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# Responses of pruning and paclobutrazol in mango (*Mangifera indica* L.): changes in tree vigour, flowering and phenols

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## Abstract

Dominant vegetative phase, if not regulated, can adversely affect the mango production particularly under high density planting systems. Pruning after fruit harvest and use of paclobutrazol (PBZ) have been identified as common strategies for tree vigour regulation and productivity enhancement in mango. The objective of the present study was to investigate the effects of 50% pruning of current and previous season vegetative growth and PBZ (3 mL/ m canopy diameter) on tree vigour, flowering and phenol contents in three mango cvs. Raspuri, Dashehari and Amrapali. Suppression of plant height, tree girth, canopy spread, shoot length and girth was witnessed with PBZ application in trees pruned to 50% of current season growth followed by trees pruned to 50% of previous season growth and unpruned trees. Early flowering witnessed as a result of PBZ application led to advanced fruit harvest by 20.4, 13.0 and 14.7 days in trees pruned to 50% of current season growth and 18.7, 13.7 and 15 days in trees pruned to 50% previous season growth in the cvs Raspuri, Dashehari and Amrapali, respectively. Drastic increase in total phenols, total flavonoids and phenolic acid contents were observed at 75 days after PBZ application in PBZ treated unpruned trees and in trees pruned to 50% of current season growth followed by in trees pruned to 50% of previous season growth. The high levels of o-coumaric acid, 4-hydroxy benzoic acid and salicylic acid and low levels of caffeic acid and t-cinnamic acid were observed following PBZ application in tree pruned to 50% of current season growth and unpruned trees compared to control. From the study it was apparent that the pruning of trees to 50% of current season growth and PBZ application are vital for regulating tree size, early flowering and advancing fruit harvest in mango and such beneficial effects of treatments were mediated through increases in phenols and flavonoids contents.

**Key words**: Mango, pruning, paclobutrazol, vigour, phenolic acids, flavonoids, flowering

## Introduction

Mango (*Mangifera indica* L.) is commercially important fruit crop of India cultivated in an area of 2.50 million ha with a production of 18.08 million tonnes (Anon., 2013). Mango flowering occurs sometimes during November to January under tropical as well as subtropical conditions and has strong dependency on prevailing environmental conditions and the age of terminal resting shoots (Davenport, 2007). Mango under tropical conditions is bound to grow vegetatively and can affect the reproductive phase particularly in high density planting systems if not regulated properly. Excessive vegetative growth causes less flowering as a result of unmanageable and large tree size. Pruning and the growth retardants are the two simple and effective means of controlling the tree vigour and enhancing flowering. While pruning exerts growth inhibitory response in developing trees by reducing total leaf area and by delaying time of leaf development, and thereby affecting photosynthesis rate (Yeshitela, 2005), the growth retardant application induces similar responses by modifying hormonal levels and plant water relations (Upreti *et al.,* 2013; Nafeez *et al.,* 2010). From the available literature is was evident that the growth inhibitory response of pruning are less studied in mango, although some studies on its growth inhibitory responses have been made in other fruit crops (Crane, 2004). Most of the reports in mango targeted pruning application as a means of induction for early and regular flowering (Singh *et al.,* 2009; Balamohan and Gopu, 2014). Among the chemicals suggested for growth retardation, paclobutrazol is considered as one of the most versatile plant growth retardant which restricted vegetative growth and induced flowering in many fruit crops like apple and pear (Williams and Edgerton, 1983), peach (Erez, 1984), citrus (Aron *et al.*, 1985) and mango (Sarkar and Rahim, 2012). The paclobutrazol induced tree vigour restriction and flowering responses have been reported as the consequences of modifications in physiological activities as well as changes in cellular metabolites (Nafeez *et al,* 2010; Abdel Rahim *et al.*, 2011; Upreti *et al.,* 2013). Among the cellular metabolites, accumulation of phenols in vegetative organs has been depicted as one of the important factors in imparting of vigour restriction effects in mango (Murthi *et al.,* 2000; Murthi and Upreti, 2003) and also for induction of flowering (Patil *et al.,* 1992). However, the possible mechanism by which phenols exerts such effects are less understood. In mango, high phenol content in terminal buds due to paclobutrazol application restricted the vigour and enhanced the flowering (Kurian and Iyer, 1992). Palanichamy *et al.* (2012) and Kumar *et al.* (2014) reported and steady increase in phenol content with advancement of flower bud differentiation. In the present investigation, attempts have been made to investigate effects of pruning and paclobutrazol alone and in combination on vigour restriction, induction of flowering and fruit yield besides phenols and flavonoids contents in three commercially important mango cultivars with a view to understand the role of phenols and flavanoids in vigour control and flowering, and to suggest recommendations for high density orchard system in mango.

## Material and methods

The investigations were conducted at the experimental farm of Indian Institute of Horticulture Research, Bangalore on 4 years old trees of mango cvs Raspuri, Dashehari and Amrapali grafted on Olour rootstock and spaced at 7 x 7 m distance during the years 2013-2014. The experiment was laid out with three replications in a factorial randamized block design with various combinations of pruning (pruning to 50% of current season growth, pruning to 50% of previous season growth and no pruning) and paclobutrazol (PBZ) application @ 3 mL/m canopy diameter. Six trees were maintained under each treatment. Pruning was carried out during 3rd week of July, 2013. PBZ (25% w/v *a.i.*; Zeneca Limited, Surry, UK) was applied once as soil drench during the month of September, 2013 by spreading in a circular band of 25 cm width at a radial distance of 75 cm from the tree trunk. Only water was applied to the control plants. The different treatment combinations used were $T_1$- pruning to 50% of current season growth + PBZ application @ 3 mL/ m canopy diameter, $T_2$- pruning to 50% current season growth, $T_3$- pruning to 50% previous season growth + PBZ application @ 3 mL/m canopy diameter, $T_4$- pruning of 50% previous season growth, $T_5$- no pruning + PBZ application @ 3 mL/m canopy diameter**,** $T_6$- no pruning and no PBZ application (control). During the experimentation, the average maximum and minimum temperatures were 29.4 and 19 $^0$C, respectively, relative humidity 74.5 % and total rainfall of 732.7 mm.

The data of the morphological characters like plant height, trunk girth and canopy spread were measured before and after six months of paclobutrazol application and difference increase between these were calculated. Canopy spread was measured as the average spread in E-W and N-S directions. After the emergence of new shoots, 50 shoots were tagged in all directions and the girth and length of new shoots were recorded during the month of December. Similarly, observations on days for 50% flowering and percent flowering were recorded from tagged shoots. Data on number of days from flowering to harvest and yield were also recorded and yield per hectare was calculated. Besides, leaf samples at 75 days after paclobutrazol application were drawn for determining the contents of total phenols, total flavonoides and phenolic acids.

**Estimation of total phenols:** Total phenols were estimated spectrophotometrically using Folin-Ciocalteu reagent according to Bray and Thorpe (1954) and the values were presented as mg/g fresh weight.

**Estimation of total flavonoides (TF):** TF content was estimated spectrophotometrically as per Zhishen *et al.* (1999) and the values were expressed as mg/g fresh weight.

**Estimation of phenolic acids:** Estimation of different phenolic acids was carried out using High Pressure Liquid Chromatography. Leaf samples were extracted according to Weidner *et al.* (1999). Fresh leaf sample (5 g) was homogenized in liquid nitrogen and the phenolic acids were extracted in 50 mL of 80% chilled methanol (v/v) for one hour at room temperature. The extract was centrifuged at 5000 rpm at room temperature and the residue was re-extracted again with another 50 mL of 80% methanol. The supernatants were pooled and dried in a rotary evaporator at 40 $^0$C under reduced pressure. The residue was dissolved in 30 mL distilled water and pH adjusted to 2.8 with 6 M HCl. The free phenolic acids were extracted 3 times with 30 mL of chilled diethyl ether. The Ethereal portion was collected and further evaporated to dryness under vacuum at 40 $^0$C. The residue was dissolved in 2 mL HPLC grade methanol and filtered through 0.2 µm syringe filter (Millipore, USA) for HPLC analysis. The HPLC system (Prominence, Shimadzu, Japan) employed had photodiode array detector (SPD-M20A) and reverse phase $C_{18}$ column (5 µm, 4.6 x 250 mm, Supel co, USA). Both the detector and column temperatures were set at 40 $^0$C. The detector was operated at 280 nm. A binary gradient of solvent system consisted mobile phase A with 10% methanol and B methanol/acetic acid (97.5: 2.5 v/v). The gradient was isocratic with A for 10 min followed linear increase of B in A to 18% for 15 min, 70% for 20 min, 75% for 30 min, 80% for 35 min and 100% B for 40 min at the uniform flow rate of 1.0 mL/min. The 10 phenolic acids namely o-caumaric acid, gallic acid, pyrocatechol, 4-hydroxy benzoic acid, caffeic acid, salicylic acid, rosmarinic acid, t-ferrulic acid, sinapic acid and cinnamic acid were quantified by comparing their respective retention times and peak areas using their standards (Sigma-Aldrich, USA).

All the data were statistically analysed using Agri Stat software and the difference of means were compared at $P$=0.05 level of significance.

## Results and discussion

**Morphological attribrutes:** From the results it was apperant that the morphological attributes like plant height, trunk girth and canopy spread were significatly reduced by pruning alone in cvs Raspuri and Dashehari and by PBZ in all the three cultivars (Table 1). However, interaction effects between pruning and PBZ were non-significant. $T_1$ treatment recorded 62, 52 and 61.5% lesser plant height, 50.2, 27.3 and 35.3% lesser trunk girth and 51.5, 45.8 and 35.3% lesser canopy spread in the cvs Raspuri, Dashehari and Amrapali, respectively followed by $T_5$ when compared with control ($T_6$). Length and girth of new shoots also differed significantly among the treatments with PBZ, and non-significantly with pruning as well as interaction of pruning and PBZ (Table 2). Raspuri, Dashehari and Amrapali trees recorded 39.6, 35.2 and 26.5% decline in shoot length and 23.7, 19.0 and 14.9% decline in shoot girth under $T_1$, followed by 35.3, 26.7 and 18.3% decline in shoot length and 23.5, 18.8 and 11.7% decline in shoot girth under $T_5$ treatment compared to control ($T_6$). The above results confer the findings of Balamohan and Gopu (2014) in Alphonso that light pruning of current seasons's growth is advantageous for tree vigour regulation without affecting the flowering. Such growth reduction responses of pruning might be the result of decline in photosynthate production following pruning induced decline in total photosynthetic area, delay in leaf development and changes in phytohormonal production and their translocation to roots. Similarly, the growth inhibitory response of PBZ observed in the study are in line with earlier findings of Sarkar and Rahim (2012) and Nafeez *et al.* (2010) in mango. Thus the combination of pruning and PBZ is expected to reduce the tree growth as evident from our results.

**Flowering characters:** Effects of pruning and paclobutrazol were significant with respect to % flowering shoots and number of days for 50% flowering (Table 3). However their interaction effect was non-significant. $T_1$ and $T_5$ treatments were at par with

Table 1. Effects of pruning and paclobutrazol on vegetative growth parameters in different varieties of mango

| Treatments | Increase in plant height (m) | | | Increase in tree girth (cm) | | | Canopy spread (m) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Raspuri | Dashehari | Amrapali | Raspuri | Dashehari | Amrapali | Raspuri | Dashehari | Amrapali |
| $T_1$ | 0.16 | 0.11 | 0.10 | 0.95 | 1.03 | 0.93 | 0.303 | 0.233 | 0.188 |
| $T_2$ | 0.36 | 0.25 | 0.20 | 1.54 | 1.16 | 1.10 | 0.433 | 0.458 | 0.258 |
| $T_3$ | 0.26 | 0.21 | 0.21 | 0.90 | 1.34 | 0.74 | 0.333 | 0.283 | 0.233 |
| $T_4$ | 0.41 | 0.35 | 0.36 | 1.75 | 1.68 | 1.16 | 0.416 | 0.466 | 0.291 |
| $T_5$ | 0.21 | 0.13 | 0.18 | 1.13 | 1.11 | 0.90 | 0.325 | 0.266 | 0.218 |
| $T_6$ | 0.43 | 0.23 | 0.26 | 1.91 | 1.43 | 1.48 | 0.626 | 0.491 | 0.291 |
| SEM | | | | | | | | | |
| Pruning | 2.51 | 4.97 | 0.2 | 0.25 | 0.18 | 0.1 | 3.38 | 4.03 | 3.24 |
| PBZ | 2.00 | 4.05 | 0.16 | 0.21 | 0.14 | 0.08 | 2.76 | 3.29 | 2.64 |
| Pruning x PBZ | 3.56 | 7.03 | 0.28 | 0.36 | 0.25 | 0.14 | 4.7 | 5.7 | 4.58 |
| CD at 5% | | | | | | | | | |
| Pruning | 7.93 | 0.15 | 0.63 | 0.81 | 0.57 | 0.32 | 0.1 | 0.12 | 0.1 |
| PBZ | 6.48 | 0.12 | 0.51 | 0.66 | 0.46 | 0.26 | 8.7 | 0.1 | 8.33 |
| Pruning x PBZ | 0.11 | 0.22 | 0.89 | 1.15 | 0.81 | 0.45 | 0.15 | 0.17 | 0.14 |
| Significance at $P$=0.05 | | | | | | | | | |
| Pruning | 21.05 | NS | 6.29 | NS | NS | NS | 6.46 | 4.2 | NS |
| PBZ | 58.39 | 7.3 | 14.2 | 9.31 | 5.38 | 17.37 | 36.6 | 31.4 | NS |
| P running x PBZ | NS | NS | NS | NS | NS | NS | NS | NS | NS |

*PBZ- paclobutrazol
$T_1$ – pruning of 50 % current season growth + soil application of PBZ @ 3 ml/m canopy diameter
$T_2$ – pruning of 50 % current season growth
$T_3$ – pruning of 50 % previous season growth + soil application of PBZ @ 3 ml/m canopy diameter
$T_4$ – pruning of 50 % previous season growth
$T_5$ – no pruning + soil application of PBZ @ 3 ml/m canopy diameter
$T_6$ – no pruning + no PBZ (control)

Table 2. Effect of pruning and paclobutrazol on shoot length and shoot girth in different varieties of mango

| Treatments | Shoot length (cm) | | | Shoot girth (mm) | | |
|---|---|---|---|---|---|---|
| | Raspuri | Dashehari | Amrapali | Raspuri | Dashehari | Amrapali |
| $T_1$ | 16.35 | 17.45 | 14.55 | 6.55 | 6.86 | 6.15 |
| $T_2$ | 24.98 | 22.78 | 18.61 | 8.39 | 7.37 | 7.4 |
| $T_3$ | 18.40 | 20.25 | 16.60 | 6.68 | 6.87 | 6.65 |
| $T_4$ | 26.91 | 24.63 | 18.14 | 8.54 | 7.86 | 7.83 |
| $T_5$ | 17.51 | 19.75 | 16.16 | 6.57 | 7.12 | 6.38 |
| $T_6$ | 27.10 | 26.98 | 19.80 | 8.59 | 8.47 | 7.23 |
| SEM | | | | | | |
| Pruning | 0.8 | 1 | 0.63 | 0.2 | 0.23 | 0.2 |
| PBZ | 0.65 | 0.81 | 0.51 | 0.16 | 0.19 | 0.16 |
| Pruning x PBZ | 1.13 | 1.41 | 0.89 | 0.28 | 0.32 | 0.29 |
| CD at 5% | | | | | | |
| Pruning | 2.52 | 3.15 | 1.99 | 0.64 | 0.73 | 0.65 |
| PBZ | 2.06 | 0.57 | 1.63 | 0.52 | 0.59 | 0.53 |
| Pruning x PBZ | 3.57 | 4.45 | 2.82 | 0.9 | 1.03 | 0.92 |
| Significance at $P$=0.05 | | | | | | |
| Pruning | NS | NS | NS | NS | NS | NS |
| PBZ | 92.49 | 23.92 | 20.03 | 65.97 | 12.45 | 21.02 |
| Pruning x PBZ | NS | NS | NS | 8.73 | 0.82 | NS |

*PBZ- paclobutrazol. Treatment details same as given below Table 1

respect to % flowering shoots and number of days for 50% flowering and flowering percentage. $T_1$ advanced the number of days for 50% flowering by 17, 21.3 and 19 days followed by $T_5$ with 14.3, 20.3 and 18.4 days in the cvs Raspuri, Dashehari and Amrapali, respectively. Among the pruning levels, 50% removal of current season growth recorded early flowering than the trees pruned to 50% of the previous season growth. More number of days taken for 50% flowering in severly pruned trees might be because of greater utilization of available carbohydrates for vegetative growth at the expense of flowering and longer time taken to replensih the carbohydrates lost in pruning. Our results are in accordance with Balamohan and Gopu (2014) and Jannoyer (2009), who reported that severe pruning delayed the flowering in mango. Early and intense flowering induced by PBZ may be the consequence of early shoot maturity and increased photosynthetic rate (Singh and Singh, 2009), carbohydrate accumulation (Abdel Rahim *et al.*, 2011) and decline in flowering reducing hormone, gibberellins (Upreti *et al.,* 2013).

Number of days from flowering to harvest ranged between 128.3-149.3 days in Raspuri, 138-159 days in Dashehari and 149-165.3 days in Amrapali under the different treatments (Table 3), thereby revealing that the early bearing cv. Raspuri maintained its earliness and late bearing cv. Amrapali maintained its late bearing character under pruning and PBZ treatments. Pruning did

Table 3. Effects of pruning and paclobutrazol on flowering characters in different varieties of mango

| Treatments | % flowering shoots | | | Days to 50% flowering | | | No. of days from flowering to harvest | | |
|---|---|---|---|---|---|---|---|---|---|
| | Raspuri | Dashehari | Amrapali | Raspuri | Dashehari | Amrapali | Raspuri | Dashehari | Amrapali |
| $T_1$ | 82.8 | 91.0 | 82.8 | 135.6 | 142.0 | 155.0 | 128.3 | 138.0 | 149.0 |
| $T_2$ | 42.2 | 38.0 | 56.7 | 159.3 | 157.3 | 174.3 | 148.3 | 155.6 | 161.6 |
| $T_3$ | 65.2 | 50.7 | 61.8 | 145.6 | 153.3 | 162.3 | 130.3 | 140.3 | 150.3 |
| $T_4$ | 23.9 | 30.9 | 40.4 | 160.6 | 166.6 | 177.3 | 149.3 | 159.0 | 161.0 |
| $T_5$ | 79.9 | 82.1 | 72.8 | 138.3 | 142.3 | 155.6 | 128.6 | 141.0 | 150.6 |
| $T_6$ | 49.4 | 33.3 | 46.9 | 152.6 | 162.6 | 174.0 | 149.0 | 154.0 | 165.3 |
| SEM | | | | | | | | | |
| Pruning | 3.68 | 2.86 | 2.59 | 1.03 | 1.12 | 1.35 | 0.71 | 0.93 | 0.90 |
| PBZ | 3.01 | 2.33 | 2.11 | 0.84 | 0.92 | 1.1 | 0.58 | 0.76 | 0.74 |
| Pruning x PBZ | 5.21 | 4.05 | 3.66 | 1.4 | 1.59 | 1.91 | 1.01 | 1.32 | 1.28 |
| CD at 5% | | | | | | | | | |
| Pruning | 11.6 | 9.02 | 8.16 | 3.26 | 3.55 | 4.26 | 2.26 | 2.94 | 2.85 |
| PBZ | 9.48 | 7.36 | 6.66 | 2.66 | 2.9 | 3.48 | 1.84 | 2.40 | 2.33 |
| Pruning x PBZ | 16.4 | 12.76 | 11.54 | 4.6 | 5.03 | 6.02 | 3.20 | 4,16 | 4.03 |
| Significance at $P$=0.05 | | | | | | | | | |
| Pruning | 8.55 | 6.48 | 12.4 | 18.83 | 22.7 | 4.73 | NS | NS | NS |
| PBZ | 80.37 | 72.34 | 68.0 | 217.64 | 99.33 | 126.22 | 646.9 | 232.4 | 146.4 |
| Pruning x PBZ | NS | NS | NS | NS | NS | NS | NS | NS | NS |

*PBZ- paclobutrazol. Treatment details same as given below Table 1

not have much influence on number of days from flowering to harvest, however PBZ significantly reduced the number of days from flowering to harvesting in all the cultivars. However, the interaction effects of pruning and PBZ were non-sigificant. The PBZ induced early flowering has been reported by Upreti *et al.* (2013) in Totapuri. The early flowering advanced the harvesting of fruits by 20.4, 13 and 14.7 days in $T_1$ in the cvs Raspuri, Dashehari and Amrapali, respectively when compared with control ($T_6$).

**Yield attributes:** The paclobutrazol effects were siginificant with respect to fruit number per tree, yield per tree and yield per hectare. However, effects of pruning and interaction of pruning and PBZ were found significant only in Raspuri (Table 4). There were cultivar differences with respect to changes in yield parameters under different treatments. The treatment $T_5$ recorded 66.8 and 56.86% higher fruit yield followed by $T_1$ (26.7 and 31.2%) in the cvs Raspuri and Dashehari, respectively. The trees of cvs Raspuri and Dashehari under $T_4$ treatment recorded lower yields as compared to control. Amrapali recorded 61.4 and 47.1% higher yields under $T_1$ and $T_5$ treatments, respectively. The higher yields in the PBZ treated trees is ascribed due to high flowering intensity which resulted higher fruit number. Yield advantage following paclobutrazol application was in agreement with the findings of Upreti *et al.* (2013) and Sarkar and Rahim (2012) in different mango varieties.

**Total phenols and flavonoids:** Effects of pruning, paclobutrazol and their interaction were significant on total phenol content in all the cultivars (Table 5). Unpruned trees of Raspuri, Dashehari and Amrapali with PBZ application ($T_5$) recorded 32.66, 30.9 and 14.3%, respectively higher phenol content followed by trees pruned to 50% of current season growth+PBZ ($T_1$) compared to control ($T_6$). The incease in phenol content by PBZ concomittant with early and profuse flowering has revealed possible involvement

Table 4. Effects of pruning and paclobutrazol on yield attributes in different varieties of mango

| Treatments | Number of fruits/tree | | | Yield /tree (kg) | | | Yield /ha (tonnes) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Raspuri | Dashehari | Amrapali | Raspuri | Dashehari | Amrapali | Raspuri | Dashehari | Amrapali |
| $T_1$ | 103.66 | 119.33 | 154.33 | 21.33 | 22.08 | 22.6 | 4.35 | 4.50 | 4.61 |
| $T_2$ | 29.33 | 25.16 | 87.83 | 5.4 | 4.50 | 13.5 | 1.10 | 0.91 | 2.75 |
| $T_3$ | 78.0 | 84.00 | 70.66 | 15.66 | 12.83 | 19.5 | 3.19 | 2.61 | 3.97 |
| $T_4$ | 9.33 | 6.66 | 58.66 | 1.86 | 1.19 | 14.5 | 0.37 | 0.24 | 2.95 |
| $T_5$ | 146.66 | 135.5 | 149.16 | 28.08 | 24.00 | 20.6 | 5.72 | 4.89 | 4.20 |
| $T_6$ | 57.5 | 96.66 | 98.33 | 16.83 | 15.30 | 14.0 | 3.43 | 3.12 | 2.85 |
| SEM | | | | | | | | | |
| Pruning | 16.96 | 19.87 | 20.51 | 3.33 | 3.33 | 3.12 | 0.68 | 0.68 | 0.63 |
| PBZ | 13.85 | 16.22 | 16.74 | 2.72 | 2.72 | 2.55 | 0.55 | 0.55 | 0.52 |
| Pruning x PBZ | 23.98 | 28.10 | 29.00 | 4.71 | 4.71 | 4.41 | 0.96 | 0.96 | 0.90 |
| CD at 5% | | | | | | | | | |
| Pruning | 76.01 | 62.59 | 64.61 | 10.50 | 10.50 | 9.84 | 2.14 | 2.14 | 2.00 |
| PBZ | 62.06 | 51.11 | 52.76 | 8.58 | 8.58 | 8.03 | 1.75 | 1.75 | 1.63 |
| Pruning x PBZ | 107.49 | 88.52 | 91.38 | 14.86 | 14.86 | 13.02 | 3.03 | 3.03 | 2.83 |
| Significance at $P$=0.05 | | | | | | | | | |
| Pruning | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| PBZ | 15.61 | 9.33 | NS | 15.15 | 15.15 | 6.7 | 15.15 | 9.64 | 4.98 |
| P running x PBZ | 9.73 | NS | NS | NS | NS | NS | NS | NS | NS |

*PBZ- paclobutrazol. Treatment details same as given below Table 1

Table 5. Effect of pruning and paclobutrazol on the total leaf phenols and flavonoids in different varieties of mango

| Treatments | Total Phenolic content (mg $g^{-1}$) | | | Total flavonoid content (mg $g^{-1}$) | | |
|---|---|---|---|---|---|---|
| | Raspuri | Dashehari | Amrapali | Raspuri | Dashehari | Amrapali |
| $T_1$ | 48.43 | 53.12 | 51.70 | 9.71 | 11.75 | 12.84 |
| $T_2$ | 39.97 | 44.75 | 53.45 | 7.69 | 8.59 | 12.50 |
| $T_3$ | 45.13 | 53.48 | 54.62 | 8.30 | 12.16 | 11.90 |
| $T_4$ | 33.73 | 46.98 | 46.72 | 6.86 | 8.25 | 9.68 |
| $T_5$ | 50.57 | 55.88 | 56.47 | 9.42 | 12.33 | 13.56 |
| $T_6$ | 38.12 | 42.67 | 49.40 | 7.41 | 7.71 | 8.10 |
| SEM | | | | | | |
| Pruning | 6.27 | 0.57 | 1.04 | 1.43 | 0.33 | 0.42 |
| PBZ | 5.12 | 0.47 | 0.85 | 1.17 | 0.27 | 0.35 |
| Pruning x PBZ | 8.87 | 0.82 | 1.47 | 2.03 | 0.47 | 0.6 |
| CD at 5% | | | | | | |
| Pruning | 0.19 | 1.82 | 3.29 | 4.52 | 1.05 | 1.35 |
| PBZ | 0.16 | 1.49 | 2.68 | 3.69 | 0.86 | 1.1 |
| Pruning x PBZ | 0.27 | 2.58 | 4.65 | 6.39 | 1.49 | 1.91 |
| Significance at $P$=0.05 | | | | | | |
| Pruning | 4295.04 | 8.03 | 5.77 | NS | NS | 8.76 |
| PBZ | 2201.24 | 258.05 | 13.33 | 4.98 | 22.19 | 23.54 |
| Pruning x PBZ | 523.8 | 18.37 | NS | NS | NS | NS |

*PBZ- paclobutrazol. Treatment details same as given below Table 1

of phenols in mango flowering. Higher phenols during flowering has been reported by Palanichamy *et al.* (2012) and Patil *et al.* (1992) in different mango cultivars. Murti *et al.* (2003) and Kurian and Iyer (1992) also reported direct relationship between vigour restriction and flower promotion in PBZ treated trees of mango rootstocks and cultivars. The PBZ induced increase in phenols may not be direct effect of PBZ on phenol biosynthesis but rather through its effects on phytohormone mediated increase in phenol content as stated by Rademacher (2000). PBZ has been reported to increase abscisic acid and cytokinins and decrease gibberellin to elicit flowering response (Upreti *et al.*, 2013). The increased phenol contents are inhibitory to growth through its negative effects on cell division and cell elongation processes. However, it needs to be clarified how increased phenols are directly associated with increased flowering.

Significant differences in flavonoid content due to pruning was observed in Amrapali only. PBZ effect was also significant but the interaction effect was non-significant (Table 5). The highest flavonoid content to the tune of 9.42, 12.33 and 13.56 mg/g was noticed in unpruned trees with PBZ ($T_5$) followed by trees pruned to 50% of current season growth ($T_1$) in the cvs Raspuri, Dashehari and Amrapali, respectively. Flavonoid content increased drastically in all the PBZ treated trees than the control trees. The PBZ induced increase in flavonoid content showed that the PBZ induced changes in growth determining characters and flowering is mediated through accumulations in flavonoids. However, it needs to be investigated that how such accumulation in flavonoids triggers such responses.

**Phenolic acids:** The composition and quantity of phenolic acids in leaves greatly varied in control and treatments in all the

Table 6. Effects of pruning and paclobutrazol on phenolic acid levels in different varieties of mango (µg $g^{-1}$) (data represents mean ± SE)

| Varieties/ Treatments | Gallic acid | 4-hydroxy BA | Caffeic acid | Salicylic acid | t-ferrulic acid | Sinapic acid | Rosmarinic acid | o-coumaric acid | t-cinnamic acid |
|---|---|---|---|---|---|---|---|---|---|
| Raspuri | | | | | | | | | |
| $T_1$ | -- | 64.32±0.16 | 1.39±0.29 | 0.97±0.04 | -- | 4.78±0.10 | -- | 47.79±0.11 | 0.41±0.16 |
| $T_2$ | 31.34±0.26 | -- | -- | 0.72±0.04 | 3.72±0.76 | -- | -- | 39.8±0.11 | 5.61±0.16 |
| $T_3$ | -- | 19.91±0.16 | -- | 0.64±0.04 | -- | 44.09±0.10 | 4.27±0.78 | 11.45±0.11 | 0.39±0.16 |
| $T_4$ | -- | -- | 9.42±0.29 | 7.50±0.04 | -- | 0.85±0.10 | -- | 0.86±0.11 | 0.38±0.16 |
| $T_5$ | -- | 79.84±0.16 | 0.85±0.29 | 6.75±0.04 | -- | 3.57±0.10 | 5.18±0.78 | 63.21±0.11 | 0.70±0.16 |
| $T_6$ | -- | 4.07±0.16 | 15.48±0.29 | 1.97±0.04 | -- | -- | -- | 1.63±0.11 | 183.31±0.16 |
| Dashehari | | | | | | | | | |
| $T_1$ | 116.84±0.26 | 5.14±0.16 | 6.95±0.29 | 49.13±0.04 | 2.37±0.76 | -- | -- | 80.02±0.11 | 0.34±0.16 |
| $T_2$ | 277.92±0.26 | -- | 10.02±0.29 | 7.43±0.04 | 24.67±0.76 | 89.57±0.10 | 35.66±0.78 | 64.17±0.11 | 2.42±0.16 |
| $T_3$ | 386.67±0.26 | 1.76±0.16 | 2.06±0.29 | 26.86±0.04 | -- | -- | -- | 62.91±0.11 | 1.14±0.16 |
| $T_4$ | -- | -- | 26.50±0.29 | 0.53±0.04 | 1.12±0.76 | 1.48±0.10 | 0.29±0.78 | 1.61±0.11 | 6.60±0.16 |
| $T_5$ | -- | 6.08±0.16 | 1.26±0.29 | 58.81±0.04 | -- | -- | -- | 152.47±0.11 | 0.27±0.16 |
| $T_6$ | -- | -- | 28.50±0.29 | -- | 73.23±0.76 | 0.96±0.10 | 0.21±0.78 | 0.75±0.11 | 71.89±0.16 |
| Amrapali | | | | | | | | | |
| $T_1$ | -- | -- | -- | 0.78±0.04 | 0.40±0.76 | 1.07±0.10 | -- | 38.37±0.11 | 0.78±0.16 |
| $T_2$ | -- | -- | -- | 0.72±0.04 | 0.43±0.76 | 0.52±0.10 | 0.72±0.78 | 0.85±0.11 | 2.05±0.16 |
| $T_3$ | -- | -- | -- | 5.95±0.04 | -- | -- | 1.59±0.78 | 18.59±0.11 | 0.88±0.16 |
| $T_4$ | -- | -- | -- | 3.72±0.04 | 6.29±0.76 | -- | -- | 0.86±0.11 | 2.72±0.16 |
| $T_5$ | -- | -- | -- | 0.91±0.04 | -- | -- | -- | 59.90±0.11 | 0.66±0.16 |
| $T_6$ | -- | -- | -- | 1.13±0.04 | -- | -- | -- | 0.73±0.11 | 5.62±0.16 |

Treatment details same as given below Table 1

varieties (Table 6). The prominent phenolic acids determined in different varieties were 4-hydroxy benzoic acid, o-coumaric acid, salicylic acid, caffeic acid and t-cinnamic acid. The prominent phenolic acids in control trees were o-coumaric acid, salicylic acid and t-cinnamic acid. Between two treatments, PBZ was more responsive in altering the composition of phenolic acids in different varieties as compared to pruning. Under $T_5$ treatment 4-hydroxy benzoic acid (79.84 and 152.47 µg/g), coumaric acid (63.21 and 152.47 µg/g) and salicylic acid (6.75 and 58.81µg/g) contents were increased, but the contents of caffeic acid (1.39 and 6.95 µg/g) and t-cinnamic acid (0.41 and 0.27 µg/g) were decreased in Raspuri and Dashehari, respectively compared to control. In Amrapali, $T_5$ treatment influenced the o-coumaric acid and t-cinnamic acid contents as evident from higher levels of o-coumaric acid (59.9 µg/g) and low levels of cinnamic acid (0.66 µg/g) compared to control. $T_5$ treatment was followed by $T_1$ in modifying the phenolic acid composition in different varieties. From the results it was evident that higher levels of 4-hydroxy benzoic acid, coumaric acid and salicylic acid content contributed to the increased levels of total phenols under PBZ treatment. Such changes in phenolic acids may be the result of sensitization of phenolic acid biosynthetic pathway by paclobutrazol treatment. The results also depicted that 4-hydroxy benzoic acid, coumaric acid and salicylic acid were some of the phenolic acids which contributed to PBZ induced growth reduction and enhanced flowering in mango. The above results are in line with the findings of Mert *et al.* (2013) who reported that hydroxycinnamic acid and p-coumaric acid contents were high in olive trees during 'on' year as compared to 'off' year.

From the study, it was concluded that the pruning of trees to 50% of current season growth and PBZ application are vital for regulating tree size, early flowering and advancing fruit harvest in mango and such beneficial effects of treatments are mediated through increase in phenolics contents.

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