Effects of Paclobutrazol on Vegetative and Reproductive Characteristics of Peach (Prunus persica L.) cv. ‘Kardi’.

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ABSTRACT
This study was conducted to investigate the effect of paclobutrazol (PBZ) on some vegetative and reproductive characteristics of peach cv. ‘Kardi’. The experiment was carried out as factorial based completely randomized block design with three replications. Peach trees were treated within 2 seasons (August and March) by applying various levels of PBZ (paclobutrazol) (0, 0.5, 1 and 1.5 g a.i. per tree) as soil drench. Evaluated traits were: the density of flower on the branches (flower numbers), percentage of final fruit set, leaf chlorophyll content, average leaf area, shoot elongation, trunk radial growth and yield. Results showed that PBZ application time had a significant effect on flower density. August application of PBZ increased flower numbers on branches (flower density). Application time and amount of PBZ had significant effect on final fruit set percentage and shoot elongation. Application of PBZ in August increased final fruit set but the effect of PBZ application during March was more effective on reducing shoot elongation. The results showed that PBZ concentration had significant effect on leaf chlorophyll content, average leaf area and trunk radial growth. PBZ did not have significant effect on the yield of ‘Kardi’ peaches. Generally, the results indicated that application of PBZ during August had the greatest effect on reproductive characteristics and its application during March had the greatest effect on vegetative features.

Keywords: Flower density, fruit set, leaf area, yield, chlorophyll content.

Abbreviations:
Chl: Chlorophyll; PBZ: paclobutrazol; FW: fresh weight; a.i.: active ingredient.

INTRODUCTION
Peach (Prunus persica L.), which belongs to the Rosaceae family, is one of the major stone fruits and it is cultivated in various parts of Iran. Peach tree has an excessive annual vegetative growth. One of the most important principles in peach orchard management is peach tree size control and growth inhibition. The application of plant growth retardants in order to reduce peach tree vegetative growth has been reported by various researchers. Paclobutrazol (PBZ) [with the common names of: Bonzi, Clipper- S, Clipper-T, Cultar, PP333; and the chemical name of: IUPAC: (2RS,3RS)-(1-4-(chlorophenyl)-4,4-dimethyl-2-(1H,1,2,4-triazol-1-yl)pentan-3-ol) is an triazole type plant growth retardant which blocks gibberellin biosynthesis (PGRSA, 2007; Tafazoli and Beyl, 1993; Watson and Jacobs, 2012). PBZ (S-enantiomer) keeps certain structural similarities with ent-kaurene and ent-kaurenoic acid which are key compounds in the gibberellins (GAs) biosynthesis path-way and therefore may inhibit cytochrome P450 monooxygenases, impairing the oxidation of ent-kaurene to ent-kaurenoic acid (Ribeiro, 2011; Magnitskiy et al., 2006; Denek; Keever, 1992). It has been reported that paclobutrazol has beneficial effects on physiological and morphological characteristics of different fruit trees. Application of PBZ reduces vegetative growth rate by improving water use efficiency and consequently increasing drought tolerance and the quality of produced fruits. Its most notable feature is the reduction of vegetative growth followed by a change in the distribution pattern of photosynthetic products, thereby, diverting them towards reproductive growth and the formation of flower buds, fruit set and fruit growth (Lever, 1986; Werner, 1993). Besides that it has been reported that PBZ promotes salt stress avoidance in peach (Abou-El-Khashab et al., 1997).

Generally, triazols reduces vegetative growth and decrease competition for photosynthetic products between vegetative and reproductive organs. Blocking gibberellin synthesis leads to a decrease in internode length, leaf area, number of leaves and consequently reducing growth
(Magnitskiy et al., 2006). A 40% reduction in leaf area and of 29% reduction in dry weight has been reported in peach trees by treatment with 2 g PBZ per tree. This reduction can decrease vegetative growth, consequently dropping production costs and environmental contamination through reducing mineral fertilization (Val et al., 1998). The present study has been designed to investigate the effect of PBZ on some vegetative and reproductive characteristics of peach cv. ‘Kardi’ in Saman region.

MATERIALS AND METHODS
Plant Material and Treatment:
This study was carried out on peach trees cv. ‘Kardi’ during 2011-2012 growth season in Saman region of Chaharmahal va Bakhtiari province, Iran. The experiment was performed in a factorial based completely randomized block design (CRBD) with three replications.

Studied factors were different levels of PBZ at 0, 0.5, 1 and 1.5 g a.i. per tree, as soil drench underneath tree canopy during 2 different application times of August 2011 and March 2012. The measured characters were: flower density on branch, final fruit set percentage, leaf chlorophyll content, average leaf area, shoot elongation, trunk radial growth and yield. The mentioned traits were measured during spring and summer 2012.

Vegetative Characteristics:
1. Flower Density:
Flower density on branch was measured by counting the numbers of flowers on a randomly selected branch with a specified size. The mentioned variable was calculated by the following formula.

\[
\text{Flower Density} = \frac{\text{Number of Leaves}}{\text{Branch Length (cm)}} \times 100
\]

2. Shoot Elongation:
Shoot elongation was determined by measuring the elongation of 10 mid-crown randomly selected branches per tree and calculating the average length elongation (branched were positioned in different directions within the tree canopy).

3. Trunk Growth:
To determine the trunk diameter growth, trunk diameter was measured (at 10 cm above the graft union at two stages during the beginning and at the end of the growing season) by caliper. This index was calculated as the percentage of trunk growth as followed.

\[
\text{Trunk Diameter Growth} = \frac{(\text{Final Diameter} - \text{First Diameter})}{\text{First Diameter}} \times 100
\]

4. Chlorophyll Content:
Chlorophyll content was measured according to Arnon (1967) method. Fresh young leaves (0.1 g) were selected from plants within each treatment, washed with deionized water and grind by acetone 80% in a porcelain mortar.

Remained leftovers in the mortar were completely washed and final volume was reached to 25 ml by acetone 80%. After centrifugation at 6000 rpm, absorption of samples were read at wavelengths of 663 and 645 nm. The device was first calibrated by control sample of acetone 80%. The following formulas were used for estimation of total chlorophyll, chlorophyll a and chlorophyll b contents:

- \[
\text{Chl a (mg g}^{-1} \text{FW}) = \frac{(12.7 \times (A 663) - 2.69 \times (A 645)) \times \frac{V}{W}}{}
\]
- \[
\text{Chl b (mg g}^{-1} \text{FW}) = \frac{(22.9 \times (A 645) - 4.68 \times (A 663)) \times \frac{V}{W}}{}
\]
- \[
\text{Total Chl (mg g}^{-1} \text{FW}) = \frac{(20.2 \times (A 645) + 8.02 \times (A 663)) \times \frac{V}{W}}{}
\]

Whereas, V: Volume of extract (ml), W: Fresh weight of the sample (g), and A: Absorbance at specific wave length.

5. Leaf Area:
In order to determine the average leaf area, 10 intact and fully matured leaves were harvested from the middle of branches, and the area of each of them was measured using leaf area meter (ADC Model: No SE 213C) and thereafter the mean leaf area was calculated.

Reproductive Characteristics:
1. Fruit Set:
To determine the fruit set percentage, the previously marked branches were used. Counting and calculating the percentage of fruit set were carried out before harvest. Fruit set percentage was determined by using the following formula.

\[
\text{Fruit Set} = \frac{\text{Total Fruit Set}}{\text{Total Bloom}} \times 100
\]

2. Tree Yield:
Yield per tree was recorded by weighting the total number of fruits per tree at harvesting time.

Data Analysis:
Data were statistically analyzed with MSTAT-C software and means were compared using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION
Effect of PBZ on Vegetative Growth:
Results indicate that application of PBZ has a significant effect on trunk diameter growth at the 1% probability level. This is while the interaction of treatments (application time × amount of PBZ) did not have a significant effect on this trait (Table 1). The mean comparison results showed that the lowest percentage of trunk diameter growth occurred by using 1.5 g a.i. PBZ per tree and the highest trunk diameter growth observed in the control trees (Fig. 1).

Analysis of variance (Table 1) indicated that the application time and PBZ levels have significant effect on shoot elongation at 1% probability level while the interaction of factors (application time × amount of PBZ) did not have a significant effect on this trait.
The lowest peach shoot elongation was achieved by the application of PBZ during March (Fig. 2). The lowest shoot elongation (24.15 cm) occurred by using 1.5 g a.i. PBZ per tree and the highest shoot elongation (43.95 cm) happened on the control trees (Fig. 3).

Paclobutrazol is a triazole type plant growth retardant and it is used to reduce vegetative growth of many plants such as potted flowering plants, indoor plants, annuals garden plants, fruit trees and ornamental trees (Reed et al., 1989; Denek and Keever, 1992). Paclobutrazol (pp333), an inhibitor of GA biosynthesis, has been shown to be very effective in inhibiting shoot growth in apple trees (Greene and Murray, 1983; Steffens et al., 1983; Watson and Jacobs, 2012), apricot (Kuden et al., 1995) and sunflower (Wample and Culver, 1983). Arzani and Roosta (2004) indicated that application of PBZ in apricot trees significantly reduced vegetative growth, total pruning dry weight, shoot growth and trunk cross sectional area. PBZ significantly reduced vegetative growth and the total dry weight of pruning and high level of PBZ caused the most growth inhibition. Therefore, PBZ treatment can benefit peach growers by saving pruning costs (Bahadori and Arzani, 2008). Erez (1986) reported that in peach, higher PBZ levels resulted in a stronger and longer period of vegetative inhibition.

**Table 1.** Analysis of variance of PBZ effect on the studied characteristics in peach cv. ‘Kardi’.

<table>
<thead>
<tr>
<th>SOV</th>
<th>df</th>
<th>Yield (kg/tree)</th>
<th>Trunk Diameter Growth</th>
<th>Shoot Elongation (cm)</th>
<th>Average Leaf Area</th>
<th>Chlorophyll Content</th>
<th>Final Fruit Set</th>
<th>Flower Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rep.</td>
<td>2</td>
<td>1.261 ns</td>
<td>0.890 ns</td>
<td>67.404 ns</td>
<td>318477 ns</td>
<td>0.009 ns</td>
<td>1.890 ns</td>
<td>31.945 ns</td>
</tr>
<tr>
<td>Application time (A)</td>
<td>1</td>
<td>19.440 ns</td>
<td>0.005 ns</td>
<td>314.650 ns</td>
<td>137410 ns</td>
<td>0.001 ns</td>
<td>30.827*</td>
<td>245.760**</td>
</tr>
<tr>
<td>Amount (B)</td>
<td>3</td>
<td>3.009 ns</td>
<td>9.137**</td>
<td>483.015 ns</td>
<td>2458305**</td>
<td>0.395**</td>
<td>95.514**</td>
<td>33.516 ns</td>
</tr>
<tr>
<td>A x B</td>
<td>3</td>
<td>5.596 ns</td>
<td>0.501 ns</td>
<td>48.478 ns</td>
<td>151586 ns</td>
<td>0.003 ns</td>
<td>0.601ns</td>
<td>42.623 ns</td>
</tr>
<tr>
<td>Error</td>
<td>14</td>
<td>8.49</td>
<td>9.09</td>
<td>14.64</td>
<td>11.64</td>
<td>12.78</td>
<td>11.13</td>
<td>9.86</td>
</tr>
<tr>
<td>C.V. (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

* and ** are significant at 0.05 and 0.01 of probability levels, respectively. While ns is not significant.

**Fig. 1.** Effect of different levels of PBZ on trunk diameter growth in peach cv. ‘Kardf’.

**Fig. 2.** Effect of different PBZ application times on shoot elongation in peach cv. ‘Kardi’.

**Fig. 3.** Effect of different PBZ levels on shoot elongation in peach cv. ‘Kardi’.

**Effect of PBZ on Leaf Characteristics:**
The results indicated that the PBZ levels had a significant effect on average leaf area and chlorophyll content at 1% probability level while the application time and interaction of factors (application time × amount of PBZ) had not the significant effect on these traits (Table 1). The Mean comparison indicated that the lowest leaf area (2334.17 mm²) occurred by using 1.5 g a.i. PBZ per tree and the highest leaf area (3782.67 mm²) happened on the control trees (Fig. 4). The results also showed that the application of 1.5 g a.i. of PBZ in peach trees increased the chlorophyll content compared to control tree (Fig. 5).
It has been shown that triazole compounds retard shoot growth, reduce leaf extension and increase chlorophyll content (Jaggard et al., 1982; Buchenauer et al., 1984; Coston, 1986). The increment of chlorophyll content is due to enhanced chlorophyll biosynthesis or is simply a "concentrating effect" due to the decrease leaf expansion or the increase of leaf thickness (Barnes et al., 1989).

**Effect of PBZ on Flower Density, Fruit Set and Yield:**

In this study, application time of PBZ had a significant effect on flower density on the branches at 1% probability level. This while, PBZ application levels and interaction of factors (application time × amount of PBZ) did not have a significant effect on these traits (Table 1). The Mean comparison indicated that applications of PBZ in August was very effective on flower density in comparison with March (Fig. 6).

With regards to PBZ effects on final fruit set, the results showed that application time and amount of PBZ had significant effects on this trait at 1% and 5% probability level respectively. This was while interaction of factors (application time × amount of PBZ) did not have a significant effect on fruit set (Table 1). The Mean comparison indicated that lowest fruit set percentage (17.9) occurred by using PBZ in March and the highest fruit set percentage (20.16) happened by use of PBZ in August (Fig. 7). Application of 1.5 g a.i. PBZ per tree had the greatest impact on the increment of final fruit set in peach trees (Fig. 8).

The results also indicated that PBZ did not have a significant effect on peach tree yield in the present study. Application of triazoles may have an impact on plant reproductive characteristics depending on plant species, concentration
and application time. Sedighi et al. (2008) reported that application of PBZ in apricot trees increases the percentage of fruit set and reduces their vegetative growth. Triazoles have been shown to be very effective for increasing flower numbers in apple trees (Lever, 1986). Moreover, it has been shown that PBZ increases fruit numbers in sweet cherries (Granger, 1993). Arzani and Roosta (2004) indicated that application of PBZ did not affect fruit load, crop density and fruit total soluble solids in apricot. Furthermore, there are also other reports that show the effectiveness of PBZ on tree reproductive characteristics during the second year after PBZ application (Lever, 1986; Erez, 1986).

**CONCLUSION**

According to the results, PBZ can be used to improve vegetative and reproductive characteristics of peach cv. ‘Kardi’ and the amount applied in this study have a positive correlation with its efficacy. The results also indicated that application of PBZ in August had the greatest effect on reproductive characteristics. This was while PBZ application during March had the greatest effect on vegetative features.

**REFERENCES**


