Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 3 (4) March 2014: 183- 187

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.533
Universal Impact Factor 0.9804

ORIGINAL ARTICLE

Pre-harvest foliar application of paclobutrazol, boric acid and gibberellic acid influences vegetative growth, reproductive characteristics and quality of strawberry (Fragaria × ananassa Duch. cv. Camarosa)

Mohsen Kazemi
Young Researchers and Elite Club, Karaj Branch, Islamic Azad University, Karaj, Iran
E-mail: kazemimohsen85@gmail.com

ABSTRACT
Foliar fertilization plays an important role in increasing the micro or macro element of fruits. The influence of paclobutrazol, boric acid and gibberellic acid on growth and quality of strawberry was investigated during the years 2011 and 2012. The experiment was conducted as a factorial experiment in a completely randomized design with 4 replications. Paclobutrazol (25, 50 and 100 mg l^{-1}), boric acid (50, 150, 200 mg l^{-1}) and gibberellic acid (50 and 100 mg l^{-1}) solutions were applied as foliar sprays and data were recorded for 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 the fruit. Results indicated that vegetative growth was reduced with paclobutrazol. The application of paclobutrazol increased number of flowers, weight of primary and secondary fruit, percentage of total soluble solids and and ascorbic acid, while reduced titratable acidity. Results indicated that gibberellic acid increased number of runners but had no effect on reproductive growth. Boron significantly enhanced the vegetative growth, number of flowers, fruit weight, vitamin C, and total soluble solid content of the fruits.
Keywords: *strawberry, foliar fertilization, vegetative growth, reproductive characteristics.*
Abbreviations: TSS, total soluble solids; TA, titratable acidity; B, boric acid; GA3, gibberellic acid.

Received 02 /01/2014 Accepted 02/03/2014

INTRODUCTION

Strawberry is one of the most delicious fruit in the world, which is a rich source of vitamin C, iron, potassium and fiber. Foliar spray of micronutrients is the common practice to overcome the micronutrients deficiencies in order to improve the fruit quality. Foliar application of fertilizers is a particular useful technique designed to meet plants specific needs for one or more micro or macro nutrients especially trace minerals. This enables us to correct deficiencies, strengthen weak or damaged crops, speed up growth and grow better and heal their plants [1]. Foliar application is based on the principle that the nutrients are quickly absorbed by leaves and transported to different parts of the plant to fulfill the functional requirement of nutrition. Foliar application of the nutrients is obviously an ideal way of evading the problems of nutrient availability [2]. Foliar nutrition may play an important role in strawberry. Previous studies indicatived a positive role of foliar nutrition in improved quality and quantity strawberry [3]. Paclobutrazol is a triazol that reduces vegetative growth in most plant species [4]. It is well known that paclobutrazol reduces the development of runners and inversely promotes the formation of lateral crowns [3]. paclobutrazol has biochemical effects on plants, such as detoxification of active oxygen, increasing levels of proline, antioxidants and chlorophyll contents [5].Gibberellic acid has bioregulatory proprieties, it can induce and force strawberry. Reaction of strawberry to gibberellic acid application is similar to environmental factors such as long days and low temperature [6].
Boron is most effective when applied as a foliar spray. Further, boron (B) is an essential nutrient element and its deficiency reduces pollen germination and growth of pollen tubes, which consequently results in the development of malformed fruits, which lowers crop yield and deteriorates fruit quality [7]. The

present study (2011-12) was conducted to assess the influence of foliar application of paclobutrazol, boric acid and gibberellic acid in improving the quality of strawberry.

MATERIALS AND METHODS

Plant Growth Conditions and Treatments

The experiment was conducted during 2011 and 2012 on strawberry plants at the experimental greenhouse, Ilam, Iran (Elevation 1339 m, Latitude East 33.638, Longitude North 46.431). Strawberry plants (*Fragaria* × *ananassa* Duch. cv. Camarosa) were grown under natural light conditions. The temperature conditions were 24 ± 5°C and 15 ± 4°C, during days and nights respectively; with relative humidity of 70%. Daughter plants of Pajaro were potted in 3 plastic pots filled with 2:1 sandy loam soil and compost. After 2 weeks of establishment, in the beginning of November, the treatments, included: paclobutrazol (25, 50 and 100 mg l^{-1}), boric acid (50, 150, 200 mg l^{-1}), gibberellic acid (50 and 100 mg l^{-1})and distilled water as control. During the experimental period, plants were fertilized with Hogland solution. Spray materials were used as follows: after plant establishment, at the beginning of flowering, and 15 days after the second time.

Measurements

In the end of 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 then. The following quality parameters of harvested fruits were determined: 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 'Camarosa' strawberry. Dry weights were expressed as gram. Length of roots was measure by using a ruler and was expressed as cm. 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 calculated and expressed as days between the first appearing flowers till end of experiment. Primary and secondary fruits were weighed in order to measure their weight as gram. Number of their achenes was counted afterwards.

Ascorbic acid content (Vitamin C)

Ascorbic Acid (AA) content of strawberry was determined by the 2, 6-dichlorophenolindophenol method [8]. An aliquot of 10 mL strawberry fruit juice extract was 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 was randomly harvested selected for quality measurements from each replicate of each treatment. TSS, expressed as Brix, was measured with a portable refract meter [9]. 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 SPSS 16 software and comparing averages was done by Duncan's test and a probability value of %5.

RESULTS AND DISCUSSION

Effect of Paclobutrazol on Vegetative Growth, Reproductive Growth, Fruit quality

The foliar application of paclobutrazol significantly decreased dry weight, number of runners, leaf area and length of the roots ($p \leq 0.05$) (Table 1). The dry weight of strawberry reduced significantly from 13 g in the control to 8 g with foliar application of paclobutrazol. The paclobutrazol (100 mg l^{-1}) application also resulted in a significant reduce in number of runners, leaf area and length of the roots of strawberry fruit as compared to control ($p \leq 0.05$) (Table 1). Highest and lowest leaf area was observed in concentration of 200, 100 and 100 mg l^{-1}, boric acid, gibberellic acid and paclobutrazol, respectively (Table 1). This was in agreement with Nishizawa [10] who reported a significant decrease in leaf area of strawberry after paclobutrazol treatment. Table 1 show that length of the roots was decreased as a result of paclobutrazol. This was according to Atkinson [11] who reported reduced fresh shoot/root in strawberry plants. Vegetative growth components were reduced after annually application of paclobutrazol in apples [12]. Studies showed that paclobutrazol could well be used to control the growth of *Dianthus caryophyllus* cv. Mondriaan and improve its commercial quality. Paclobutrazol is a triazol that promotes reproductive growth by reducing vegetative growth. The mean length of flowering period, weight of primary and secondary fruits and number of their achenes increased significantly with foliar

application of paclobutrazol ($p \leq 0.05$) (Table 2). The highest length of flowering period, weight of primary and secondary fruits and number of their achenes was obtained from paclobutrazol at 100 mg l^{-1}, while control produced the low yield (Table 2). This was in agreement with Kirschbaurn [13] reported that application of paclobutrazol increased total yield. This confirms the results obtained by Ramina *et al.,* [14] and Braun and Garth [15]. Contrary to our findings, Maheswari *et al.,* [16] reported that paclobutrazol reduced fruit size. In agreement to our findings studies of Yadava and Singh [17] showed that paclobutrazol is needed to use annually to increase the yield of mango fruit. Also, McArthur *et al.,* [18]; and Shakeri *et al.,* [19]; reported that paclobutrazol increased fruit number and achenes per fruit of strawberry. In the present study paclobutrazol significantly increased TSS and vitamin C in fruit compared to untreated plants (Table 3). Among different concentrations of paclobutrazol, 100 mg L^{-1} was better than the others concentrations. Foliar application the treatments paclobutrazol induced higher TA compared to untreated plants (Table 3). Organoleptic quality of strawberries depends strongly on the TSS/TA ratio. Teferi Belayneh [20] observed that the TSS/TA ratio in mango fruits increased as a result of paclobutrazol application.

Effect of Gibberellic acid on Vegetative Growth, Reproductive Growth, Fruit quality

The mean dry weight and length of the roots increased significantly with foliar application of 100 mg l^{-1} gibberellic acid ($p \leq 0.05$) (Table 1). This phytohormone as a bioregulator has a great influence on over all plant growth and development. Many previous studies reported promoting impact of GA3 on growth parameters due to its effect on cell division and enlargement [21-23]. GA3 increased leaf area and number of runners. Maximum number of runners obtained when plants were treated with GA3 (100 mg l^{-1}), this can be due to higher rate of cell division and stimulation of vegetative growth (Table 1) [24]. This was in accordance with Paroussi *et al.,* [25] who have shown that gibberellic acid increased petiole length and leaf area of strawberry cultivar 'C skip'. The number of flowers, length of flowering period, weight of primary and secondary fruits and number of their achenes were not significantly affected by the foliar application of GA3 ($p \leq 0.05$) (Table 2). In strawberry GA3 reduces flowering and as a result vegetative growth including production of runners increases [24]. The TSS content of strawberry fruit was not significantly affected by the application of GA3, also GA3 concentration (from 5to 10 mg l^{-1}) decreased titratable acidity (Table 3). These results agreed with Liu *et al.,* [26] and Gholami *et al.,* [27] that reported the application of GA3 reduced acidity percentage and TSS.

Effect of Boric acid on Vegetative Growth, Reproductive Growth, Fruit quality

B significantly influenced vegetative growth, reproductive growth, and quality parameters of 'Camarosa' strawberry at harvest ($p \leq 0.05$) (Table 1,2,3). These treatments have slightly affected dry weight, but significantly influenced number of runners, leaf area and length of the roots (Table 2). Maximum number of runners, leaf area and length of the roots obtained when plants were treated with 100 mg l^{-1} B. Meena [28] reported the increasing in vegetative growth of tomato could be attributed to physiological role of boron and its involvement in the metabolism of protein, synthesis of pectin, resynthesis of adenosine triphosphate (ATP) , translocation of sugar at development of the flowering and fruiting stages. Treatment containing Boron could improve growth by increasing IAA content and IAA/cytokinin ratio in leaves by blocking IAA oxidase inhibitors and forming complexes with them [29]. It has been established that adventitious roots develop on stem cuttings of bean only when Boron is supplied [30]. The mean length of flowering period, weight of primary and secondary fruits and number of their achenes increased significantly with foliar application of B (Table 2). The highest length of flowering period, weight of primary and secondary fruits and number of their achenes was obtained in treatment supplemented with B at 200 mg l^{-1} in compared to control (Table 2).

Table 1) Effect of pre-harvest application of paclobutrazol, boric acid and gibberellic acid on dry weight, number of runners, leaf area, number of flowers and length of the roots

Treatment		Dry weight)g(	Number of runners	Leaf area)cm^2(	Length of roots)cm(	Number of flowers
Control	0	13d	3.1d	18.14 d	17.5 d	8.69 bc
paclobutrazol (mg l^{-1})	25	10.8 i	3.4cd	17.5 de	16 f	7.8c
	50	11.8 ef	2.45 ef	17.8 de	12.1 g	9 bc
	100	8j	2.6 ef	15.6 fg	10.5g	17.8 a
boric acid (mg l^{-1})	50	12e	2.9 f	15.6 f	18e	12.8 b
	150	15 c	3 d	20.1 d	18.9 d	12b
	200	17.12b	6.8 a	32.5 a	30 a	18.1 a
gibberellic acid (mg l^{-1})	50	16.12b	3.4 c	18.4 ef	21.14b	7.6 c
	100	18.11a	6.8a	33.5 a	30a	7.1c

Means followed by same letter are not significantly different at 5% probability using Duncan's test.

Table 2) Effect of pre-harvest application of paclobutrazol, boric acid and gibberellic acid on length of flowering period, weight of primary and secondary 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	16 c	9 c	6.5 c	114.1 c	100.8 c
paclobutrazol ($mg\ l^{-1}$)	25	12 c	14.8 b	11 b	140.6bc	132.4bc
	50	20.01 b	14.5 b	11.4 b	165.4b	160.5b
	100	32.5a	19.3 a	15.8a	215.1a	208.7 a
boric acid ($mg\ l^{-1}$)	50	12.6c	13.6 b	10.1b	131.5 c	122.7c
	150	19b	15.4 b	10 b	180.14 b	174.2b
	200	31.14a	20 a	16.2a	212.5 a	204.8 a
gibberellic acid ($mg\ l^{-1}$)	50	19.7b	10 bc	8bc	141.2bc	134.5bc
	100	26.8ab	8c	15.3a	210a	205.8a

Means followed by same letter are not significantly different at 5% probability using Duncan's test.

Table 3) Effect of pre-harvest application of zinc sulfate, iron and calcium on Tss, TA, and Vitamin C of 'Pajaro' strawberry

Treatment		pH	Tss	TA g(citric acid)/(g/L)	Vitamin C)mg/100 g(
Control	0	3.18 abc	4.4 fg	4.17 g	20j
paclobutrazol ($mg\ l^{-1}$)	25	3.17 bc	6.3de	5 f	26.4e
	50	3.15bcd	7.64 c	7.99 c	50.3 b
	100	3.39 a	9.94a	9.7 a	65.1a
boric acid ($mg\ l^{-1}$)	50	3cd	5.1 f	6.8 e	43.3e
	150	3.18 abc	6.8 d	7 d	44 c
	200	3.2 ab	8.4b	8.7 b	60.7b
gibberellic acid ($mg\ l^{-1}$)	50	3.11 d	5.6 ef	6.6 e	41.89f
	100	3.17 bc	5.9ef	9.6 a	40.12f

Means followed by same letter are not significantly different at 5% probability using Duncan's test

This was in agreement with el-Khawaga [31] who reported foliar spray with boric acid, zinc chelate and urea in 'Manzanillo' olive were effective in shoot length, number of nodes per shoot and leaf area. Macronutrients sprays contains 0.5% urea, orthophosphoric acid, potassium and magnesium sulphate which promote higher rate of growth traits (shoot length, number of nodes per shoot, leaf area) in olive than girdling or micronutrient foliar application alone. Also, micro or macro elements foliar spray with girdling were the most effective in increasing vegetative characteristics. It was reported increaseing in leaf area was due to high concentration of nitrogen, Boron and zinc which have important effect on development of leaf cells. The Boron requirement is much higher for reproductive growth than vegetative growth. It increases flower production and retention, pollen tube elongation and germination, seed and fruit development [32]**.** The application of Boron as foliar spray also enhanced the fruit set in papaya [33]**.** In citrus B deficiency leads to low sugar content, granulation and excessive fruit abortion [34] as well as rind thickening; symptoms that are seen regularly in citrus orchards grown in Dargai area. At harvest, fruit which were harvested from plants sprayed with B, had higher TSS, TA and ascorbic acid content than those harvested from plants under control (Table 3). According to our previous studies and Wojcik and Lewandowski [35]; B application could not influence the quality parameters in strawberry, but Cheng [36] had reported that B deficiency in strawberry usually result in poor accumulation of TSS, and vitamin C content.

REFERENCES

1. Salmasi S., Behrouznajhad S., Ghassemi-Golezani K.,International Conference on Environment, Agriculture and Food Sciences (ICEAFS'2012) August 11-12, 2012 Phuket (Thailand) 2012.
2. Shukla A.K., Effect of foliar application of calcium and boron on growth, productivity and quality of Indian gooseberry (Emblica officinalis). Indian Journal of Agricultural Sciences. 81 (7) (2011) 628–32.
3. Abdollahi M., Eshghi S., Tafazzoli E., Moosavi N., Effects of Paclobutrazol, Boric Acid and Zinc Sulfate on Vegetative and Reproductive Growth of Strawberry cv. Selva. J. Agr. Sci. Tech. 14 (2010) 357-363.
4. Davis T. D., Curry E. A., Chemical Regulation of Vegetative Growth. Crit. Rev. Plant Sci. 10(1991) 151-188.

5. López-Aranda J.M., Soria C., Sánchez-Sevilla J.F., Gálvez J., Medina J.J., Arjona A., Marsal J.I. , Bartual R., HortSci. 39 (2004) 1776-1777.
6. Tehranifar A., Battey N.H., Comparison of the effects of GA3 and chilling on vegetative vigour and fruit set in strawberry. Acta Hort. 409 (1997) 629-630.
7. Sharma R.R., Sharma V.P., The Strawberry. ICAR, New Delhi, India (2004).
8. Tefera A., Seyoum T., Woldetsadik K.,Effect of disinfection, packaging, and storage environment on the shelf life of mango. Biosyst. Eng. 97(2) (2007) 201-212.
9. Moraes B., De Castro F., Genovese M.I., Antioxidant capacity and mineral content of pulp and peel from commercial cultivars of citrus from Brazil. Food Chemistry (2012).
10. Nishizawa T., The effect of paclobutrazol on growth and yield during first year greenhouse strawberry production. Sci. Hort. 54 (1993) 267-274.
11. Atkinson D., Effects of some plant growth regulators on water use and the uptake of mineral nutrients by tree crop. Acta Hort. 179 (1986) 395-402.
12. Khurshid T., McNeil D.L., Trought M.C.T., Hill G.D., Sci. Hortic. 72(1997) 1l-24.
13. Kirschbaur D.S., Temperature and growth regulator effects on growth and development of strawberry (Fragaria × ananassa Duch.) M.S. University of Florida, (1998) 144p.
14. Ramina A., Tonutti P., Tosi T., The Effect of Paclobutrazol on Strawberry Growth and Fruiting. J. Hort. Sci. 60 (1985) 501- 506.
15. Braun J. W., Garth J. K. L., Strawberry Vegetative and Fruit Growth Response to Paclobutrazol. J. Amer. Soc. Hort. Sci. 111 (1986) 364-367.
16. Maheswari T.U., Haripriya K., Poonkodi P., Kamalakannan S., Effect of foliar application of organic nutrients on some quality indices and economics of chilli (*Capsicum annuum* L.). Advances-in-Plant-Sci. 17 (2004) 259-262.
17. Yadava R.B.R., Singh V.K., Ind. J. Plant Physiol. 3(2) (1998) 166-167.
18. McArthur D.A.J., Eaton G.W., Sci. Hortic. 34 (1-2) (2003) 33-45.
19. Shakeri F., Baninasab B.,Ghobadi S., Mobli M., J. Hort. Sci. 23((2009))18-24.
20. Teferi Belayneh Y., Effect of cultural practices and selected chemicals on flowering and fruit production in some mango (*Mangifera indic*a L.) cultivars. Doctoral Thesis, University of Pretoria. 8 (2005) 173-191.
21. 21.Reid, J.B., Ross J.J., A mutant-based approach using Pisum sativum to understand plant growth. Int J Plant Sci. 154(1999) 22-34.
22. Hedden, P., Philips A.J., Gibberllin metabolism: new insights reveald by the genes. Trends Plant Sci. 5(2000) 523-530.
23. O'Neil D.P., Ross J.J., Regulation of gibberellin pathway in pea. Plant Physiol. 130(2002) 1974-1982.
24. Arteca R.N., Plant Growth Substances, Principles and Applications. Chapman and Hall, New York, USA (1995).
25. Paroussi G., Voyiatzis D.G., Paroussis E., Drogoudi P.D., Growth, flowering and yield responses to GA3 of Strawberry grown under different environmental conditions. Sci. Hort. 96 (1/4) (2002) 103- 113.
26. Gholami M., Sedighi A., Ershadi A., Sarikhani H., Effect of pre- and postharvest treatments of salicylic and gibberellic acid on ripening and some physicochemical properties of 'Mashhad' sweet cherry (Prunus avium L.) Fruit. Acta Hort. 884(2010) 257-264.
27. Liu M.J., Zhao Z.H., Germplasm resources and production of jujube in china. Acta Hort, (ISHS). 840(2009) 25-32.
28. Meena R.S., Effect of Boron on Growth, Yield and Quality of Tomato (*Lycopersicon esculentum* Mill.) cv. Pusa Ruby Grown under Semi-Arid Conditions. International Journal of Chemical Engineering Research. 2(2) (2010) 167-172.
29. Puzina T.I., Effect of zinc sulfate and boric acid on the hormonal status of potato plants in relation to tuberization. Russian Journal of Plant Physiology. 51(2) (2004) 209-214.
30. Ali, A.H.N., Jarvis B.C., Effects of auxin and boron on nucleic acid metabolism and cell division during adventitious root regeneration. New Phytol. 108 (1988) 381–391.
31. El-Khawaga A.S., Improving growth and productivity of Manzanillo olive trees with foliar application of some nutrients and girdling under sandy soil. Journal of Applied Science Research. 3(9) (2007) 818-822.
32. Peres L.A., Reyes R.D., J. Agric. Univ. Puerto Rico. 67(1983) 181-187.
33. Jeyakumar P., Durgadevi D., Kumar N., Effect of zinc and boron fertilization on improving fruit yields in papaya (*Carica papaya* L.) cv. Co5. J. Plant Nut. Food Security & Sustainability of agroecosystems. Kluwer Academic, Netherland. (2001) pp,356-357.
34. Reuther W., Batchelor L.D.,Webber H.J., The citrus industry. Vol. 2. Univ. of California. Div. of Agric. Oakland, CA (1968).
35. Wojcik P., Lewandowski M., Effect of calcium and boron sprays on yield and quality of Elsanta strawberry. J. Plant Nutr. 26 (3) (2003) 671–682.
36. Cheng B.T., Ameliorating Fragaria and Rubus idoeus productivity through boron and molybdenum addition. Agrochemina. 38 (3) (1994) 177–185.

How to cite this article:
Mohsen Kazemi. Pre-harvest foliar application of paclobutrazol, boric acid and gibberellic acid influences vegetative growth, reproductive characteristics and quality of strawberry (Fragaria × ananassa Duch. cv. Camarosa). Bull. Env.Pharmacol. Life Sci. 3 (4) 2014: 187-191