and Ca at 10 mM significantly influenced T.S.S, TA and ascorbic acid ($p \leq 0.05$) (Table 3).

Iron deficiency inhibited leaf growth, cell number, size and cell division, as well as chlorophyll, protein, starch and sugar content (Marschner, 1995). Iron (Fe) is a cofactor for approximately 140 enzymes that catalyze unique biochemical reactions (Brittenham, 1994). Hence, Iron fills many essential roles in plant growth and development; including chlorophyll synthesis, thylakoid synthesis and chloroplast development. Iron is required at several steps in the biosynthetic pathways. Foliar spray application of 50g Iron EDDHA per tree, by adding two rows, leads to a significant increase in leaf chlorophyll content of peach (Sanz *et al.*,2002). The beneficial effect of calcium in increasing fruit set might be due to the higher availability of photosynthesis and these chemicals are also associated with hormone metabolism which promotes synthesis of auxin, essential for fruit set and growth. Iron improves photosynthesis, yield and assimilates transportation to sinks and finally increased seed yield (Alvarez - Fernandez *et al.*,2006). Zaiter *et al.*,(1993) showed that foliar feeding of Iron chelate on strawberry increased the Performance by increasing the number of fruits. Calcium is an important nutrient that plays a key role in the structure of cell walls, cell membranes, fruit growth, and development, as well as general fruit quality (Kadir, 2004). The effect of Iron on the amount of soluble solids may be due to its availability in foliar feeding of plants and the role of Iron in photosynthesis; that cause higher photosynthetic rate. This finding is in accordance to report of Yogeesha (2005) on the grapes. Result shown that calcium (10 mM) increased TSS, TA and vitamin C (Table 3). This indicates that calcium may be more critical for the TSS contents of strawberry fruit. These results could be ascribed to increasing the soluble matter in the juice by the penetrated calcium chlorides. Higher ascorbic acid content in such fruit may primarily be due to the reason that Ca has influence on vitamin C content (Kadir, 2004). In general, Ca pre-harvest treatment, fruit of ‘Pajaro’ strawberry have higher TSS and ascorbic acid content, lower acidity than control .In conclusion the application of $ZnSO_4$ at 150 mg l^{-1} is recommended to improve vegetative growth, yield and fruit quality of strawberry in strawberry, cultivar Pajaro.

Table 1. Effect of application of zinc sulphate, Iron (Fe - EDDHA) and calcium chloride on dry weight, number of runners, leaf area, number of flowers and length of the roots of" Pajaro" strawberry .

Treatment		Plant dry weight (g)	Number of runners	Leaf area (cm^2)	Length of roots (cm)	Number of flowers
Control	0	8.6 i	2.11 i	18.14 g	11.36 h	7.2 c
zinc sulfate (mg l^{-1})	50	10.8 h	2.54g	29f	11.36h	6.93c
	100	12.5f	3.45b	33.65d	29.7c	7.37c
	150	17.8a	5.1a	46.3a	33.1a	15.27a
Iron (mg/l)	250	12.8e	2.89 g	23.5g	17.8g	10.29 b
	500	13d	3f	31e	20.3d	10.37b
	1000	16.4b	3.4c	45b	30b	15.17 a
Calcium (mM)	5	11.43g	3.16 e	23.5g	18f	7.36 c
	10	14.8c	3.3 d	44.12c	18.5e	15.28a

Means within a column followed by the same letter are not significantly different at p >.05 using LSD test.

Table 2. Effect of application of zinc sulphate, Iron (Fe - EDDHA) and calcium chloride on length of flowering period, weight of primary and secondary" pajaro" strawberry fruits and number of their achenes

Treatment		Length of flowering period (days)	Weight of primary fruit (g)	Weight of secondary fruit (g)	Number of achenes of primary fruit	Number of achenes of secondary fruit
Control	0	15.64d	9.37d	7 f	134.46h	108 g
zinc sulfate	50	16.11d	12.43c	8.57e	156.7f	115.53f
(mg l^{-1})	100	21..31c	12 c	9 e	176.44d	160.01d
	150	34.73a	18.3 a	16.47 a	220.93b	210.4 ab
Iron (mg/l)	250	13.43e	11.77c	10.28 d	138.34g	101.6h
	500	20.56c	12 c	8.93e	188.34c	163.63c
	1000	33.18a	18.26 a	15.71 ab	220.86b	208.6b
Calcium	5	20.5 c	14.57b	11.44c	160.17e	133.16e
(mM)	10	27.48b	17.9 a	15.58b	226.16 a	211.13a

Means within a column followed by the same letter are not significantly different at p >.05 using LSD test.

Table 3. Effect of application of zinc sulphate, Iron (Fe - EDDHA) and calcium chloride on TSS, TA and vitamin C of 'Pajaro' strawberry

Treatment		TSS	TA g(citric acid)/(g/L)	Vitamin C (mg/100 g)
Control	0	5.5d	4.31f	23.15h
zinc sulfate (mg l^{-1})	50	5.86cd	5 e	38.58g
	100	7.44cb	7.61c	52.34d
	150	9.95 a	9.05b	67.41a
Iron (mg/l)	250	5.51d	6.75d	46.54e
	500	7 cd	6.81d	47.26e
	1000	9.32ab	8.85b	59.55c
Calcium (mM)	5	5.93cd	6.57d	41.33f
	10	9.9 a	9.7 a	65.34b

Means within a column followed by the same letter are not significantly different at p >.05 using LSD test.

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تأثير الحديد (الحديد- EDDHA) ،كلوريد الكالسيوم وكبريتات الزنك على النمو الخضري والمحصول وجودة الثمار من الفراولة (Fragaria × Ananassa Duch. Cv. Pajaro)

*محسن كاظمي**

ملخص

تم في هذه الدراسة، التحقق من تأثير إضافة الحديد، وكلوريد الكالسيوم وكبريتات الزنك بطريقة الاضافة على الأوراق على النمو الخضري اللاجنسي والتكاثري الجنسي وتأثيرها على المحصول وبعض خصائص نوعية فاكهة الفراولة "Pajaro". وقد شملت المعاملات كبريتات الزنك على ثلاثة مستويات (50، 100 و 150 ملغ /لتر)، الحديد (الحديد – EDDHA) على ثلاثة مستويات (250 و 500 و 1000 ملغ /لتر) وكلوريد الكالسيوم على مستويين (5 و 10 ملي مولار) والماء المقطر كمعاملة الشاهد (Control) . ادى اضافة الحديد (500 ملغ/ لتر) وكبريتات الزنك (150 ملغ /لتر) الى زيادة عدد السيقان،و وزن النبات الجاف وطول جذور النبات. عملية رش كبريتات الزنك بمعدل 150 ملغ /لتر، الحديد بمعدل 1000 ملغ /لتر وكلوريد الكالسيوم بمعدل 10 ملي مولار زادت بشكل ملحوظ من طول فترة الإزهار، عدد الأزهار، وزن الفاكهة الابتدائي والثانوي وعدد من الاشينات من الفاكهة الابتدائية والثانوية . وتم تحقيق أعلى نسبة من إجمالي المواد الصلبة الذائبة والحموضة وحمض الاسكوربيك في الفواكه التي تعامل بكبريتات الزنك بمعدل 150 ملغ /لتر وكلوريد الكالسيوم عند 10 ملي مولار وحقق أدنى مستوى في معاملة الشاهد (control). بشكل عام، ويُنصح رش كبريتات الزنك بمعدل 150 ملغ وكلوريد الكالسيوم بمعدل 10 ملي مولار لزيادة الناتج.

الكلمات الدالة: التسميد الورقي، فراولة، حديد، كبريتات الزنك، كلوريد الكالسيوم.

*كلية العلوم الزراعية والموارد الطبيعية، فرع البحوث والعلوم، جامعة ازاد، ايران.
✉kazemimohsen85@gmail.com

تاريخ استلام البحث 2013/8/15 وتاريخ قبوله 2014/7/24.