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Research Article

MORPHO-PHYSIOLOGICAL AND BIOCHEMICAL RESPONSES OF ROOTSTOCK, PRUNING AND PACLOBUTRAZOL IN MANGO (*MANGIFERA INDICA* L.) CV. ALPHONSO UNDER HIGH DENSITY PLANTING

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Abstract: Use of paclobutrazol (PBZ), grafting with suitable size controlling rootstock and pruning are strategic tools for optimizing tree growth and fruit production. However, not much information on their combined effects on vigour regulation and associated physio-biochemical changes is available. Thus, studies were made on combined effects of rootstocks (Olour and Vellaikolamban), pruning (current or previous season's vegetative growth) and PBZ (0.75 g a.i./m canopy diameter) on tree vigour, flowering, fruit yield and physio-biochemical changes in mango cv. Alphonso maintained under ultra-high-density planting. The plant height, trunk girth and canopy spread in Vellaikolamban grafted trees showed greater decline and produced shoots of shorter length and girth as compared to pruning of current season's growth and PBZ treatments. Flowering and yield attributes differed significantly with pruning and PBZ treatments alone rather than their interaction effects. Also, trees pruned to current season's growth and under PBZ treatments recorded less number of days for 50 % flowering, high % flowering shoots, less number of days from flowering to harvest and high yield/tree. Irrespective of the rootstock, Alphonso trees treated with PBZ and pruned to current season's growth showed early flowering and better fruit yields with distinct increase in C: N ratio, leaf water potential and ABA content along with decreased GA_3 content. The study thus revealed that grafting on Velliakolamban rootstock, pruning of current season's growth and PBZ were ideal for better canopy management without compromising fruit yields under ultra-high-density planting in Alphonso mango.

Keywords: Rootstock, Pruning, High Density Planting
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Introduction

Mango (*Mangifera indica* L.) is an important commercial fruit crop of India with an area of 2.50 million ha and production of 18.08 million tonnes. India ranks first in mango production, contributing 45.5 % total world's mango production [1]. The mango orchards in general experiences production constraints because of excessive vegetative growth and low planting densities. The high-density planting (HDP) with proper canopy management strategies is considered one of the ideal cultural practices to enhance the mango production efficiency. Use of rootstocks, pruning and application of growth retardants are suggested as the simple and effective means of regulating canopy vigour and promoting flowering, and enhancing production efficiency in many fruit crops including mango. With the advent of HDP for intensifying the fruit production, role of rootstocks has been increased in the recent years. Its selection has been majorly focused with view to manipulate plant roots to reduce excessive shoot growth and promote flowering. Rootstocks influence on the scion growth [2], flowering time and duration [3] and alternate bearing tendency has been reported in many fruit crops. Such effects are found as the consequences of improvement in water uptake and nutrient mobilization [4], and hydraulic conductance [5]. Concerted attempts have also been made to identify suitable rootstock for vigour regulation in fruit crops including mango. The beneficial effects of pruning are associated with management of canopy architecture, alteration of biochemical system and early flowering [6]. In mango, favourable effects due to pruning intensities have been reported on light interception [7] growth parameters [8,9], fruit yield [10] and regular bearing [11]. Plant growth retardants find wide use in chemical manipulation of growth and development by modifying associated biochemical and physiological processes.

Among the plant growth retardants suggested, PBZ is considered as one of the most versatile plant growth retardants which restricted vegetative growth and induced flowering in many fruit crops including mango [12]. The PBZ 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 [13,14]. Among the cellular metabolites, accumulation of phenols in vegetative organs and altered biochemical balance are important characteristic features linked to restriction of vigour in mango [15] and also for induction in flowering [16]. Vigour regulation is complex and most likely regulated by a number of factors in tandem rather than in isolation. Most of the studies undertaken with respect to growth regulation and flowering in mango are confined to independent use of rootstocks, pruning and paclobutrazol and thus observed effects are not variable and in convincing Hence, the present investigation was carried out with the hypothecation that, the combined effect of rootstock, pruning and PBZ can be more effective in the tree vigour regulation and flowering in mango.

Materials and methods

The experiment was conducted at the experimental farm of ICAR-Indian Institute of Horticultural Research, Bengaluru on 3 years old Alphonso mango trees spaced at 3 X 2 m distance during 2013-14. The experimental field is located at an altitude of 890 meters above MSL 13.58' N latitude and 77.37' E longitude. The experiment was laid out with four replications in a factorial randomized block design with various combinations of rootstock (Olour and Vellaikolamban), pruning (current season's growth, previous season's growth and no pruning) and PBZ application (0.75 g a.i/m canopy diameter).

Experimental plot had a total of 48 trees (one tree in each replication) under different treatment combinations. The different treatment combinations are

$R_1P_1C_1$-Olour + pruning of current season's growth + PBZ application 0.75 g a.i./ m canopy diameter

$R_1P_1C_2$-Olour + pruning of current season's growth,

$R_1P_2C_1$-Olour + pruning of previous season's growth + PBZ application @ 0.75 g a.i./m canopy diameter

$R_1P_2C_2$-Olour + pruning of previous season's growth

$R_1P_3C_1$-Olour + no pruning + PBZ application @ 0.75 g a.i./ m canopy diameter

$R_1P_3C_2$-Olour + no pruning and no PBZ application

$R_1P_1C_1$-Vellaikulamban + pruning of current season's growth + PBZ application 0.75 g a.i./ m canopy diameter

$R_2P_1C_2$-Vellaikulamban + pruning of current season's growth,

$R_2P_2C_1$-Vellaikulamban + pruning of previous season's growth + PBZ application @ 0.75 g a.i./ m canopy diameter

$R_2P_2C_2$-Vellaikulamban + pruning of previous season's growth

$R_2P_3C_1$-Vellaikulamban + no pruning + PBZ application @ 0.75 g a.i./ m canopy diameter

$R_2P_3C_2$-Vellaikulamban + no pruning and no PBZ application

Pruning was carried out by removing tree branches according to the pruning level during 3rd week of July, 2013. PBZ (25% w/v a.i., Zeneca Limited, Surry, UK) was applied once as soil drench during the last week 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 used for the PBZ untreated trees. During the experimentation, the average maximum and minimum temperatures were 29.4 and 19.00C respectively, relative humidity 74.5 % and total rainfall 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 PBZ application and difference increases between each parameter were calculated. Canopy spread in a span of six months after treatments were measured and presented as the average spread in E-W and N-S directions. After the emergence of new shoots, 50 shoots were tagged in all the directions of tree, 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 shoots were recorded from tagged shoots. Data on number of days from flowering to harvest and fruit yield were also recorded. Calculation of fruit yield per hectare was also made. Besides, leaf samples at 45 and 75 days after PBZ application were drawn for determining the biochemical and phytohormonal contents.

Determination C:N ratio in shoots

For estimation of C: N ratio, shoots were dried to constant mass at 80°C in a hot air oven and powdered in grinding mill. The contents of total C and N were determined employing CHNS analyzer (Model-Cube, Elementar, Germany) and C: N ratio was calculated from the respective values.

Estimation of leaf water potential

The leaf water potential (Ψw) was obtained using pressure bomb (Arimad-3000, MRC Ltd., Isrel) and expressed as –MPa.

Phytohormonal analysis

The phytohormones like gibberellic acid (GA_3) and abscisic acid (ABA) were analyzed following the HPLC procedure of Kelen *et al*. (2004) [17] with modifications. The HPLC system (Model: Prominence, Shimadzu, Japan) was equipped with photodiode array detector (SPD-M20A) and Synergi 4 µm fusion RP-C18 column (Phenomenex, USA, 250 X 4.6 mm). The mobile phase consisted of acetonitrile: water (pH4.0, adjusted with 1.0 M o-phosphoric acid) (30:70, v/v) at 0.8 ml/min flow rate. The GA_3 and ABA were detected at 200 and 260 nm, with retention times of 6.37 and 16.2 minutes, respectively. The quantification of these phytohormones was carried out using GA_3 and ABA (Sigma-Aldrich, USA) as external standards. All the data were statistically analyzed according to Panse and Sukhatme (1985) and the difference in the means were compared at 5% level of significance [18].

Results

Morphological attributes

From the results, it was observed that the effects of rootstock, pruning and PBZ were significant with respect to plant height, canopy spread, trunk girth, shoot length and shoot girth [Table-1]. Among the interaction effects, only canopy spread differed significantly with the interaction of rootstock, pruning, and PBZ [Table-2]. Alphonso scion grafted on Vellaikullamban rootstock (R_2) recorded 12.5, 9.0 and 17.5% decline, pruning of current season's growth (P_1) recorded 9.1, 2.6 and 5.3% decline, and application of PBZ (C_1) recorded 30.7, 13.7 and 26.2% decline in plant height, trunk girth and canopy spread, respectively. Trees grafted on Vellaikullamban rootstock (R_2) recorded lowest shoot length (17.63 cm) than those grafted on Olour rootstock. Similarly, PBZ application (C_1) recorded short shoots (15.78 m) and lowest girth (6.70 mm) than trees without application of PBZ. The magnitude of increase in canopy spread was significantly lowest (0.37 m) in unpruned trees grafted on Vellaikolamban rootstock and with PBZ application ($R_2P_3C_1$) and was at par with trees grafted on Vellaikolamban rootstock, pruned to current season's growth and with PBZ application ($R_2P_1C_1$).

Flowering attributes

Results from the study revealed that the flowering attributes like days to 50% flowering and % flowering shoots were significantly differed with pruning and PBZ treatments alone rather than their interaction effects [Table-3] while non-significant with rootstock. Trees pruned to current season's growth (P_1) recorded a smaller number of days for 50% flowering (148.6) and highest flowering shoots (56.6%) than trees pruned to previous season's growth and unpruned. Irrespective of rootstock and pruning effects, application of PBZ (C_1) took a smaller number of days for 50% flowering (143.6 days) and recorded highest % flowering shoots (61.5%) than PBZ untreated trees.

Similarly, the interaction of pruning and PBZ was significant [Table-4]. Trees pruned to current season's growth and with PBZ application (P_1C_1) recorded highest flowering shoots % (72.2%) followed by 55.6% flowering shoots in unpruned trees grafted with PBZ application (P_3C_1).

Yield attributes

The effects of rootstock, pruning and PBZ were significant with respect to fruit number and yield per tree [Table-3]. Trees grafted on Olour rootstock (R_1) recorded higher fruit yield/tree (2.13 kg) by recording a greater number of fruits per tree (11.3) than trees grafted on Vellaikolamban rootstock. Pruning of current season's growth (P_1) recorded a greater number of fruits/tree (12.7) and higher yield/tree (2.51 kg) than other pruning treatments. PBZ application (C_1) enhanced the fruit yield by (2.80 kg) by recording more fruit number/tree (15) than the untreated trees.

Among the interaction effects, interaction between pruning and PBZ, and rootstock and PBZ were found to be significant with respect to yield per tree [Table-4]. Among the pruning and PBZ interactions, trees pruned to current season's growth and with PBZ application (P_1C_1) recorded higher fruit yields (3.25 kg/tree). Similarly, among rootstock and PBZ interactions, trees grafted on Olour rootstock and with PBZ application (R_1C_1) recorded higher fruit yield (3.12 kg/tree).

C:N ratio

C: N ratio differed significantly with rootstock, pruning and PBZ [Fig-1] while all the interaction effects were non-significant. Alphonso trees grafted on Olour rootstock (R_1) recorded higher C: N ratio (35.13) than trees grafted on Vellaikolamban. Pruning of current season's growth (P_1) enhanced the C: N ratio by 8.29% than unpruned trees. Similarly, PBZ application (C_1) significantly enhanced the C: N ratio by 29.2% as compared to untreated trees.

Leaf water potential (Ψw)

Ψw was significantly influenced only by PBZ [Fig-1d] while the effects of rootstock, pruning and all the interactions were non-significant. PBZ treated trees recorded higher Ψw (1.69 –MPa) as compared to untreated trees (2.34 –MPa)

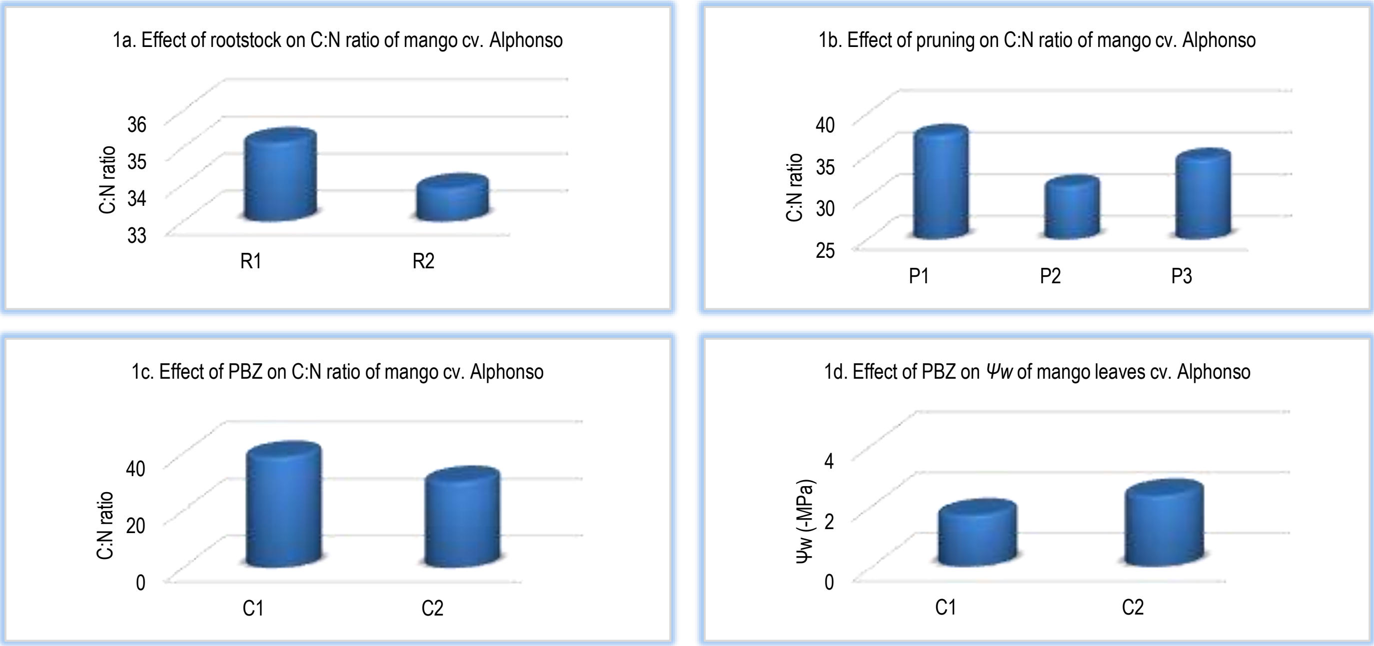

Fig-1 Effect of rootstock, pruning and PBZ on C:N ratio and water potential (Ψw) in leaves of mango cv. Alphonso
R_1- Olour rootstock, P_1- pruning of current season's growth, C_1- PBZ @ 3 ml/ m canopy spread
R_2- Vellaikolamban, P_2- pruning of previous season's growth, C_2- no PBZ, P_3- no pruning

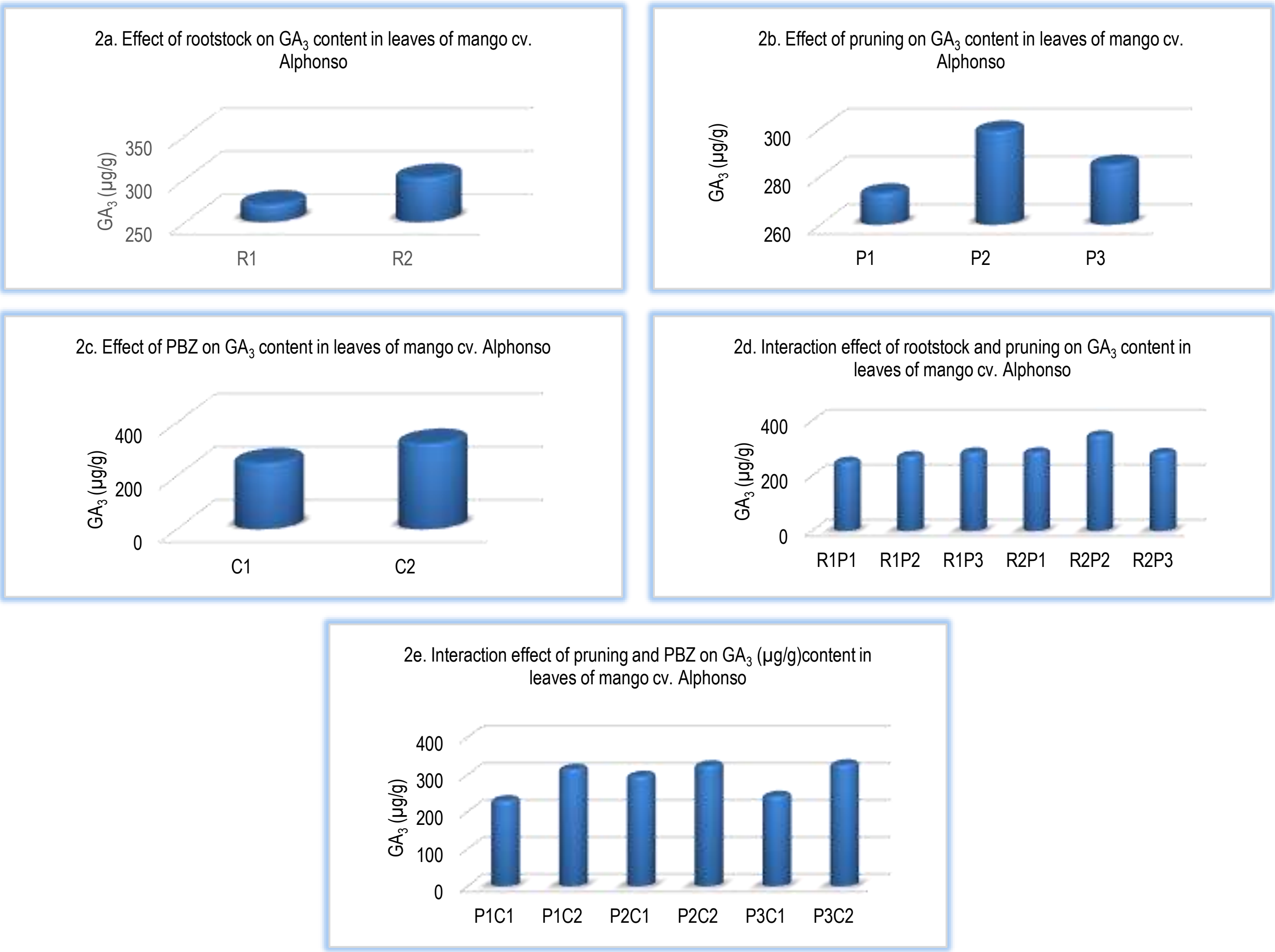

Fig-2 Effect of rootstock, pruning and PBZ on GA_3 content in leaves of mango cv. Alphonso
R_1- Olour rootstock, P_1- pruning of current season's growth, C_1- PBZ @ 3 ml/ m canopy spread
R_2- Vellaikolamban, P_2- pruning of previous season's growth, C_2- no PBZ, P_3- no pruning

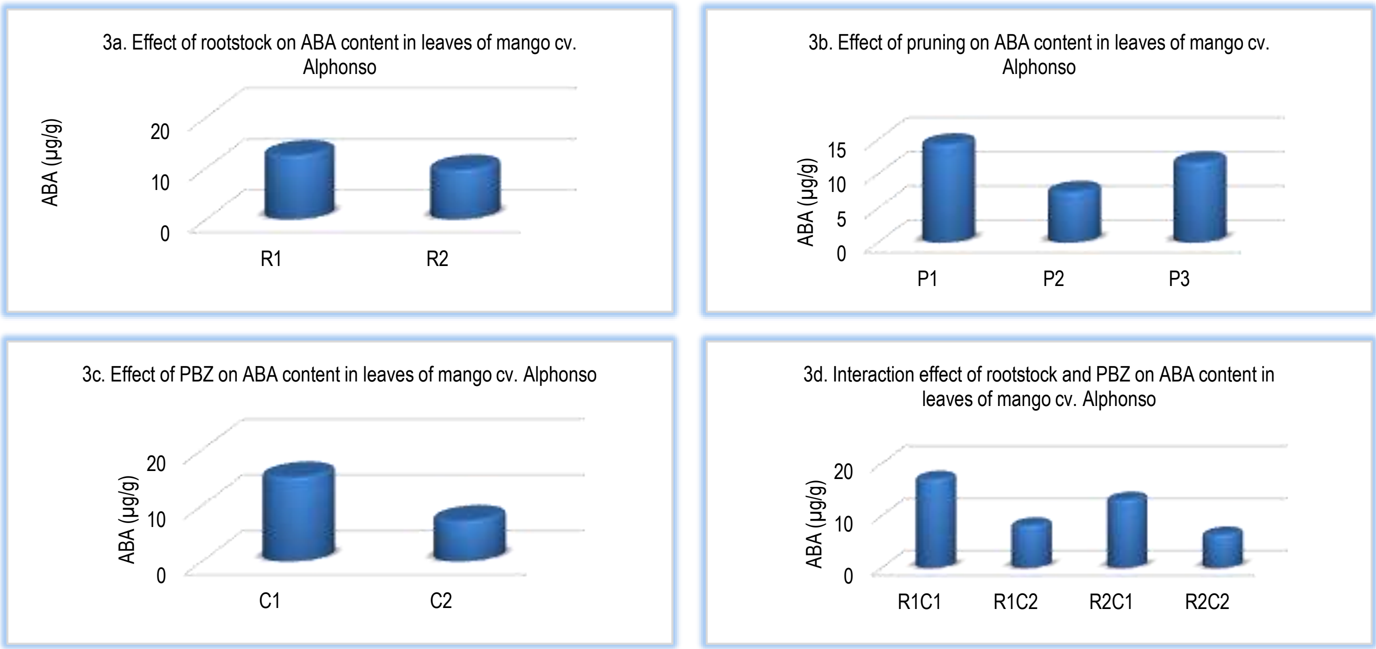

Fig-3 Effect of rootstock, pruning and PBZ on ABA content in leaves of mango cv. Alphonso
R_1- Olour rootstock, P_1- pruning of current season's growth, C_1- PBZ @ 3 ml/ m canopy spread
R_2- Vellaikolamban, P_2- pruning of previous season's growth, 2- no PBZ, P_3- no pruning

Phytohormones

From the results of study, it was apparent that, the effects of rootstock, pruning and PBZ alone were significant on phytohormone content of Alphonso mango. Alphonso trees grafted on Olour rootstock (R_1), pruned of current season's growth (P_1) and PBZ application (C_1) recorded lower GA_3 levels (270.5, 273.2 and 249.2 µg/g, respectively) and higher ABA levels (12.63, 14.38 and 15.09 µg/g, respectively). Among the interaction effects, interaction of rootstock and pruning, and pruning and PBZ were significant on GA_3 content [Fig-2d and 2e]. Similarly, only the interaction effect of rootstock and PBZ was significant on ABA content in leaves [Fig-3d].

Discussion

Morphological attributes

From result it was evident that the treatments alone were effective in regulating the tree vigour than in combination and produced smaller size trees having less plant height, less trunk girth, lesser canopy spread with short shoots and effect was drastic with Velailulamban rootstock. The Alphonso scion grafted on Vellaikullamban rootstock recorded 12.5, 9.0 and 17.5% decline in plant height, trunk girth and canopy spread, respectively when compared to Olour rootstock confirming the dwarfing effect of Velaikullamban rootstock on scion vigour. Dwarfing rootstocks are known to reduce the growth rate of scion shoots through the exchange of resources like water, nutrients and carbohydrates [19]. It is expected that the dwarfed shoots would grow slowly and have less leaf area which inturn lead to less photo assimilate accumulation than those of vigorous ones. However, the way leaves oriented on the tree also influence their ability to intercept solar radiation and converts into fruit production through photosynthesis. Such factors may contribute to the reduction in tree size associated with dwarfing rootstocks was reported by Atkinson *et al*. (2003), Reddy *et al*. (2003) and Gawankar *et al*. 2010) [20] in different mango cultivars.

Significant reduction in plant height (30.7 %), trunk girth (13.7 %) and canopy spread (26.2 %) was reported in trees pruned to current season's growth as compared to unpruned trees. The reduction in canopy size confer the findings of Balamohan and Gopu (2014) in Alphonso that, light pruning of current season's growth is advantageous for tree vigour regulation without effecting the flowering. Such growth reduction responses of pruning might be result of declined photosynthate production following pruning induced lowering in total photosynthetic area [21], delay in leaf development and changes in phytohormonal production [22] and their translocation. On the other hand, trees pruned to previous season's growth recorded increase in vegetative vigour than the trees pruned to current season's growth. The increase in vegetative vigour with increased pruning severity could be attributed to increased biosynthesis of gibberellins as suggested by [23]. Increase in vegetative vigour with the increase in pruning severity has also been reported by Gross (1996) [24], Lal *et al*., (2000) [25] and Das and Jana (2012) in mango [26].

Similarly, PBZ treated plants recorded 30.7, 13.7 and 26.2% decline in plant height, trunk girth and canopy spread, respectively. The growth reduction response of PBZ in mango could also be the consequences of modification in photosynthesis rate and carbohydrates [27] besides reductions in gibberellins [28]. These results indicated that rootstock, pruning and PBZ treatments alone were relatively more effective in the regulation of tree vigour as compared to their combined effect.

Flowering attributes

Pruning of current season's growth recorded intense flowering than pruning of previous season's growth and unpruned trees. The beneficial effects of light pruning in inducing early flowering is associated with management of canopy architecture, alteration of biochemical system and early flowering (Singh *et al*., 2009; Balamohan and Gopu, 2014). However, the delayed flowering and lower % of flowering shoots (15.5%) in trees pruned to previous season's growth can be attributed to the delayed bud sprouting and higher rate of shoot growth due to increased biosynthesis of GA_3. Reduced flowering intensity with increase in pruning severity has also been reported by Das and Jana (2012) in mango.

The early and intense flowering due to PBZ is ascribed to the early reduction of endogenous gibberellins in the shoots causing them to reach maturity earlier (Abdel Rahim *et al*., 2011; Upreti *et al*., 2014).

Yield attributes

Trees grafted on Olour rootstock (R_1) recorded 17.3% higher fruit yield/tree by recording 28.4% more number of fruits per tree than trees grafted on Vellaikolamban rootstock. The higher fruit yield in trees grafted on Olour rootstock than on Velaikulumban might be due to the appropriate graft combination for specific environmental condition and due to vigorous growth in the initial stages resulting from good water relations, leaf gas exchange, mineral uptake, plant size, blossoming, timing of fruit set, and yield efficiency [29,30].

Table-1 *Effects of rootstocks, pruning and PBZ on the extent of changes in morphological attributes of mango cv. Alphonso*

Treatments	Plant height(m)	Trunk girth(cm)	Canopy spread (m)	Shoot length (cm)	Shoot girth (mm)
Rootstock					
R_1	0.24	0.78	0.40	19.75	7.33
R_2	0.21	0.71	0.33	17.63	7.09
SEm±	0.004	0.005	0.003	0.63	0.10
CD at 5%	0.012	0.01	0.01	1.86	NS
Pruning					
P_1	0.20	0.73	0.36	18.39	6.88
P_2	0.24	0.75	0.37	18.61	7.07
P_3	0.22	0.75	0.38	19.07	7.68
SEm±	0.005	0.006	0.004	0.77	0.13
CD at 5%	0.014	NS	NS	NS	0.38
PBZ					
C_1	0.18	0.69	0.31	15.78	6.70
C_2	0.26	0.80	0.42	21.60	7.72
SEm±	0.004	0.005	0.003	0.63	0.10
CD at 5%	0.012	0.01	0.01	1.86	0.31
Rootstock x Pruning					
R_1P_1	0.22	0.77	0.39	18.88	6.99
R_1P_2	0.25	0.79	0.42	17.75	6.86
R_1P_3	0.24	0.78	0.41	16.27	7.41
R_2P_1	0.22	0.74	0.37	16.88	7.62
R_2P_2	0.25	0.76	0.37	22.45	7.45
R_2P_3	0.21	0.72	0.34	20.51	7.96
SEm±	0.007	0.009	0.006	1.10	0.18
CD at 5%	NS	NS	NS	NS	NS
Pruning x PBZ					
P_1C_1	0.17	0.67	0.30	16.06	6.68
P_1C_2	0.24	0.80	0.42	21.15	7.45
P_2C_1	0.23	0.75	0.38	17.33	6.92
P_2C_2	0.28	0.80	0.41	22.87	7.39
P_3C_1	0.18	0.69	0.32	16.00	7.04
P_3C_2	0.27	0.81	0.44	20.78	8.33
SEm±	0.007	0.009	0.006	1.10	0.18
CD at 5%	NS	NS	NS	NS	NS
Rootstock x PBZ					
R_1C_1	0.20	0.72	0.35	14.72	6.44
R_1C_2	0.27	0.83	0.46	20.54	7.73
R_2C_1	0.17	0.65	0.28	16.84	6.96
R_2C_2	0.25	0.77	0.38	22.65	7.71
SEm±	0.005	0.008	0.005	0.90	0.15
CD at 5%	NS	NS	NS	NS	NS

Table-2 *Interaction effects of rootstocks, pruning and PBZ on the extent of changes in morphological attributes of mango cv. Alphonso*

Treatments	Plant height(m)	Trunk girth(cm)	Canopy spread (m)	Shoot length (cm)	Shoot girth (mm)
$R_1P_1C_1$	0.18	0.70	0.32	15.26	6.81
$R_1P_1C_2$	0.25	0.83	0.45	21.40	7.47
$R_1P_2C_1$	0.22	0.73	0.36	17.30	6.37
$R_1P_2C_2$	0.28	0.84	0.47	23.50	7.42
$R_1P_3C_1$	0.19	0.73	0.36	17.96	7.69
$R_1P_3C_1$	0.29	0.83	0.46	23.06	8.23
$R_2P_1C_1$	0.15	0.64	0.27	16.86	6.55
$R_2P_1C_2$	0.23	0.76	0.39	20.90	7.43
$R_2P_2C_1$	0.19	0.66	0.29	13.26	6.37
$R_2P_2C_2$	0.27	0.75	0.35	22.23	7.35
$R_2P_3C_1$	0.17	0.65	0.28	14.03	6.39
$R_2P_3C_2$	0.24	0.79	0.41	18.50	8.42
SEm±	0.001	0.001	0.009	1.55	0.26
CD at 5%	NS	NS	0.02	NS	NS

**RS- rootstock, P-pruning, PBZ-paclobutrazol*

R_1- Olour rootstock, P_1- pruning of current season's growth, C_1- PBZ @ 3 ml/ m canopy spread

R_2- Vellaikolamban, P_2- pruning of previous season's growth, C_2- no PBZ, P_3- no pruning

Reddy *et al.* (2003) also reported that Olour rootstock expressed higher vigour and fruit yield for Alphonso scion during the earlier years. Pruning of current season's growth (P_1) recorded 24.5% more number of fruits/tree and 62.9% higher yield/tree than other pruning treatments. Higher yields due to light pruning might be due to tree vigour regulation, better light penetration into tree canopy that increases the photosynthetic efficiency and diverting the photosynthates towards fruit production. Our results of high yield in current season's pruning is in line with findings of Das and Jana (2012) and Balamohan and Gopu (2014) in different mango cultivars. PBZ application (C_1) enhanced the fruit yield by 143.5% by recording 194.1% more fruit number/tree than the untreated trees. Increased production with PBZ application could be the cumulative effect of profuse flowering, increased fruit set and reduced fruit drop. The higher yields in the PBZ treated trees has also been reported in different mango varieties due to high flowering intensity and more number fruits through partitioning of photosynthates towards reproductive development, improved plant water relations and altered hormonal balance (Upreti *et al.*, 2013 and Reddy *et al.*, 2014).

Table-3 *Effects of rootstock, pruning and PBZ on flowering and yield parameters of mango cv. Alphonso*

Treatments	Days to 50% flowering	% flowering shoots	Days from flowering to harvest	No. of fruits/plant	Yield/tree (kg)
Rootstock					
R_1	150.4	45.5	130.9	11.3	2.13
R_2	151.3	47.7	131	8.8	1.82
SEm±	0.71	2.17	0.533	0.47	0.115
CD at 5%	NS	NS	NS	1.39	0.33
Pruning					
P_1	148.6	56.6	129.4	12.7	2.51
P_2	155.3	36.1	133.9	7.2	1.54
P_3	148.7	47.2	130.6	10.2	1.88
SEm±	0.87	2.65	0.65	0.58	0.141
CD at 5%	2.57	7.79	1.91	1.71	0.41
PBZ					
C_1	143.6	61.5	124.2	15	2.8
C_2	158.1	31.8	137.8	5.1	1.15
SEm±	0.71	2.17	0.53	0.47	0.115
CD at 5%	2.1	6.36	1.56	1.39	0.33
Rootstock x Pruning					
R_1P_1	147	55.5	129	14.7	2.76
R_1P_2	155.5	33.3	133.7	8	1.72
R_1P_3	148.8	47.8	130.2	11.3	1.93
R_2P_1	149.2	52.2	130.5	9	1.83
R_2P_2	160.2	31.1	139	5	1.14
R_2P_3	148.7	46.7	128.7	9.1	1.83
SEm±	1.24	3.76	0.92	0.82	0.199
CD at 5%	NS	NS	NS	NS	NS
Pruning x PBZ					
P_1C_1	141.5	72.2	122.7	17.5	3.25
P_1C_2	155.8	41.1	136.6	8	1.78
P_2C_1	153.7	48.9	133.3	10.3	2.19
P_2C_2	162	15.5	139.3	2.7	0.67
P_3C_1	141	55.6	121.3	15.6	2.76
P_3C_2	156.5	38.9	137.5	4.8	1
SEm±	1.24	3.76	0.92	0.82	0.199
CD at 5%	NS	11.02	2.7	2.42	0.58
Rootstock x PBZ					
R_1C_1	143.7	62.2	124.5	17.5	3.12
R_1C_2	157.1	28.8	137.3	5.1	1.15
R_2C_1	143.5	60.7	123.8	12.4	2.48
R_2C_2	159.1	34.8	138.3	5.2	1.15
SEm±	1.01	3.07	0.75	0.67	0.163
CD at 5%	NS	NS	NS	1.97	0.47

Table-4 *Interaction effects of rootstock, pruning and PBZ on flowering and yield parameters of mango cv. Alphonso*

Treatments	Days to 50% flowering	% flowering shoots	Days from flowering to harvest	No. of fruits/plant	Yield/tree (kg)
$R_1P_1C_1$	140.6	75.5	122.3	21	3.66
$R_1P_1C_2$	153.3	35.5	135.6	8.3	1.85
$R_1P_2C_1$	149	51.1	129	13	2.67
$R_1P_2C_2$	162	15.5	138.3	3	0.77
$R_1P_3C_1$	141.6	60	122.3	18.6	3.03
$R_1P_3C_1$	156	35.5	138	4	0.82
$R_2P_1C_1$	142.3	68.8	123	14	2.83
$R_2P_1C_2$	158.3	46.6	137.6	7.6	1.7
$R_2P_2C_1$	148	62.2	128	10.6	2.14
$R_2P_2C_2$	162	15.5	140.3	2.3	0.57
$R_2P_3C_1$	140.3	51.1	120.3	12.6	2.48
$R_2P_3C_2$	157	42.2	137	5.6	1.18
SEm±	1.75	5.31	1.3	1.16	0.282
CD at 5%	NS	NS	NS	NS	NS

R_1- Olour rootstock, P_1- pruning of current season's growth, C_1- PBZ @ 3 ml/ m canopy spread
R_2- Vellaikolamban, P_2- pruning of previous season's growth, C_2- no PBZ, P_3- no pruning

The interaction effect between rootstock, pruning and PBZ enhanced fruit yield is expected to be cumulative in increasing the yields as evident from our results.

C: N Ratio

High C: N ratio in trees grafted on Olour rootstock might be due to vigorous growth during the initial stages and rootstocks have the differential ability to divert food reserves in favour of reproductive development (Gonçalves *et al.*, 2003). Pruning accelerates bud sprouting causing the shoots to reach maturity earlier and have sufficient time to accumulate carbohydrates (Das and Jana, 2012; Balamohan and Gopu, 2014) resulting higher C: N ratio.

High C: Nratio in PBZ treated plants might be due to high chlorophyll content in leaves [31], a higher photosynthetic rate [32] as well as retarded vegetative growth [33]. As the PBZ treated trees had high C: N ratio in shoot, which could be consequent of increased food reserve accumulation leading to flowering in mango. PBZ induced increase in C: N ratio has been reported in different varieties of mango (Upreti *et al.*, 2013; Subadrabandhu *et al.*, 1997).

Leaf water potential (*Ψw*)

Application of PBZ inclined the *Ψw* by 27.7% as compared to PBZ untreated trees. Dwarfing rootstocks reduces the hydraulic conductance across the graft union as a consequence of reduced functional xylem area, associated with lowered water potential. Jones (2012) [34] reported that *Ψw* is an illustrative of the plant water status and plant water relations underlie tree size control. Gonclaves *et al*. (2003) reported that different size-controlling rootstocks had different water relations and gas exchange that causes changes in vegetative growth. A higher *Ψw* values indicated the water stress which could be vital for floral induction in mango. PBZ induced increase in *Ψw* is also reported by Upreti *et al*. (2013) which is ascribed due to reduced transpiration [35] or increased root hydraulic conductivity and/or increased ABA content.

Phytohormones

Olour rootstock showed decline in GA_3 levels by 10.2% and incline in ABA content by 29.4% than Vellaikolamban rootstock. Each rootstock and scion clones may genetically differ in their potential capacity for shoot elongation, branching, root proliferation by regulated synthesis of different phytohormones and maintenance of required concentration ratio of different hormones in specific site of action. Since, hormones moving from root to shoot and vice versa be capable of modifying the synthetic capacity of hormones in the other organs. Differential ability of rootstocks to produce hormones and their transport from root to shoot has been reported in apple rootstocks [36,37].

Trees pruned to current season's growth recorded 4.2% lower GA_3 and 22.3% higher ABA content that are vital for flowering in mango. Reduction in GA_3 is expected to favour growth reduction and promoting flowering as evident from the results. Pruning induced changes in GA_3 has also been reported by Singh *et al*., (2009) in different varieties of mango.

PBZ treated trees recorded 22.8% decline in GA_3 contents and 106.9% incline in ABA content than PBZ untreated trees. PBZ is well known for its growth inhibitory effect by interrupting gibberellin biosynthetic pathway. As gibberellins and ABA share common intermediate for their biosynthesis in the isoprenoid pathway; the PBZ induced increase in ABA may be consequence of diversion of biosynthetic intermediate for ABA production. Reduction in endogenous gibberellins and increase in ABA content induced by PBZ has been reported by Upreti *et al*. (2013) and Abdel Rahim *et al*. (2011).

Conclusion

Grafting of Alphonso trees on Vellaikolamban rootstock, pruning of current season's growth and PBZ application was relatively more effective than the combined treatment for regulating tree vigour and effects are due to reduction in gibberellins and increase in ABA besides increases in leaf water potential. The reduction in tree vigour also resulted increase in flowering intensity.

Application of research: The early flowering and improved fruit yield was noticed on trees grafted on vigorous rootstock Olour and pruning of current season's growth under PBZ treatment under ultra-high-density planting system.

Research Category: Horticultural Research

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University: ICAR-Indian Institute of Horticultural Research, Bengaluru, 560 089

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Study area / Sample Collection: ICAR-Indian Institute of Horticultural Research, Hessaraghatta Lake Post, Bengaluru, 560 089

Cultivar / Variety / Breed name: Mango (*Mangifera indica* L.) cv. Alphonso

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