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

M. Abdollahi¹*, S. Eshghi², E. Tafazzoli¹, and N. Moosavi¹

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 (H₃BO₃) 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 (ZnSO₄) at concentrations of 100-100 mg l⁻¹ PP333×ZnSO₄ had positive effects on reproductive growth including inflorescence number and yield. Zinc sulphate at concentration of 100 mg l⁻¹ with no PP333 and H₃BO₃ 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...
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$_3$BO$_3$) 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 sulphonate induces pollen tube growth through its role in tropothan 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, P$_2$O$_5$, K$_2$O, 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 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$_3$BO$_3$ 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).
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$_3$BO$_3$ (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$_3$BO$_3$ application. Similar results have been reported by Francois (1984). Shoot fresh weight was also negatively affected by the interactions

**Table 1.** Mean squares of characters measured.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>df</th>
<th>Shoot fresh weight</th>
<th>Root fresh weight</th>
<th>Fresh shoot/root weight ratio</th>
<th>Fruit number</th>
<th>Crown number</th>
<th>Fruit size</th>
<th>Pedunule length</th>
<th>Inflorence number</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP333</td>
<td>1</td>
<td>1712.08±8.0</td>
<td>25.68±1.3</td>
<td>8.39±1.1</td>
<td>493.03±8.0</td>
<td>1.125±0.1</td>
<td>662.2±6.0</td>
<td>68.2±6.0</td>
<td>0.889±0.1</td>
</tr>
<tr>
<td>ZnSO$_4$</td>
<td>2</td>
<td>130.55±1.3</td>
<td>4.54±0.1</td>
<td>2.98±0.1</td>
<td>54.17±1.3</td>
<td>1.323±0.1</td>
<td>51.63±1.3</td>
<td>74.16±1.3</td>
<td>1.45±0.1</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>48.34±1.3</td>
<td>1.66±0.1</td>
<td>0.83±0.1</td>
<td>16.18±1.3</td>
<td>0.512±0.1</td>
<td>18.64±1.3</td>
<td>24.35±1.3</td>
<td>1.31±0.1</td>
</tr>
<tr>
<td>PP333×ZnSO$_4$</td>
<td>2</td>
<td>453.02±1.3</td>
<td>13.78±1.3</td>
<td>2.86±0.1</td>
<td>37.63±1.3</td>
<td>1.185±0.1</td>
<td>36.54±1.3</td>
<td>25.39±1.3</td>
<td>1.29±0.1</td>
</tr>
<tr>
<td>PP333×B</td>
<td>2</td>
<td>48.34±1.3</td>
<td>1.66±0.1</td>
<td>0.83±0.1</td>
<td>16.18±1.3</td>
<td>0.512±0.1</td>
<td>18.64±1.3</td>
<td>24.35±1.3</td>
<td>1.31±0.1</td>
</tr>
<tr>
<td>PP333×ZnSO$_4$×B</td>
<td>4</td>
<td>310.32±1.3</td>
<td>9.62±0.1</td>
<td>1.73±0.1</td>
<td>23.78±1.3</td>
<td>0.738±0.1</td>
<td>22.72±1.3</td>
<td>21.29±1.3</td>
<td>1.38±0.1</td>
</tr>
</tbody>
</table>

*Paclobutrazol; a, b, c, ZnSO$_4$, H$_3$BO$_3$, (alone) not significantly different at P≤0.05, and *ns, significantly different at P≤0.01, respectively.
Figure 2. Effects of PP333, ZnSO$_4$ and H$_3$BO$_3$ (alone) on root fresh weight. (LSD (1%): PP333= 1.06, ZnSO$_4$, H$_3$BO$_3$= 2.13).

PP333×H$_3$BO$_3$ 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$_3$BO$_3$ (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). P abolbutrazol (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$_3$BO$_3$ (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$_3$BO$_3$ of 200-300 mg l$^{-1}$, respectively. The improved fruit number was attributed to the important role...
Table 2. PP333×H₃BO₃ interaction effect on shoot fresh weight in g per plant.

<table>
<thead>
<tr>
<th>PP333 (mg l⁻¹)</th>
<th>H₃BO₃ (mg l⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>76.11 66.25 65.39</td>
</tr>
<tr>
<td>100</td>
<td>55.55 62.36 60.58</td>
</tr>
</tbody>
</table>

LSD (1%): PP333×H₃BO₃= 2.25

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

<table>
<thead>
<tr>
<th>PP333 (mg l⁻¹)</th>
<th>ZnSO₄ (mg l⁻¹)</th>
<th>Shoot fresh weight (g)</th>
<th>No. Fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>75.36 62.45 69.94</td>
<td>24.08 24.42 19.42</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>58.48 62.23 57.78</td>
<td>20.83 26.67 21.67</td>
</tr>
</tbody>
</table>

Figure 4. Effects of PP333, ZnSO₄ and H₃BO₃ (alone) on ‘fresh shoot/ root weight’ ratio. (LSD (1%): PP333= 0.03, ZnSO₄, H₃BO₃= 0.0)

Figure 5. Effects of PP333, ZnSO₄ and H₃BO₃ (alone) on fruit number per plant. (LSD (1%): PP333= 0.83, ZnSO₄, H₃BO₃= 1.05).

CONCLUSIONS

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, ZnSO₄ 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 ZnSO₄ at 200 mg l⁻¹ is recommended to improve reproductive growth in strawberry, cultivar Selva.

Table 4. Effects of H₃BO₃ and ZnSO₄ alone along with their interaction effect on yield in (g) per plant.

<table>
<thead>
<tr>
<th>ZnSO₄ (mg l⁻¹)</th>
<th>H₃BO₃ (mg l⁻¹)</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>255.2 157.3 196.4</td>
<td>203.0</td>
</tr>
<tr>
<td>100</td>
<td>244.2 192.6 183.2</td>
<td>206.7</td>
</tr>
<tr>
<td>200</td>
<td>203.7 211.2 207.5</td>
<td>207.5</td>
</tr>
<tr>
<td>Mean</td>
<td>234.3 187 195.7</td>
<td></td>
</tr>
</tbody>
</table>

LSD (1%): ZnSO₄, H₃BO₃= 0.35, H₃BO₃×ZnSO₄= 6.96.
ACKNOWLEDGEMENTS

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REFERENCES


Strawberry Growth as Affected by pp333, B and Zn


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چکیده

رشد روشی زیاد توت فرنگی سبب گردیده افشانی نامنظم و در نتیجه، کاهش تشكل میوه و افزایش تولید میوه‌های بد شکل می‌شود که با کمک پاکلوبرترزول می‌توان رشد روشی را کنترل نمود. از طرف دیگر، تمایل به موقع عناصر غذایی مورد نیاز گیاه، سبب افزایش عملکرد و بهبود خواص کیفی میوه می‌شود. بنابراین پژوهش به مانیتور بررسی اثر پاکلوبرترزول بر روی و روش در کاهش رشد روشی و بهبود عملکرد توت فرنگی انجام شد. نتایج این پژوهش نشان داد، پاکلوبرترزول با کاهش وزن تر و خشک شاخصه موجب کاهش رشد روشی شد، در حالی که در صفات زایشی مانند تعداد میوه و تعداد گل‌ها و افزایش داد. ثابت شد که تیمار بور به نهایی تاثیر قابل ملاحظه‌ای بر رشد زایشی گیاه توت فرنگی نداشت. اثر متقابل بور-پاکلوبرترزول نشان داد، غلظت (1 mgl⁻¹) 100- پاکلوبرترزول) با افزایش تعداد میوه، کل و افزایش وزن میوه، مناسب‌ترین غلظت، برای رسیدن به حداکثر رشد زایشی بود. در تیمار تکمیلی روش-پاکلوبرترزول، غلظت (1 mgl⁻¹) 100 روش-پاکلوبرترزول) بیشترین تعداد میوه، بدست آمد. در پهن‌کشت هر سه تیمار، بیشترین رشد زایشی زمانی مشاهده شد که سولفات در غلظت (1 mgl⁻¹) 100، بدون حضور در تیمار دیگر استفاده شد که این نشان دهنده تأثیر متفاوتی پاکلوبرترزول و بور بر روی بود.