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Effects of Paclobutrazol, Boric Acid and Zinc Sulfate on Vegetative and Reproductive Growth of Strawberry cv. Selva

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ABSTRACT

Excessive vegetative growth may bring about improper pollination and consequently lead to reduced fruit set and misshapen fruits. Paclobutrazol (PP333) reduces vegetative growth. On the other hand, balanced nutrient uptake at all developmental stages increases fruit quality and yield. An experiment was conducted with the aim of reducing vegetative growth and improving yield of strawberry, Selva cultivar, using combinations of PP333, boron and zinc. Results indicated that PP333 reduced vegetative growth by reducing both fresh and dry weights of shoots while simultaneously some such reproductive characters as inflorescence and fruit number were increased. Boron (H_3BO_3) alone had no effect on reproductive growth. A combination of PP333 plus B (100-00 mg l^{-1}) was the most effective in increasing fruit number as well as fruit weight. Paclobutrazol combined with zinc sulfate ($ZnSO_4$) at concentrations of 100- 100 mg l^{-1} PP333×$ZnSO_4$ had positive effects on reproductive growth including inflorescence number and yield. Zink sulphate at concentration of 100 mg l^{-1} with no PP333 and H_3BO_3 application increased yield, inflorescence and fruit number as compared with other treatments.

Keywords: Boron, Paclobutrazol, Reproductive growth, Strawberry, Zinc.

INTRODUCTION

Excessive plant growth in some strawberry cultivars may often cause untimely pollination, reduced fruit set and as well a greater incidence of misshapen fruits (Ramina *et al.*, 1985). Paclobutrazol (PP333) is a triazol that inhibits gibberellin biosynthesis (Hedden and Graebe, 1985), and consequently reduces vegetative growth in most plant species (Davis and Curry, 1991). It is well known that PP333 reduces the development of runners and inversely promotes the formation of lateral crowns (Braun and Garth, 1986). The increase in the number of flower clusters in strawberry plants is often accompanied by an increase in the number of lateral crowns (Braun and Garth, 1986). Paclobutrazol (PP333), a powerful growth retardant, has been observed to reduce shoot growth, while increasing fruit set in 'd' Anjou' pear (Raese and Burts, 1983). Mc Arthur and Eaton (1987) demonstrated that high concentrations of PP333 in the soil reduced yield in strawberry. Stang and Weis (1984) reported shortened petioles, peduncles, and pedicels in strawberry, giving the plant a compact appearance, after being treated with PP333.

Foliar nutrition may play an important role in perennial fruit plants. Both qualitative and

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quantitative aspects of perennial fruit crops have been improved through foliar application of nutrients (Brown *et al.*, 1996).

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 (Hanson, 1991; Wojcik and Wojcik, 2003).

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 sulephate 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 achenes (Dreher and Poovaiah, 1982), so an application of $ZnSO_4$, a prerequisite of auxin, is potentially useful in increasing fruit size as well as its quality.

The interaction between PP333, B and $ZnSO_4$ on strawberry growth and fruiting is not fully understood. Paclobutrazol reduces vegetative growth while increasing yield. Since Zn and Boron are involved in pollination and fruit set processes, their individual as well as interaction effects have been investigated in this study.

MATERIALS AND METHODS

The experiments were conducted in 2007 and 2008 on strawberry plants (*Fragaria ananassa* Duch. cv. Selva) in a hydroponic greenhouse located at Sadra, Shiraz (latitude 29°32´N, longitude 52°35´E). Plants were grown under natural day light conditions. The temperature readings were 26±4°C and 15±4°C, during the days and at nights respectively, with mean relative humidity of 60±15%. Runner plants were rooted in plastic pots (12 cm diameter) filled with Leca (a clean and attractive soil free media for hydroponics) and perlite. They were watered three times a day. Rooted plants were transplanted into 3 liter pots. The pots were filled with Leca, perlite and peatmoss (1:3:1 v/v/v). The plants were fertilized with the fully enriched nutrient solutions containing: N, P2O5, K2O, Ca, Mg, S, Fe, Mn, Mo and Cu. Electrical conductivity (EC) was kept within the range of 0.5- 0.8 ds m^{-1}, while the pH of the solution maintained between 5.5 and 6.2.

Paclobutrazol, at the rate of 100 mg l^{-1}, zinc sulfate at the rates of 100 and 200 mg l^{-1} as well as boric acid at the rates of 150 and 300 mg mg l^{-1} were applied as foliar sprays up to the point of run off. The surfaces of the pots were covered with aluminium foil to prevent the intrusion of PP333, H_3BO_3 and $ZnSO_4$ into root media. Untreated plants were left as control. The experimental period lasted for 4 months. Each 4 plants received a randomly assigned combination of treatment(s).

At the end of the experimental period, the remnants of growth media were gently washed away from roots, while the plants being divided into their leaves, crowns and roots to make measurements of the fresh weights of shoots (leaves and crowns) as well as roots. These were then oven dried at 70°C until a constant mass reached to make measurements of the dry weights. The shoot/root ratio as well as crown numbers were also found out.

Inflorescence was numbered and peduncle length measured three times during the experiments, with mean data being recorded. Fresh weight, achene number, as well as the size of primary and secondary fruits were found out for each plant during the period of the experiment. Total fruit weight was registered and considered as yield.

The experiment was of a factorial incompletely randomized design of 18 treatments and 4 replications. Data were analyzed using MSTATC and treatment means compared using least significant differences (LSDs) at ($P\leq 0.01$).

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RESULTS AND DISCUSSION

Vegetative Growth

Paclobutrazol treatment clearly reduced vegetative growth, with shoot fresh weight becoming significantly less than that in control (Figure 1 and Table 1). On the other hand, root fresh weight was increased (Figure 2). Similar results have been reported by Aloni and Pashkar (1987) for pepper. Stimulation of root growth through PP333 application is due to diversion of assimilate as suggested by Symons *et al.* (1990). Root fresh weight was also increased through both zinc sulfate and boric acid applications (Figure 2 and Table 1). Puzina (2004) has claimed that boric acid reduces IAA oxidase, and therefore increasing auxin level. Figure 3 shows, the interaction between PP333 and H_3BO_3 (PP333×B) and between PP333 and $ZnSO_4$ (PP333× $ZnSO_4$) which resulted in increased root fresh weight. The highest root fresh weight was observed at high levels of concentration in each treatment. A negative correlation was observed to exist between B concentration and shoot fresh weight. This is demonstrated in Figure 1 where shoot fresh weight is gradually reduced from that in control to that at the highest level of H_3BO_3 application. Similar results have been reported by Francois (1984). Shoot fresh weight was also negatively affected by the interactions

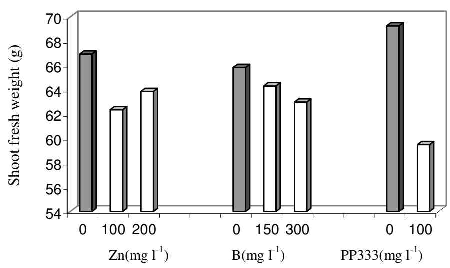

Figure 1. Effects of PP333, $ZnSO_4$ and H_3BO_3 (alone) on shoot fresh weigh (LSD (1%): PP333= 1.16, $ZnSO_4$, H_3BO_3= 1.45).

Table 1. Mean squares of characters measured.

Treatment	df	Shoot fresh weight	Root fresh weight	Fresh shoot/root weight ratio	Fruit number	Crown number	Yield	Fruit size	Peduncle length	Inflorescence number
PP333[a]	1	1712.685**	28863.2*	8.93**	493.503**	1.125**	662.546*	0.008**	682.651**	0.889**
Zn[b]	2	130.535**	7313.3**	2.114**	14.233**	0.847**	54.170*	0.064 *	2.635**	3.431**
B[c]	2	48.744**	522.3**	0.11**	26.712 ns	0.181**	37.635 ns	0.023 ns	1.253**	1.931**
PP333×Zn	2	443.029**	5996.1**	1.895**	23.816 ns	3.042 ns	84.590*	0.023 ns	24.558 ns	6.681**
PP333×B	2	527.264**	111.9 **	0.154**	3.378**	0.042*	6.349*	0.001 **	5.397**	2.347**
B×Zn	4	560.152**	1168.2 **	0.312**	15.378**	2.014 ns	32.947 ns	0.019 ns	18.413 ns	4.222**
PP333×Zn×B	4	871.485**	1798.0**	0.358**	25.722 ns	0.583*	21.239 ns	0.015 **	18.190 ns	21.389 ns

[a] Paclobutrazol; [b] $ZnSO_4$, [c] H_3BO_3.
ns: Not significantly different at $P \leq 0.05$.
* and **: Significantly different at $P \leq 0.05$ and $P \leq 0.01$, respectively.

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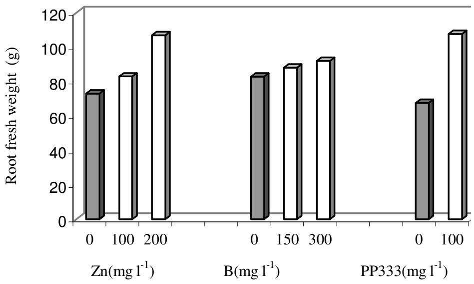

Figure 2. Effects of PP333, $ZnSO_4$ and H_3BO_3 (alone) on root fresh weight. (LSD (1%): PP333= 1.06, $ZnSO_4$, H_3BO_3= 2.13).

PP333×H_3BO_3 and PP333×$ZnSO_4$ (Tables 2 and 3) respectively. The shoot/root ratio was reduced through PP333 application (Figure 4 and Table 1). Atkinson (1986) has reported that PP333 has reduced this ratio in several plants due to a diversion of assimilates.

Reproductive Growth

Figure 5 and Table 1 show that both PP333 and zinc sulfate increased fruit number, though the fruit size was significantly reduced (Table 1). Similar results have been reported by Sansavini *et al.* (1986) for apple. Positive effect of $ZnSO_4$ on fruit number is well documented (Chaplin and Westwood, 1980). Boron did not affect the primary and secondary fruit size (Table 1), in agreement with the results obtained by Neilson and Eaton (1983). The highest fruit number was obtained with PP333 and $ZnSO_4$ either singly or in interaction at contents of 100-100 mg l^{-1}; respectively in comparison with the untreated control (Tables 1 and 3). When applied individually PP333 and $ZnSO_4$ also increased fruit number significantly (Table 3). Both PP333 and H_3BO_3 (Tables 4 and 1) when applied singly reduced yield as compared to control. This confirms the results obtained by Ramina *et al.* (1985) and Braun and Garth (1986). However $ZnSO_4$ gave some increase in yield (Tables 4 and 1) which is in agreement with the findings of Littlemore *et al.* (1991). Pablobutrazol (PP333) at concentrations used in these experiments reduced fruit weight (primary and secondary fruits (Table 1)). Beech *et al.* (1988) reported that PP333 reduced fruit size in 'Cambridge,' 'Hipel' and 'Pentagon'. Both the number of branch crowns and fruit clusters increased following treatment with PP333 and H_3BO_3 (Figure 6 and Table 1). Zinc sulphate, when singly applied, increased number of clusters, although it did affect number of branch crowns. Tafazzoli (1975) reported that nutrient application before flower induction in strawberry increased the number of clusters. The highest number of fruit clusters was obtained through application of a combination of $ZnSO_4$×H_3BO_3 of 200-300 mg l^{-1}, respectively. The improved fruit number was attributed to the important role

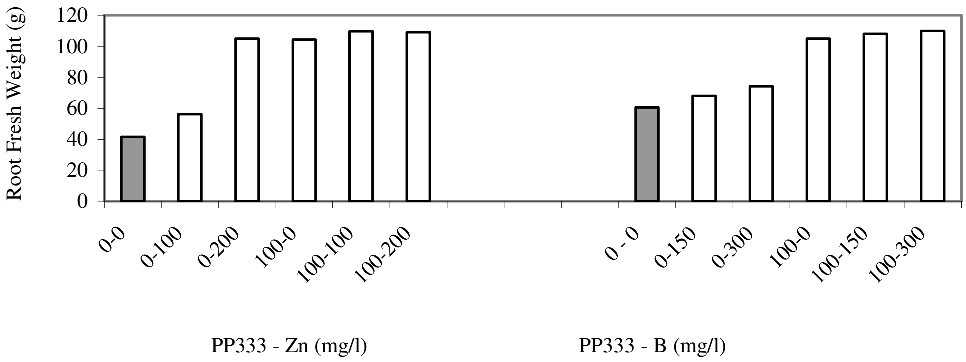

Figure 3. Interaction effects of (PP333× H_3BO_3) and (PP333×$ZnSO_4$) on root fresh weight.

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Table 2. PP333×H_3BO_3 interaction effect on shoot fresh weight in g per plant.

PP333 (mg l^{-1})	H_3BO_3 (mg l^{-1})		
	0	150	300
0	76.11	66.25	65.39
100	55.55	62.36	60.58

LSD (1%): PP333×H_3BO_3= 2.25
LSD (1%) for fruit number: PP333×$ZnSO_4$ =1.62

Table 3. Interaction effects on shoot fresh weight and fruit number per plant.

PP333 (mg l^{-1})	$ZnSO_4$ (mg l^{-1})		
	0	100	200
	Shoot fresh weight (g)		
0	75.36	62.45	69.94
100	58.48	62.23	57.78
	No. Fruit		
0	24.08	24.42	19.42
100	20.83	26.67	21.67

of the increase in leaf area, photosynthesis as well as auxin content (Stiles and Reid, 1995). Paclobutrazol (PP333) also reduced pedicle length in strawberry (Table 1) which is in agreement with the results obtained by Stang and Weis (1984) and Nishizawa (1993).

CONCLUSONS

As a whole, PP333 increased crown no., root fresh weight as well as such reproductive growth as number of fruits and inflorescences, but was accompanied by a decrease in fruit size. Paclobutrazol is a triazol that promotes reproductive growth by reducing vegetative growth. Zinc sulfate was effective in increasing fresh weight of roots and number of crown. Also, $ZnSO_4$ increased inflorescence and fruit size because of its important role in pollination and fruit set. Boron increased crown no. and root fresh weight, but decreased yield. In general the application of $ZnSO_4$ at 200 mg l^{-1} is recommended to improve reproductive growth in strawberry, cultivar Selva.

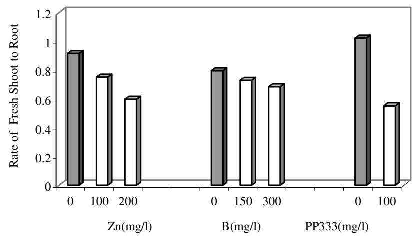

Figure 4. Effects of PP333, $ZnSO_4$ and H_3BO_3 (alone) on 'fresh shoot/ root weight' ratio. (LSD (1%): PP333= 0.03, $ZnSO_4$, H_3BO_3= 0.0

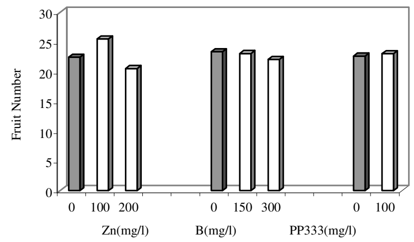

Figure 5. Effects of PP333, $ZnSO_4$ and H_3BO_3 (alone) on fruit number per plant. (LSD (1%): PP333= 0.83, $ZnSO_4$, H_3BO_3= 1.05).

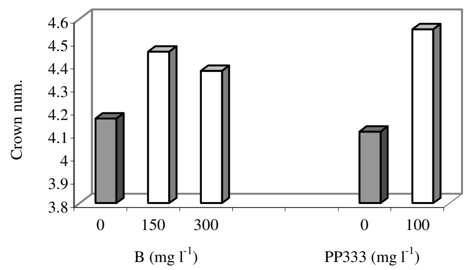

Figure 6. Effects of PP333 and H_3BO_3 (alone) on crown number per plant. (LSD (1%): PP333= 0.83, $ZnSO_4$, H_3BO_3= 1.05).

Table 4. Effects of H_3BO_3 and $ZnSO_4$ alone along with their interaction effect on yield in (g) per plant.

$ZnSO_4$ (mg l^{-1})	H_3BO_3 (mg l^{-1})			Mean
	0	150	300	
0	255.2	157.3	196.4	203.0
100	244.2	192.6	183.2	206.7
200	203.7	211.2	207.5	207.5
Mean	234.3	187	195.7	

LSD (1%): $ZnSO_4$, H_3BO= 03.35, H_3BO_3×$ZnSO_4$= 6.96.

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تاثیر پاکلوبوترازول، اسیدبوریک وسولفات روی بر رشد رویشی و زایشی توت فرنگی رقم سلوا

م. عبدالهی، س. عشقی، ع.تفضلی، ن. موسوی

چکیده

رشد رویشی زیاد توت فرنگی سبب گرده افشانی نامنظم و در نتیجه، کاهش تشکیل میوه و افزایش تولید میوه‌های بد شکل می‌شود که با کمک پاکلوبوترازول می‌توان رشد رویشی را کنترل نمود. از طرف دیگر، تأمین به موقع عناصر غذایی مورد نیاز گیاه، سبب افزایش عملکرد و بهبود خواص کیفی میوه می‌شود. بنابراین پژوهشی به منظور بررسی اثر پاکلوبوترازول، بُر و روی در کاهش رشد رویشی و بهبود عملکرد توت فرنگی انجام شد. نتایج این پژوهش نشان داد، پاکلوبوترازول با کاهش وزن تر و خشک شاخساره موجب کاهش رشد رویشی شد، درحالیکه برخی صفات زایشی مانند تعداد میوه و تعداد گلاذین را افزایش داد. تیمار بور به تنهایی تأثیر قابل ملاحظه‌ای بر رشد زایشی گیاه توت فرنگی نشان نداد. اثر متقابل بر- پاکلوبوترازول نشان داد، غلظت (mgl^{-1} ۳۰۰- ۱۰۰ بر- پاکلوبوترازول) با افزایش تعداد میوه ، گل و افزایش وزن میوه، مناسبترین غلظت، برای رسیدن به حداکثر رشد زایشی بود. در تیمار ترکیبی روی ـ پاکلوبوترازول، غلظت (mgl^{-1} ۱۰۰- ۱۰۰ روی ـ پاکلوبوترازول) بیشترین تعداد میوه، بدست آمد. در برهمکنش هر سه تیمار، بیشترین رشد زایشی زمانی مشاهده شد که سولفات روی در غلظت ۱۰۰mgl^{-1} ، بدون حضور دو تیمار دیگراستفاده شد که این نشان دهنده تاثیر منفی پاکلوبوترازول و بور برروی بود.

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