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Effect of Paclobutrazol and Salinity on Vegetative and Sexual Growth and Fruit Quality of Strawberry (*Fragaria* × *Ananassa* Duch. cv. Selva)

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ABSTRACT

Paclobutrazol (PBZ) and sodium chloride (NaCl) were sprayed on strawberry (Fragaria × Ananassa Duch. cv. Selva). The experiment was carried out in a factorial randomized complete block design with three replications in greenhouse conditions. Plants were treated with two levels of NaCl (0 and 20 mg L^{-1}) and four levels of PBZ (0, 30, 60 and 90 mg L^{-1}). Results showed that PBZ is an important factor for increasing the generative traits and fruit quality, but not on vegetative traits. The highest leaf number, leaf area, petiole length, and total soluble solid (T.S.S.) percent were observed in control plants, while highest fruit number, fruit weight, fruit set, flower number and yield of strawberry were obtained in plants treated with 90 mg L^{-1} PBZ. Foliar application of PBZ prior to flowering is recommended to increase the yield of strawberry.

Key words: fruit set, salinity, strawberry, paclobutrazol, yield

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INTRODUCTION

The cultivated strawberry is a hybrid plant crossed between two species, *Fragaria chiloensis* and *Fragaria virginiana*. The botanical name of the common cultivated strawberry is *Fragaria* × *ananassa*. Since 1850 hundreds varieties have been selected and named. Several cultivated forms of strawberry can be grouped as June bearing, overbearing and day-neutral [21].

Triazole compounds are new synthetic plant growth regulators that act as anti gibberellins and known to inhibit shoot growth in plants [12]. Include the increased antioxidant potentials, inhibition of plant growth, decreased inter-node elongation, increased chlorophyll levels, thicker leaf tissue and increased root to shoot ratio [37]. Triazoles affect the isoprenoid pathway and alter the levels of certain plant hormones by inhibiting gibberellins synthesis, increasing cytokinin levels and reducing ethylene evolution [25]. Paclobutrazol (PBZ) is a potent inhibitor of gibberellins biosynthesis by inhibiting the oxidation of ent-kaurene to ent-kaurenoic acid through inactivating cytochrome P450-dependent oxygenases [19]. Triazoles, also stimulate the accumulation of ABA in the leaves [2]. PBZ can be applied as an overall spray, as a soil drench or by way of trunk painting; better results have been

achieved when used as a soil drench, reportedly effective in inducing flowering in apple and pear [56] and reducing stem elongation in apple [53] and citrus [1]. PBZ has been used to provide plant protection against abiotic stresses such as water stress [5, 6, 59], chilling [32] and salinity [14, 29, 42, 46], drought, low and high temperature [15, 38]. PBZ has biochemical effects on plants, such as detoxification of active oxygen [30] and increased levels of proline [34], antioxidants [49] and chlorophyll contents [16].

Strawberries differ in their responses to NaCl salinity [4] and the complexity in the salt-stress adaptation of the plants is determined by many interacting environmental variables, NaCl concentration, plant and developmental stages [36]. Negative influences of NaCl salinity on strawberry growth and fruit productivity have been reported by Awang and Atherton [3] and D'Anna et al. [10]. The salt stress resulted in the development of leaf necroses and accelerated leaf senescence, thus reducing photosynthetic capability of the plants [18]. Chemical parameters related to the fruit quality of pepper were improved by salinity. It has been observed in other horticultural crops [8, 35]. Fertirrigation management is an approach to improve salinity tolerance in crops [43]. We studied the role of PBZ nutrition on the incidence of salinity in strawberry. In this study, we also determined the changes of vegetative and sexual growth and yield of strawberry with or without PBZ to examine if PBZ could alleviate the plant's response on salinity qualification.

MATERIALS AND METHODS

Plant Materials

The experiment was conducted during 2011 and 2012 on strawberry plants at a greenhouse located in Gorgan city, Golestan province, in the northern part of Iran (latitude 36°50´N, longitude 24°44´E). This work was carried out with strawberry cv. 'Selva'.

PBZ and Salinity Treatments

The interaction effect of PBZ and NaCl on vegetative and sexual growth, yield and fruit quality in strawberry was evaluated. Plants were treated with four levels of PBZ (0, 30, 60 and 90 mg L^{-1}) and two levels of NaCl (0 and 20 mg L^{-1}). Control plants were watered without PBZ and NaCl. PBZ and NaCl treatments were applied as a foliar spray and with irrigation, respectively.

Measurements

At the end of the experiment and after application of treatments, five plants were randomly sampled for the measurement of growth parameters. The leaf area, the number of leaf and length of petiole were measured in each plant treatment. The areas of primary leaves were determined by an area meter (Crump Scientific Products, UK) [27]. Following flowering, the number of flower was counted in each plant treatment. Fruits were harvested early in the morning and rapidly transferred to the laboratory. Strawberries were sorted on the basis of size, color (70% full red color) and absence of physical damage, and were randomly divided into lots of ten fruit. Fruits were selected based on module of weight and computation, toward the get yield per plant. The numbers and weight of fruits per plant computation were measured in each of the plants per treatment. Total fruit weight of each plant was separately measured and considered as yield. To evaluate fruit quality, total soluble solid (T.S.S.) were measured using a refractometer [10]. To obtain total fruit set, mean of fruit number were divided on flower number per plant.

Analytical Procedures

The study was carried out in a factorial experiment based on completely randomized block design in three replications. The experiment with 12 treatments was included with 5 shrubs allocated to block with three replications. Thus, the 192 shrubs were used.

Statistical Analysis

Data were subjected to analysis of variance in SPSS statistical software and means were compared by the F test at the 0.05 and 0.01 of probability level.

RESULTS AND DISCUSSION

PBZ, NaCl and their interaction significantly decrease vegetative growth in strawberry cv. Selva. PBZ reduced the vegetative growth rate in all stages of plant growth as compared to the control. Length of petiole was reduced after application of optimum concentration of PBZ as compared to the control. PBZ reduced all vegetative growth traits.

Total shoot length per plant was reduced for the strawberry plants after PBZ application. The number of leaves per plant was reduced in PBZ-treated plants. The highest dose (90 mg L^{-1}) was more effective than the lower dose (30 mg L^{-1}) on decrease leaves per plant. Maximum leaf number (21.10/plant), leaf area (42.40 cm^2) and petiole length (8.60 cm) were obtained in control plants (Table 2). High concentrations of PBZ and salinity could be toxic [48]. When NaCl was added to the plants previously treated with PBZ, shoot length was reduced. Total shoot length was reduced after the PBZ application. Reports indicated that PBZ, a growth retardant, exerts its antagonistic effect due to lowering of endogenous gibberellins levels which in turn causes reduced vegetative growth but profuse flowering in mango [55]. PBZ used for growth has been reported to reduce the growth on strawberry. Flores et al. [17] found that salt stress inhibits the uptake and transport of potassium, calcium and phosphorus. According to Maas [33], the capability of plants to survive at these extreme conditions could not be correlated with the reduction of growth at more moderate salinities. PBZ reduces petiole length and internodes elongation [31, 45]. PBZ used for growth has been reported to reduce leaf number and leaf area on strawberry [27, 50, 58]. Vegetative growth components were reduced the year after the repeat application of PBZ in both trials [28]. These results confirm our findings. Most researchers have focused on the inhibitory role of Cl on plant growth. It is known that high concentrations of NaCl induce calcium deficiencies in different plants and decrease the growth [41]. Shiyab et al. [51] also observed a significant decrease in the growth parameters at high concentration of NaCl (20 mM) in sour orange (*Citrus aurantium*).

Our data indicated that PBZ significantly increased fruit yield (Table 3). Maximum and minimum yield (109.40 and 48.90 g per plant, respectively) was obtained in plants treated with 90 mg L^{-1} PBZ without NaCl and the control, respectively (Table 3). The repeated application of PBZ significantly increased the number of fruit for the irrespective of initial treatment, cultivar, or cropping cycle. On the other hand, yield efficiencies increased when fruit weight was increased due to increased fruit number. Fruit weight seemed to be showing compensation effects and yield with PBZ treatment. Also the heavy fruit load may have depleted carbohydrates reserves necessary for the following year's flower initiation, fruit set and/or initial growth of the plant. Fruit yield of plants receiving supplementary PBZ at 90 mg L^{-1} were higher than those at 30 and 60 mg L^{-1}. Addition of NaCl to nutrient solution significantly reduced fruit yield in terms of fruit number per plant (Table 3). PBZ reduced the fresh weight of strawberry after application. Maximum and minimum fruit weight (9.60 and 7.10 g per plant, respectively) was obtained in plants treated with 90 mg L^{-1} PBZ without NaCl and the control, respectively (Table 3). PBZ may also have had indirect effects in increasing the crop by reducing vegetative growth. Yield efficiency values were consistent with the fruit yield values. The efficacy of PBZ on growth, flowering, fruiting and fruit quality has been reported earlier [52]. PBZ caused a reduction in fruit weight when the fruit numbers were high. Fruit-size reduction in apples has been previously reported by many researchers [13, 20]. The year after application of PBZ, total yield increased in 'Golden Delicious' apples [54]. PBZ reduced fruit size [40, 44]. Studies have shown that PBZ is needed to be applied annually to increase fruit yields in mango, also flower number and fruit yield in strawberry [50, 57]. PBZ caused an increase in fruit weight with increased fruit number [24, 50]. McArthur and Eaton [39] reported that PBZ increased achenes per fruit in strawberry**.** Many crop plants including tomato are susceptible and cannot survive under high salinity conditions or can survive only with decreased yield [7]. In salt stress condition, assimilation of carbohydrates available for fruit production is reduced [26, 47]. PBZ alone, significantly decreased T.S.S content, and salinity, significantly increased T.S.S content (Table 2). Maximum and minimum T.S.S content (8.20 and 6.50, respectively) was obtained in control plants and plants treated with 90 mg L^{-1} PBZ without NaCl, respectively (Table 2). PBZ reduced fruit soluble solids content in several species [9, 12, 23].

Table 1: The main chemical properties of the growing medium

Type of soil	Potassium (ppm)	Phosphorus (ppm)	Nitrogen (ppm)	EC (×10)	pH	Sand (%)	Clay (%)	Lay (%)
Silt-loam	254	20	0.17	3.0	7.2	24	60	16

Table 2: Effects of PBZ and NaCl on vegetative growth and quality of fruit in strawberry (*Fragaria* × *Ananassa* Duch. cv. Selva)

Treatment (mg L^{-1})	T.S.S (%)	Leaf number	Length of petiole (cm)	Leaf area (cm^2)
Control	8.20a	21.10a	8.60a	42.40a
(PBZ 30 + NaCl 0)	7.40a	19.70ab	7.70ab	40.90ab
(PBZ 60 + NaCl 0)	7.00a	18.80bc	6.90ab	38.80cd
(PBZ 90 + NaCl 0)	6.50a	17.30cd	6.50b	37.50cde
(PBZ 30 + NaCl 20)	7.60a	18.90bc	7.10ab	39.30bc
(PBZ 60 + NaCl 20)	7.20a	17.80c	6.30b	37.20de
(PBZ 90 + NaCl 20)	6.90a	15.60d	6.00b	35.90e

In each column, means with the similar letters are not significantly different at 5% level of probability using F test

Table 3: Effects of PBZ and NaCl on sexual growth and yield of strawberry (*Fragaria* × *Ananassa* Duch. cv. Selva)

Treatment (mg L^{-1})	Fruit No./plant	Average fruit weight (g)	Yield/plant (g)	Flower No./plant	Fruit set (%)
Control	6.90d	7.10b	48.90f	7.90c	87.30bc
(PBZ 30 + NaCl 0)	8.30cd	8.06ab	66. 90e	9.60b	86.40c
(PBZ 60 + NaCl 0)	9.80abc	8.40ab	82.30c	10.30b	95.10a
(PBZ 90 + NaCl 0)	11.40a	9.60a	109.40a	12.60a	94.20ab
(PBZ 30 + NaCl 20)	9.10bc	7.80ab	70.90d	10.10b	90.00abc
(PBZ 60 + NaCl 20)	9.60abc	7.20b	68.10e	10.20b	94.10ab
(PBZ 90 + NaCl 20)	10.80ab	8.70ab	93.90b	12.10a	85.70c

In each column, means with the similar letters are not significantly different at 5% level of probability using F test

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