



## Seasonal variation in the root activity and appropriate placement of superphosphate in productive Alphonso mango trees as influenced by application of paclobutrazol

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### ABSTRACT

In 20-year old productive Alphonso mango (*Mangifera indica* L.) trees, the intensity of root activity was significantly higher under 'control' (236 557 dpm/g dry matter) compared to when paclobutrazol was applied @ 3.75 a.i/tree (220 067). Among the seasons, the highest intensity was observed during late rainy season (434 077) while the least was during early rainy season (66 340). The interaction effect showed that during early rainy and winter having good soil moisture regime, 'control' trees showed higher intensity while the reverse was true during drier months of early rainy and summer seasons. Active roots dominated 25 cm depth during early season (76–86%) under paclobutrazol application compared to 60–67% found in 'control'. During late rainy and summer seasons the active roots were uniformly distributed between 25 and 50 cm depths under both 'control' and paclobutrazol treatment. In terms of lateral distance, the active roots predominated 100 cm distance during early rainy season under paclobutrazol treatment. In the following seasons, most of the roots were uniformly distributed between 100 and 200 cm distances. The application of paclobutrazol reduced the intensity of root activity and caused the roots to move closer to the trunk and the soil surface during seasons of higher soil moisture regime. The absorption of P supplied through superphosphate during early- and late-rainy seasons was significantly reduced relative to the untreated 'control' trees. In such trees, the fertilizer had to be placed closest to the trunk (between 90–160 cm radial distances) to achieve high absorption of P compared to the farther placements at 160–230 cm and 230–300 cm found optimum for the untreated 'control' trees to attain high fertilizer use efficiency as consequence of migration of active roots closer to the trunk (100–200 cm radial distance) and towards surface layer (15 cm depth) especially during late rainy season due to the intervention of growth retardant to overcome alternate bearing habit of Alphonso mango trees. These findings form the basis for evolving practical fertilizer management schedules to the mango growers in such situations after more detailed studies employing conventional (non-tracer) techniques.

**Key words:** *Mangifera indica*, Mango, Paclobutrazol, Root activity, Seasonal changes, Tracer technique

Application of paclobutrazol, a triazol, has emerged as a potent measure to induce regular bearing in mango trees in which alternate bearing is an observed phenomenon. Substantial physiological changes in the tree such as inhibited growth of meristem, thickened roots and decreased root length are indicated due to paclobutrazol ([2RS, 3RS]-1-[4-chlorophenyl]-4, -4-dimethyl-2-[1, 2, 4-triazol-1-yl] pent-3-ol) application (Blaikie *et al.* 2004). Earlier studies carried out during late rainy season on 19-year old productive mango (*Mangifera indica* L.) trees (Kotur 2006) had shown that the active roots substantially bunched towards the trunk and the soil surface leading to a nearly one-half of the active roots

(45-58%) to migrate to the zone of 80cm distance and 25cm depth relative to the untreated 'control' trees. Therefore, the effect of the triazole on the root activity of 20-year old healthy trees of Alphonso mango trees was monitored in detail during the entire annual growth cycle involving 4 seasons using soil injection of carrier-free <sup>32</sup>P. An attempt was also made to optimize the appropriate fertilizer placement in paclobutrazol treated mango trees *vis-à-vis* untreated 'control' trees using <sup>32</sup>P-labelled superphosphate to achieve high phosphorus-use efficiency.

### MATERIALS AND METHODS

The trees were raised on a red sandy loam (Typic Haplustalf) having a textural B<sub>1</sub> horizon at 20cm+ depth (>41% clay) overlying a loamy layer (11–14% clay). The soil showed pH of 5.9, organic carbon of 0.3%, cation exchange capacity of 8.8 cmoles (p+)/kg and available (Bray-I) P of

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18 kg/ha at the beginning of the experiment. The first experiment to determine root activity distribution was carried out during 2005–07 in a split plot design with two main treatments: (a) 'control' and (b) paclobutrazol @ 3.75 a.i/tree in 10 concentric holes, 30 cm deep at 1.5 m distance from the trunk in September 2004 when the soil was moist. There were 6 sub-treatments being all possible combinations of 3 radial distances (100, 200 and 300 cm from trunk) and 2 depths (25 and 50 cm from surface). There were 3 replications. Four injections were given during early rainy (June–August 2005), late rainy (September–November 2005), winter (December 2005–February 2006) and summer (March–May 2006) seasons of the annual growth cycle. The tracer (carrier-free  $^{32}\text{P}$  @ 8.86–9.15 mCi or 327.82–334.85 megabecquerels/tree) was applied in pre-installed PVC pipes located concentrically around the tree at different depth-distance locations. Third open leaf from the recent growth was sampled at 15 days interval after the injection of the isotope. The samples were dried in oven at 70° C, powdered and digested in diacid (9:4 nitric: perchloric acid). The activity of  $^{32}\text{P}$  in the digest was determined in a liquid scintillation analyzer by Cerenkov counting. The root activity was calculated from the activity of the tracer monitored in the leaf as:

$$\text{Root activity (\%)} = \frac{\text{Activity of } ^{32}\text{P at a given location}}{\text{Activity of } ^{32}\text{P at all the locations}} \times 100$$

The second experiment was carried out to standardize appropriate fertilizer placement to achieve high fertilizer use efficiency during 2008–09 in a split plot design having 3 replications. Application of paclobutrazol was repeated during September 2007 in the same manner. The main treatments consisted of: (a) 'control' and (b) paclobutrazol @ 3.75 a.i/tree. The sub-treatments consisted of 3 placements of  $^{32}\text{P}$ -labelled superphosphate (between 90 and 160 cm, 160 and 230 cm and 230 and 300 cm radial distance from trunk). The fertilizer placements were evaluated during June–August 2008 (early rainy season) and October–December 2008 (late rainy season) which received one split each of the recommended annual fertilizer dose. Each tree received 500 g of labelled SSP (8% P) along with 250 g of N and 188 g of K in each season. Specific activity of the single superphosphate was 0.210 and 0.283 mCi/g of P during early and late rainy season, respectively. The labelled superphosphate along with the N and K fertilizer was applied in the trenches of 5 cm depth and covered with soil immediately after application. After application of the fertilizer, the recently mature leaves were sampled at fortnightly intervals and the activity of  $^{32}\text{P}$  absorbed from the fertilizer was determined as detailed in the first experiment. The total phosphorus in the digest was determined using vanadomolybdate yellow colour method. Phosphorus derived from the fertilizer (Pdff,%) was calculated

using specific activity in the leaf as follows:

$$\text{Pdff (\%)} = \frac{\text{Specific activity of } ^{32}\text{P in leaf}}{\text{Specific activity of } ^{32}\text{P in fertilizer}} \times 100.$$

## RESULTS AND DISCUSSION

### *Intensity of root activity*

The total radio-activity absorbed by the tree from all the locations in the rooting volume is indicative of the intensity of root activity. Under paclobutrazol application, the intensity of root activity was significantly reduced from 236 557 dpm/g dry matter to 220 067 under 'control' (Table 1). Among seasons, late rainy season showed the most intense root activity (434 077 dpm/g dry matter) followed by summer (249 934), winter (162 895) and early rainy season (66 340). The trends of intensity of root activity were clear under 'control' which can be explained based on the changes in the soil moisture regime which in turn is mainly influenced by the rainfall received. Early rainy season received 446.1 mm rainfall followed by 587.6, 3.2 and 265.3 mm in the following seasons. The lowest soil moisture was prevalent in summer due to only 162.6 mm rainfall received coupled with higher evapo-transpiration losses during March–May 2005. Early rainy season carried forward the drought or low soil moisture regime of the previous summer season and therefore, showed the lowest intensity of root activity. In the late rainy season, the soil moisture regime improved leading to a peak intensity of activity of the roots. The interaction effect showed that during late rainy and winter seasons, 'control' trees showed higher intensity (477 378 and 237 437) while the reverse was true during drier early rainy and summer seasons (Table 2). The reduced intensity of root activity under 'control'

Table 1 Effect of paclobutrazol application on intensity of root activity (dpm/g dry matter) in different seasons of the annual cycle in Alphonso mango trees

Treatment	Intensity of root activity (dpm/g dry matter)
<i>Application of paclobutrazol</i>	
Control	236 557
Paclobutrazol	220 067
SEm (±)	2 324.2
CD (P = 0.05)	4 093.0
<i>Seasons</i>	
Early rainy	66 340
Late rainy	434 077
Winter	162 895
Summer	249 934
SEm (±)	3 287.0
CD (P = 0.05)	5 788.3

Table 2 Interaction effect of paclobutrazol application and seasons on intensity of root activity (dpm/g dry matter) of Alphonso mango trees in different seasons of the annual cycle

Treatment	Seasons			
	Early rainy	Late rainy	Winter	Summer
Control	44 267	477 378	237 437	187 145
Paclobutrazol	88 413	390 777	88 353	312 724
SEm ( $\pm$ )	4 648.5			
CD ( $P = 0.05$ )	8 185.9			

during early rainy (44 267) and summer (187 145) seasons reflect a decline due to lower soil moisture regime during these seasons. This pattern of intensity of root activity is disrupted when paclobutrazol is applied. During drier seasons like early rainy and summer season, the intensity of root activity showed a spurt while during those seasons of relatively high soil moisture the intensity was reduced and markedly so during winter season. Evidently, paclobutrazol application retarded the intensity of root activity under prevailing higher soil moisture regime. Blaike *et al.* (2004) observed that application of morphactin, a derivative of hydroxyfluorine-9-carboxylic acid applied @ 10-26 mg a.i./tree, systematically stopped the current growth on Kensington Pride mango. It also inhibited further development of meristematic tissues of shoots and presumably of roots. As a result, the weight of new roots produced by morphactin-treated trees was about 33-50% of that recorded in the untreated control trees. Such a reduction of growth may limit the capacity of roots to absorb nutrients and water necessitating more intensive fertilizer and irrigation practices in paclobutrazol treated trees. Paclobutrazol application is envisaged best to reduce tree vigour, promote flowering, increase fruit set and yield of mango trees in which alternate bearing is an observed phenomenon. To promote this any undesirable effect on its root activity or distribution during the growing season will have to be managed through appropriate placement and timing of fertilizers.

#### Root activity distribution

A perusal of Fig 1 in respect of depth wise distribution of root activity during different seasons showed that during early rainy season, the active roots dominated at 25 cm depth, especially under paclobutrazol application. During late rainy and summer seasons, the active roots were fairly well-distributed at between 25 and 50 cm depths. During winter, however, the roots migrated *en masse* to 50 cm depth to the extent of 68–88%. With increasing distance from the trunk, in general, the distribution of root activity declined. At 100 cm distance, 46–66% of active roots were present except during early rainy season under 'control' (29–44%) and during late rainy season (35–48%) under paclobutrazol application. At 200 cm distance, 19–45% and at 300 cm

distance, 8–45% roots were present during the annual growth cycle.

**Early rainy season:** At 15 days after injection of the isotope, the root activity distribution was fairly uniform throughout the rooting volume. From 30<sup>th</sup> day onwards, however, the roots tended to move closer to the soil surface (Fig 1). This affect was more pronounced under paclobutrazol treatment and 76.17–86.84% of active roots were observed at 25 cm depth compared to 60.87–67.38% under 'control'. Distance wise, generally the root activity decreased with increasing lateral distance from the trunk (Fig 2). Under paclobutrazol treatment, from 30<sup>th</sup> day onwards, the active roots tended to concentrate close to the tree trunk at 100 cm distance (45.97 to 67.22%, Fig 2) with a concomitant reduction of root activity at 300 cm distance (10.89–14.63%). In untreated trees ('control'), the active roots appeared to be well-distributed between 100 and 300 cm distance up to 30 days after injection of the isotope. Later on, the percentage root activity decreased with distance. In comparison with paclobutrazol treatment, however, this effect was less pronounced.

**Late rainy season:** In terms of depth, under paclobutrazol treatment, the active root continued to dominate 25 cm depth (52.88–63.50%) but there was a gradual gain at 50 cm depth from 36.5 to 46.17% from 15<sup>th</sup> day to 60<sup>th</sup> day of sampling.

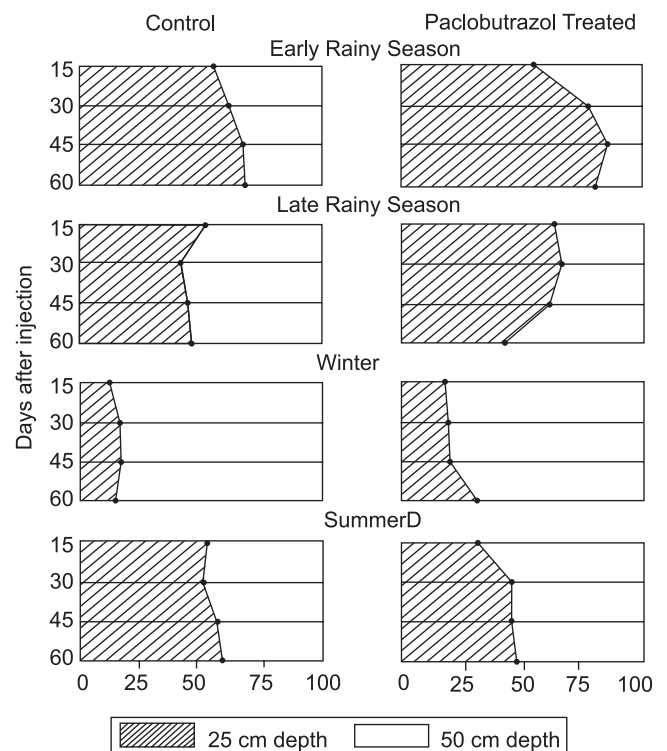


Fig 1 Root activity distribution (%) at 25 and 50 cm depths from surface during different days of sampling after injection of the tracer

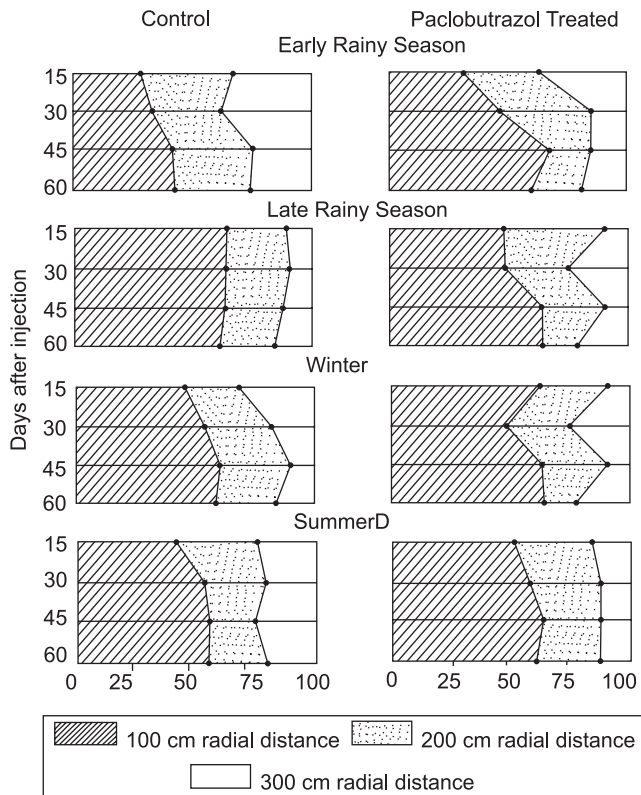


Fig 2 Root activity distribution (%) at 100, 200 and 300 cm radial distances from the trunk during different days of sampling after injection of the tracer

Under 'control', however, the active roots were fairly well-distributed between 25 and 50 cm depths at 15 days after injection. In the later samplings the roots showed a higher root activity at 50 cm depth (54.57–59.53%) compared to at 25 cm depth (40.47–45.43%). In terms of lateral distance, under paclobutrazol treatment, about 80% of active roots were present up to 200 cm and at 300 cm distance only 17.90 – 20.94% of roots were present. Under 'control', however, 62.50 – 65.45% of active roots were found at 100 cm distance and gradually decreased at 200 cm (24.44–27.19%) and 300 cm (8.09–15.31%) distances. From 15 to 60 days after injection, there was a gradual increase in active roots present at 300 cm distance corresponding to a decrease at 100 cm distance. The results closely conformed to those of Kotur (2006) during this season earlier.

**Winter season:** Under both the treatments, a similar root activity was observed. Over one-half of active roots (46.81 to 63.10%) were present at 100 cm lateral distance. With increase in the lateral distance, the percentage of active roots, generally, decreased. Depth wise, at 25 cm distance, a lower percentage of active roots (12.04–17.78%) was observed while the bulk of 82.2–87.96% of active roots migrated to 50 cm depth. At 60<sup>th</sup> day of injection, under paclobutrazol treatment, however, 31.76% of active roots were present at 25 cm depth.

**Summer season:** Under both the treatments, the percentage of active roots decreased with increasing lateral distance. However, at 100 cm distance, relatively higher quantum of active roots (52.62–64.61%) was observed under paclobutrazol treatment compared to under 'control' (42.64–57.49%). Depth wise, under paclobutrazol treatment relatively lower amounts of active roots (46.94–31.91%) were observed at 25 cm compared to under 'control' (59.93–49.66%). The results showed that the application of paclobutrazol reduced the intensity of root activity and caused the roots to move closer to the trunk and the soil surface during seasons of higher soil moisture regime needing a relook at appropriate placement of fertilizers in the zone of high root activity to enhance fertilizer-use efficiency.

#### *Appropriate placement of superphosphate to achieve phosphorus-use efficiency*

Generally, higher values of Pdf were observed (Table 3) in the late rainy season due to the higher soil moisture regime prevalent in the soil. Among the treatments, 'control' trees showed significantly higher absorption of P from the applied superphosphate owing to the higher intensity of root activity observed in this season (Kotur 2006). The overall low values of Pdf may be attributed to the dilution of the tracer in the massive biomass of the mature productive mango trees. The changes of Pdf attained significance in the 45<sup>th</sup> and 60<sup>th</sup> day samples. From the interaction effect between application of paclobutrazol (S, Table 1) and placement of fertilizer (P) during late rainy season at 45<sup>th</sup> day sampling, the highest absorption of 0.624% Pdf was evident under paclobutrazol treatment at 90-160 cm placement which was *at par* with 0.600% under 'control' at 230-300 cm placement. However, when superphosphate was placed between 90 and 160 cm radial distances, under paclobutrazol treatment the highest Pdf of 0.903% was observed. Under 'control' the highest Pdf of 0.689 and 0.708% which were *at par* were found when the fertilizer was placed between 160 and 230 cm as well as between 230 and 300 cm radial distances. The results indicated that application of paclobutrazol to 'Alphonso' mango trees caused significantly lower absorption of fertilizer P. In paclobutrazol treated mango trees the fertilizer had to be placed closest to the trunk (90-160 cm) while the untreated ones showed high absorption from farther placements (between 160-300 cm radial distances) as a 70 cm band, away from the trunk. This is a consequence of migration of active roots closer to the trunk (100-200 cm radial distance) and towards surface layer (15 cm depth) especially during late rainy season due to the intervention of growth retardant. This calls for a change in the quantum of P dose as well as the fertilizer management practices to sustain high phosphorus absorption when paclobutrazol is used to overcome alternate bearing habit of Alphonso mango trees. The results of this experiment using radioactive labeled fertilizer acts as pointer to the issue of fertilizer management

Table 3 Phosphorus derived from fertilizer (Pdff, %) during early and late rainy seasons as influenced by paclobutrazol application to mango trees

Application of paclobutrazol (P)	Early rainy season				Late rainy season			
	Placement of fertilizer (S) (between radial distances, cm)			Mean	Placement of fertilizer (S) (between radial distances, cm)			Mean
	90–160	160–230	230–300		90–160	160–230	230–300	
<i>15<sup>th</sup> day after application of the <sup>32</sup>P labeled superphosphate</i>								
Control	0.089	0.094	0.103	0.095	0.088	0.058	0.071	0.072
Paclobutrazol	0.097	0.105	0.093	0.098	0.094	0.058	0.058	0.070
Mean	0.093	0.100	0.098	0.097	0.091	0.058	0.064	0.071
Statistical parameters	SEm (±)			CD (P=0.05)	SEm (±)			CD (P=0.05)
P	0.0014			NS	0.0019			NS
S	0.0017			NS	0.0024			0.0054
P×S Interaction	0.0024			0.0054	0.0034			0.0075
<i>30<sup>th</sup> day after application of the <sup>32</sup>P labeled superphosphate</i>								
Control	0.174	0.168	0.216	0.186	0.236	0.203	0.202	0.214
Paclobutrazol	0.176	0.176	0.194	0.182	0.197	0.204	0.193	0.198
Mean	0.175	0.172	0.205	0.184	0.583	0.394	0.422	0.206
Statistical parameters	SEm (±)			CD (P=0.05)	SEm (±)			CD (P=0.05)
P	0.0014			NS	0.0064			NS
S	0.0017			0.0037	0.0078			NS
P×S interaction	0.0024			0.0054	0.0034			NS
<i>45<sup>th</sup> day after application of the <sup>32</sup>P labeled superphosphate</i>								
Control	0.200	0.263	0.231	0.231	0.462	0.398	0.600	0.486
Paclobutrazol	0.198	0.159	0.224	0.193	0.624	0.390	0.244	0.419
Mean	0.199	0.210	0.227	0.212	0.543	0.394	0.422	0.453
Statistical parameters	SEm (±)			CD (P=0.05)	SEm (±)			CD (P=0.05)
P	0.0032			0.0072	0.0135			0.0302
S	0.0040			0.0088	0.0166			0.0370
P×S interaction	0.0056			0.0125	0.0234			0.0523
<i>60<sup>th</sup> day after application of the <sup>32</sup>P labeled superphosphate</i>								
Control	0.741	0.891	0.960	0.864	0.511	0.689	0.708	0.636
Paclobutrazol	0.747	0.856	0.768	0.790	0.903	0.520	0.709	0.711
Mean	0.744	0.875	0.864	0.827	0.707	0.605	0.709	0.674
Statistical parameters	SEm (±)			CD (P=0.05)	SEm (±)			CD (P=0.05)
P	0.0182			0.0414	0.0140			0.0313
S	0.0223			0.0501	0.0172			0.0383
P×S interaction	0.0310			NS	0.0243			0.0542

of mango receiving paclobutrazol. However, more detailed research needs to be taken up using conventional methods to evolve practical fertilizer management schedules in conjunction with paclobutrazol application to overcome alternate bearing malady.

#### REFERENCES

- Blaike S J, Kulkarni V J and Muller L J. 2004. Effects of morphactin and Paclobutrazol flowering treatments on root and shoot phenology in mango cv Kensington. *Scientia Horticulturae* **101**: 51–68.
- Keshava Murthy S V and Kotur S C. 1998. Fertilizer use efficiency in citrus, grape, banana, mango and guava as influenced by time of application and placement method. *Karnataka Journal of Agricultural Sciences* **11**: 1023–9.
- Kotur S C and Keshava Murthy S V. 2003. Standardization of method of fertilizer placement in 'Surya' papaya (*Carica papaya*) using <sup>32</sup>P-labelled superphosphate. *Indian Journal of Agricultural Sciences* **73**: 269–71.
- Kotur S C. 2006. Effect of paclobutrazol on root activity of mango (*Mangifera indica*). *Indian Journal of Agricultural Sciences* **76**: 143–4.