Paclobutrazol and Tip Pruning in the Management of ‘Palmer’ Mango Trees in the Semi-Arid Region of Brazil

M.B. Oliveira, M.C.T. Pereira, G.P. Mizobutsi, M.A.C. Mouco
V.M. Maia, J.F. Silva, J.A.A. Oliveira, Embrapa Semiárido
I.J.S. Costa, S. Nietsche and E.F. Santos, Petrolina-PE
Department of Agricultural Sciences, Brazil
Janaúba-MG, Brazil

Keywords: Mangifera indica, yield, branch length, fruit quality

Abstract

Paclobutrazol (PBZ), a synthetic plant growth regulator, was applied to mango trees to control vegetative growth and induce flowering. The objective of this study was to evaluate the effect of PBZ and tip pruning on flowering, yield and fruit quality of mango trees, cultivar ‘Palmer’, in irrigated conditions in a semi-arid region of Brazil. Uniform trees were selected at a commercial farm located in Jaíba County, Minas Gerais, Brazil. A randomized complete block design experiment was used with two methods of pruning and five different dosages of PBZ (0, 0.3, 0.6, 0.9 and 1.2 g (a.i.) ml⁻¹ PBZ), with four replicates and one plant per plot in a factorial combination. The PBZ was dissolved in 2 L of water and applied directly onto the soil. Vegetative growth parameters, reproductive characteristics, fruit quality and yield were evaluated. Differences among treatments were determined using analysis of variance at 5% of probability. Means separation among the treatments was performed using a Tukey’s test, and regression models were developed. The dosage of 0.86 g (a.i.) ml⁻¹ promoted a significant reduction in branch length. The different dosages of PBZ in conjunction with tip pruning produced significant flowering. Applying PBZ at 0.3 g (a.i.) ml⁻¹ increased the yield per branch and fruit firmness and reduced fruit length, fruit weight, pH and soluble solids. The fruit yield was not affected by tip pruning or PBZ application.

INTRODUCTION

The cultivation of mango (Mangifera indica L.) has great importance in the Brazilian semi-arid region in the northern region of Minas Gerais, occupying extensive planted areas primarily within the Jaíba Irrigation Project. In this region, which has a hot, dry climate, mango trees can produce fruit of excellent quality during any part of the year under irrigation conditions, provided that technology is adopted to manage the induction of flowering.

Flowering management in mango trees using plant growth regulators is a practice that enables the scheduling of production for periods when the fruit value is higher (Cardoso et al., 2007). Paclobutrazol (PBZ) is widely used in mango crops, and its application inhibits the synthesis of gibberellins, alters the phloem/xylem ratio, and affects the redistribution of metabolic substances necessary for the processes of flowering and fruiting (Taiz and Zeiger, 2012).

The use of plant regulators has shown great potential in the cultivation of mango in cultivars such as ‘Tommy Atkins’ (Silva and Neves, 2011), ‘Rosa’ (Cardoso et al., 2007), ‘Haden’, ‘Kensington’ and ‘Mangovar’ (Johnson and Robinson, 2000), possessing an essential function in inducing flowering in periods more appropriate for commercialization.

The ‘Palmer’ cultivar displays high plant vigor yet suffers from the high temperatures and resulting high water conduction under an irrigated regime in the northern region of Minas Gerais, which tends to compromise the management of flowering. The practice of tip pruning in productive branches prevents continuous vegetative growth, which is a consequence of inappropriate climate conditions and has
allowed for the high rate of flowering in axillary buds. Davenport (2006) confirms that the pruning of the tips of branches stimulates the cycles of branching of lateral shoots and removes structures that inhibit reproductive budding originating from the previous productive cycle.

Responses to the application of plant growth regulators in mango crops among different commonly used commercial cultivars are observed to vary with the influence of climate and the age and nutrition of the plant (Albuquerque et al., 2002). Moreover, management of branch pruning is performed without further studies regarding its direct effect on the production and post-harvest quality of fruits. Thus, studies of the doses of PBZ to be applied and the management of branch pruning are necessary to obtain improved productive and economic yields through the practice of flowering induction.

The objective of this study was to evaluate the effect of different doses of PBZ in combination with branch pruning on the vegetative characteristics, production and post-harvest quality of ‘Palmer’ mango fruits.

MATERIALS AND METHODS

The experiment was conducted in a commercial orchard of ‘Palmer’ mango trees grafted with ‘Espada’ on the Agroindustrial Rio Verde property, located at 15°21.616’S and 43°42.134’W in the municipality of Jaíba-Minas Gerais (MG), Brazil, a region characterized as of Aw climate, according to the Köppen classification (Reis et al., 2011). The soil of the experimental area is characterized as Red Eutrophic Latosol (Eutrudox) with clayey texture (Silva et al., 2011). The experiment was performed in a six-year-old orchard with four years of vegetative period followed by two years with productive cycles. The spacing between plants was 8×5 m, with micro-sprinkler irrigation.

The experimental design was that of randomized blocks in a factorial arrangement of 2×5, with the first factor being the pruning management (with and without branch pruning) and the second factor being the dose of PBZ: 0; 0.6; 0.9 or 1.2 g of active ingredient per linear meter of crown. The treatments were distributed in four blocks, and one plant was used per experimental plot. The parameters evaluated in the experiment were branch length and diameter, number of inflorescences and number of fruits per branch, production per branch, productivity and post-harvest fruit quality, including length, diameter and mean mass of fruits, ripening grade, pulp and peel color, juice yield, titratable acidity, soluble solids and pH.

The experiment began with the application of PBZ to the soil on June 22, 2011, when the plant displayed two vegetative cycles. The commercial product 25% Cuttar® in homogeneous solution was used, with each of the PBZ doses mixed in 2 L of water. Beginning thirty days after the application of PBZ, the length and diameter of each of the 12 branches selected in the middle portion of the crown were measured at intervals until the end of flowering, which occurred between August 27 and October 21, 2011.

The management of floral induction in the orchard was performed following Albuquerque et al. (2002). The gradual reduction of irrigation depth was performed 50 days after the application of PBZ until 50% of the volume applied was reached. This volume was associated with three applications of 3% potassium sulfate, with the last application supplemented with ethephon at a dose of 50 ml per 100 L of water. Prior to the first application of calcium nitrate (total of three applications, at seven day intervals), 105 days after the application of PBZ, on November 3, 2011, the tip pruning management began. The pruning was performed by manually breaking the tip of the branch at approximately five centimeters from its apex.

When the plants exhibited inflorescences on at least 80% of the branches, which occurred on 11/21/2011, the number of inflorescences per branch was assessed. On 03/02/2011, the number of fruits per branch was counted. The fruits were collected on 05/14/2011, 150 days after flowering.

The data collected were subjected to an analysis of variance and F-test using SISVAR (Ferreira, 2003), and a transformation factor was applied when necessary.
RESULTS AND DISCUSSION

Increasing PBZ doses resulted in shorter branch lengths in ‘Palmer’ mango trees (Fig. 1a), which is in agreement with the findings of Mouco et al. (2010). Moreover, this effect in contrast with the observed trend for branch diameter (Table 1), in which a differentiated effect on diameter was observed between production periods that could be attributed to the natural development of branches.

Mendonça et al. (2003) stated that the first effect of the use of PBZ is the stoppage of vegetative growth, affecting the new sprouts and reducing the extension of branches. Therefore, the management of vegetative growth becomes of great relevance in the production of fruit crops because it prevents excessive sprouting, favoring precocious flowering and fruiting in young plants (Rademacher, 2004). The reduced extension of branches and the favorable conditions for the maintenance of metabolism enable the accumulation of photoassimilates, leading to an increase in the diameter and swelling of buds (Srisvatava, 2002).

Significant differences were observed in the number of inflorescences (P<0.05) in the interaction between the tip pruning and the PBZ doses applied. The greatest number of inflorescences was observed when tip pruning was used in ‘Palmer’ mango trees (Table 2 and Fig. 1b). The PBZ doses applied to ‘Palmer’ mango trees showed a significant effect (P<0.05) on the number of fruits per branch (Fig. 1b) and the production per branch (Fig. 1a), with better results when 0.5 g (a.i.) ml⁻¹ of PBZ were applied. The greater number of inflorescences observed when a dose of approximately 0.6 g (a.i.) ml⁻¹ of PBZ was used directly influenced the number of fruits per branch and consequently the production per branch.

According to Srivastava (2002), the reduction in the auxin content in the apices of the branches, which results from tip pruning, can momentarily alter the direction of the translocation of assimilates, allocated more assimilates toward stimulating the floral emission of the axillary buds of the branches in flowering conditions and thus the fixation of inflorescences and fruits. The PBZ, in conjunction with the climatic conditions and the state of maturation of the branches, creates conditions favorable to flowering (Albuquerque et al., 2002), which explains the greater flowering from a dose of 0.3 g ml⁻¹.

When studying the flowering and fruiting of ‘Rosa’ mango trees promoted by different PBZ doses, Cardoso et al. (2007) observed the emergence of a greater number of inflorescences. Mouco and Albuquerque (2005) state that the use of PBZ is only efficient in the induction of flowering during hot periods when applied in higher concentrations, which promotes flowering with very compact panicles. However, the results obtained showed that low concentrations of PBZ together with branch tip pruning were responsible for providing greater flowering per branch in ‘Palmer’ mango trees.

PBZ not only inhibits the synthesis of gibberellins but also increases the ratio of hermaphroditic flowers in mango tree panicles and inhibits the synthesis of ethylene, which results in a greater number of fruits retained per plant (Singh, 2001); this explaining the greater number of fruits per branch in this study.

Treatments did not differ statistically (P<0.05) relative to fruit production, suggesting the use of practices that incur lower production costs. Mouco and Albuquerque (2005) observed greater production when a dose of 2.0 g (a.i.) ml⁻¹ was used on ‘Tommy Atkins’ mango trees.

Quality assessments of fruit of the ‘Palmer’ cultivar showed that the luminosity (L) of pulp and peel (Fig. 2a) and the hue angle of the pulp (Fig. 2a) showed significant differences (P<0.05) when the PBZ doses were altered. The chromaticity index (C) exhibited a significant difference with branch tip pruning management with values of 61.60 and 63.36 for treatments without tip pruning. The hue angle (°Hue) of the peel varied with PBZ dose (Fig. 2a) and tip pruning. The ripening grade of pulp did not differ statistically among the treatments according to the F-test (P<0.05).

The soluble solids content differed statistically in the interaction between post-harvest days and PBZ doses, with the second period of evaluation presenting greater rates
of soluble solids (Table 3). An increase in the content of soluble solids in fruits grown without tip pruning was observed in the second evaluation period. The inverse occurred in the first period, most likely because of the difficulty of standardizing the moment of fruit harvest (Fig. 2b). The pH increased in the absence of PBZ despite the trend toward stability when the PBZ doses are increased (Fig. 2b). The mean values of titratable acidity and the SS/TA ratio did not show significant differences (P<0.05).

Chitarra and Chitarra (2005) state that the soluble solids content represents one of the best ways of evaluating the level of sweetness of the product. Because the plants that did not receive PBZ displayed the lowest number of fruits, there was likely a greater accumulation of photoassimilates in those fruits, leading to greater levels of soluble solids.

In the case of fruit crops, the concentration of soluble solids tends to increase with the evolution of ripening because of the biosynthesis processes or the degradation of polysaccharides (Borguini and Silva, 2005). Because of these processes, the increase in pH occurs simultaneously with the increase in the soluble solids content. Chitarra and Chitarra (2005) confirmed that organic acids are found dissolved in the cell vacuoles both in a free form and in combination with salts, esters, and glycerides. With the process of ripening, fruits tend to increase in pH as the biochemical and metabolic processes involved in ripening convert acid compounds into other chemical compounds. In fruits, organic acids not only contribute to acidity but to the characteristic aroma.

The fruit mass varied significantly with evaluation day, branch tip pruning, PBZ doses and the interaction between the tip pruning and PBZ doses. The effect of PBZ doses did not differ with tip pruning, except for the 0.3 g (a.i.) ml\(^{-1}\) dose with which branch tip pruning resulted in lower mean fruit mass than did the absence of tip pruning (Table 2). The greater number of fruits per plant and the greater production per plant most likely influenced fruit mass because the greater numbers of fruits for the same plant led to competition for photoassimilates and consequently smaller fruits. Lower fruit mass was observed when 0.68 g (a.i.) ml\(^{-1}\) of PBZ was applied without the use of tip pruning and when 1.20 g (a.i.) ml\(^{-1}\) of PBZ was applied with tip pruning (Fig. 3a).

The length of fruits showed a significant difference (P<0.05) only for the different PBZ doses (Fig. 3b). With respect to the fruit diameter, significant differences were observed for branch tip pruning and the different PBZ doses used (Table 3). Despite of the fact that only at 0.3 g (a.i.) ml\(^{-1}\) of PBZ was significant may indicate that this is not so relevant. It is suggested that the decrease in the fruit diameter observed in the present work may have occurred due the high number of fruits per plant with lower fruit mass. The mean fruit length showed a square root response relative to the PBZ doses applied, reaching its greatest value in the treatment without PBZ, showing a reduction from a dose of 0.3 g (a.i.) ml\(^{-1}\), and tending toward stability with increased PBZ doses. Similar behavior was observed for the fruit diameter, with higher values when there was no application of PBZ and a considerable reduction when PBZ was applied. The stability of this reduction was noted beginning at 0.3 g (a.i.) ml\(^{-1}\), and the smallest fruit diameter was obtained when 0.58 g (a.i.) ml\(^{-1}\) of PBZ was applied along with branch tip pruning and when 1.2 g (a.i.) ml\(^{-1}\) of PBZ without branch tip pruning (Fig. 3b).

Competition for assimilates among fruits affects the growth rate of the plant and the fruit setting in many species. Thus, the increase in the number of fruits in the plant can increase the proportion of photoassimilates allocated among fruits at the expense of vegetative growth (Andriolo and Falcão, 2000). The increase in the number of fruits set induces competition for assimilates among the fruits, leading to reduction in fruiting and in soluble solid content, as previously observed in tomato (Bertin et al., 1998) and ‘Cantaloupe’ melon (Valantin-Morison et al., 2006).

There were no significant differences (P<0.05) among the treatments with PBZ or branch tip pruning with respect to productivity, with an overall mean of 23.6 t ha\(^{-1}\), perhaps because of the different number of productive branches among plants, even though the greatest uniformity possible was sought.
CONCLUSIONS

Application of PBZ in doses greater than 0.3 g (a.i.) ml⁻¹ in association with tip pruning promote greater flowering and fruit production per branch, while also reducing the mass, size, soluble solid content and pH of fruits in mango trees of the ‘Palmer’ cultivar.

ACKNOWLEDGEMENTS

Special thanks to the financial support of the Minas Gerais Research Foundation (Fundação de Amparo à Pesquisa do Estado de Minas Gerais – FAPEMIG), Syngenta, Solução Agronegócios, Aminoagro and Nutrivale Agrícola.

Literature Cited


Academic Express, New York.

Tables

Table 1. Means with transformation factor (y+1)^0.5 of the branch diameter of ‘Palmer’ mango trees for the initial data and 58 days after the beginning of the treatments.

<table>
<thead>
<tr>
<th>Evaluation date</th>
<th>Branch diameter (cm)</th>
<th>Arithmetical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(y+1)^0.5</td>
<td></td>
</tr>
<tr>
<td>08/27/2011</td>
<td>3.06 b</td>
<td>8.58</td>
</tr>
<tr>
<td>10/21/2011</td>
<td>3.16 a</td>
<td>9.14</td>
</tr>
</tbody>
</table>

Means followed by distinct letters differ based on an F-test at the 5% probability level (P<0.05).

Table 2. Means with transformation factor (y+1)^0.5 of the number of inflorescences per branch and mean fruit mass of ‘Palmer’ mango trees subjected to different paclobutrazol doses and two management regimes of branch pruning.

<table>
<thead>
<tr>
<th>Tip pruning</th>
<th>Number of inflorescences</th>
<th>Paclobutrazol dose (g (a.i.) ml^-1)</th>
<th>Mean fruit mass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.0 0.3 0.6 0.9 1.2 0.0 0.3 0.6 0.9 1.2</td>
<td></td>
</tr>
<tr>
<td>With</td>
<td>1.4 a 2.2 a 2.1 a 2.2 a 2.1 a 458.1 a 341.6 b 377.8 a 372.2 a 349.2 a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without</td>
<td>1.1 b 1.4 b 1.4 b 1.4 b 1.4 b 471.5 a 381.5 a 378.9 a 379.1 a 357.2 a</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Means followed by distinct letters in the column differ based on an F-test at the 5% probability level (P<0.05).

Table 3. Mean values of soluble solid content of fruit juice and fruit diameter of ‘Palmer’ mango trees subjected to different paclobutrazol doses and two regimes of branch pruning.

<table>
<thead>
<tr>
<th>Tip pruning</th>
<th>Fruit diameter (cm)</th>
<th>Soluble solid content (°Brix)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Paclobutrazol dose</td>
<td>Days postharvest</td>
</tr>
<tr>
<td></td>
<td>0.0 0.3 0.6 0.9 1.2</td>
<td>1 7</td>
</tr>
<tr>
<td>With</td>
<td>8.5 a 7.6 b 7.9 a 7.9 a 7.8 a</td>
<td>9.5 B a</td>
</tr>
<tr>
<td>Without</td>
<td>8.5 a 8.0 a 8.0 a 7.9 a 7.8 a</td>
<td>8.5 B c</td>
</tr>
</tbody>
</table>

Means followed by distinct letters in the column differ based on an F-test at the 5% probability level (P<0.05).

*Means followed by distinct letters, lowercases in the column and uppercase in the row, differ based on an F-test at the 5% probability level (P<0.05).
Figures

**Fig. 1.** a) Branch length ($\hat{Y}=5.69^{**}-2.37x^{**}+1.37x^{2*}$, $R^2=0.96$) and fruit production per branch ($\hat{Y}=1.10^{*}-0.21x^{**}+0.30x^{0.5**}$, $R^2=0.87$) of ‘Palmer’ mango trees subjected to different paclobutrazol (PBZ) doses; and b) Number of inflorescences per branch with tip pruning ($\hat{Y}=1.38^{**}-1.42x^{**}+2.17x^{0.5**}$, $R^2=0.96$) and without tip pruning ($\hat{Y}=1.14^{**}-0.39x^{**}+0.67x^{0.5**}$, $R^2=0.95$) and number of fruits per branch ($\hat{Y}=1.18^{*}-0.47x^{**}+0.66x^{0.5**}$, $R^2=0.84$) of ‘Palmer’ mango trees subjected to different paclobutrazol (PBZ) doses. Mean values with transformation factor $(y+1)^{0.5}$.

**Fig. 2.** a) Luminosity ($L$) of pulp ($\hat{Y}=51.75^{**}-9.90x^{*}+13.61x^{0.5**}$, $R^2=0.89$) and peel ($\hat{Y}=57.97^{**}-5.37x^{**}+12.23x^{0.5**}$, $R^2=0.98$), hue angle ($^\circ$Hue) of pulp ($\hat{Y}=68.91^{**}-2.27x^{**}+5.84x^{0.5**}$, $R^2=0.98$) and peel ($\hat{Y}=69.23^{**}-15.67x^{**}-41.62x^{2**}+22.21x^{3**}$, $R^2=0.99$) of fruits of ‘Palmer’ mango trees subjected to different paclobutrazol doses; and b) Level of soluble solid ($\hat{Y}=16.06^{**}+3.90x^{**}-7.40x^{0.5**}$, $R^2=0.98$) and pH of fruit juice ($\hat{Y}=4.38^{**}+0.72x^{**}-1.14x^{0.5**}$, $R^2=0.96$) of ‘Palmer’ mango trees subjected to different paclobutrazol doses.
Fig. 3. a) Mean mass of fruits of ‘Palmer’ mango trees with tip pruning \( \bar{Y}=453.64^{**}+143.06x-235.14x^{0.5**}, R^2=0.78 \) and without tip pruning \( \bar{Y}=470.05^{**}+89.06x-194.88x^{0.5**}, R^2=0.98 \) submitted to different paclobutrazol doses; and b) Fruit length \( \bar{Y}=3.79^{**}+0.26xns-0.42x^{0.5**}, R^2=0.89 \) and fruit diameter with tip pruning \( \bar{Y}=843^{**}+1.13x-1.72x^{0.5**}, R^2=0.76 \) and without tip pruning \( \bar{Y}=8.47^{**}+0.43x-1.02x^{0.5**}, R^2=0.98 \) of ‘Palmer’ mango trees subjected to different paclobutrazol doses. Mean values with transformation factor \((y+1)^{0.5}\) for fruit length.