Effect of Soil Applied Paclobutrazol on Fruit Retention, Fruit Size, Tree Yield and Tree Revenue in Sensation and Tommy Atkins Mango

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ABSTRACT
Soil application of paclobutrazol was primarily evaluated as a measure to increase fruit size in Sensation, and to increase fruit retention in Tommy Atkins.
One or 10 ml of Cultar® made up to 100 ml with water (0.25 g a.i. or 2.50 g a.i.) was applied to the soil by making a 60 cm-diameter ring around the trunk of two-year-old Sensation and Tommy Atkins mango trees just prior to the initiation of postharvest flushing. In Sensation, average fruit weight (final fruit size) and tree revenue were increased in direct relation to the rate of paclobutrazol (PBZ) applied. Number of fruit retained and tree yield were not affected. In Tommy Atkins, number of fruit retained, average fruit weight, tree yield, and tree revenue were reduced in direct relation to the rate of PBZ applied. The contrasting results between the cultivars appeared to relate to a difference in responsiveness to paclobutrazol. The retarding effect of paclobutrazol on extension or expansion growth was generally limited in Sensation, but was pronounced in Tommy Atkins.

INTRODUCTION

South African exports of mangoes comprise cultivars originating in Florida (USA). Fresh mangoes are almost exclusively sent to Europe, where potential grower returns are greatest, and where price per kilogram is strongly related to size.

Fruit retention is relatively high in Sensation, the number of inflorescences retaining fruit generally exceeding 70% (Oosthuyse, 1995a). However, the fruit are relatively small at harvest. Consequently, inferior prices are obtained, and a large proportion of the fruit falls into size classes that are uneconomical to export. In Tommy Atkins, the proportion of inflorescences retaining fruit varies from 10 to 25% (do, unpublished). The fruit of this cultivar tend to be large, and often fall beyond the size-range receiving maximum prices in Europe.

Paclobutrazol (PBZ) is a growth retardant inhibiting gibberellin biosynthesis in plants (Graebe, 1982; Hedden and Graebe, 1985). In Alphonso mango, relatively low rates of PBZ applied via the soil were found to increase the number of fruit retained per inflorescence (Kurian and Iyer, 1993b). Reductions in fruit retention and in fruit size were found following soil applications at relatively high rates to `Kensington Pride' and `Alphonso' mango trees (Winston, 1992; Kurian and Iyer, 1993b; 1993c).

Manual fruit thinning was found to increase fruit size and tree revenue in Sensation mango (Oosthuyse, 1995b). Relatively high soil application rates of PBZ to Sensation trees might thus be expected to effect an increase in fruit size and tree revenue by reducing fruit retention. In Tommy Atkins, treatments increasing fruit retention were previously found to reduce fruit size (Oosthuyse, 1993). Relatively low soil application rates of PBZ might thus be expected to increase fruit retention and reduce fruit size, and thereby increase tree revenue in Tommy Atkins.

The present study was performed to assess the effect of a low or of a high rate of soil applied PBZ on fruit retention, fruit size, tree yield, and tree revenue in Sensation and Tommy Atkins mango.

MATERIALS AND METHODS

In early December 1992, 30 Sensation and 30 Tommy Atkins mango trees were selected in separate cultivar blocks at Mariepskop Estate (dry subtropical; latitude: 24^{0}25'S; longitude: 30^{0}52'E; elevation: 550 m) in the Northern Province of South Africa. The soils in each block were similar in composition (Sensation: 80% sand; 9% silt; 11% clay; Tommy Atkins: 82.5% sand; 7% silt; 10.5% clay). The trees of both cultivars were two years old when treated, and had shown substantial growth. Irrigation was scheduled, and water-stress was not imposed at any stage. Five hundred grams of composted chicken manure supplemented with guano (10%) and dried kelp (5%), and 30 g of limestone ammonium nitrate (28% N) were applied monthly to each tree. Fungicides and insecticides were administered regularly to control harmful insects and pathogens. The vigorous terminal shoots on each tree had been tipped (specific removal of the apical bud) after each flushing cycle from the time of planting to encourage branching and growth.

PBZ was applied just prior to the initiation of postharvest flushing. Accordingly, the Tommy Atkins trees were treated on Feb. 19 1993, and the Sensation trees were treated on April 8 1993. One or 10 ml of Cultar® (250 g PBZ / l) made up to 100 ml with water (0.25 g a.i. and 2.50 g a.i. respectively), was applied to the soil by making a 60 cm-diameter ring around the trunk. Directly after treatment, the trees were irrigated for one hr (one microjet per tree deliv-

Table 1 *Means and contrast significance levels (P) for number of fruit retained, average fruit weight, tree yield, and tree revenue in Sensation.*

Paclobutrazol (PBZ) applied (g)	Number of fruit per tree	Average fruit weight (g)	Tree yield (kg)	Tree revenue (Rands)
0.00	58	221	12.8	8.3
0.25	52	233	12.2	10.1
2.50	52	251	13.1	14.1
ANOVA results - ^{x}P values				
Linear	ns	**	ns	**
Quadratic	ns	ns	ns	ns

^{x}Non-significant (ns), or significant at P < 0.005 (*), 0.01 (**) or 0.001 (***)

Table 2 *Means and contrast significance levels (P) for inflorescence development index, inflorescence number, inflorescence length, number of flushes, new shoot length, number of new shoot leaves, leaf area, and canopy diameter in Sensation.*

Paclobutrazol (PBZ) applied (g)	Inflorescence development index	Inflorescence number	Inflorescence length (cm)	Number of flushes	New shoot length (cm)	Number of shoot leaves	Leaf area (cm^2)	Canopy diameter (m)
0.00	0.39	165	25.9	1.11	13.7	10.6	27.1	1.17
0.25	0.45	145	22.0	1.04	14.4	10.1	26.7	1.01
2.50	0.55	179	14.1	1.08	11.9	9.0	25.1	1.01
ANOVA results - ^{x}P values								
Linear	*	ns	***	ns	*	ns	*	*
Quadratic	ns	ns	ns	ns	ns	ns	ns	**

^{x}Non-significant (ns), or significant at P < 0.005 (*), 0.01 (**) or 0.001 (***)

ering 46 l per hr). In each cultivar, 10 trees were treated with each concentration, and 10 untreated trees served as controls. A randomized complete blocks design was employed where single trees served as plots. Shortly after the trees were treated, eight vigorous terminal shoots on each tree were tagged. They were selected so as to be well distributed on the canopy periphery.

Flushing and subsequent flowering of the tagged shoots (branches) resulted only from the development of the apical buds. Flowering commenced during June or July 1993. To ascertain differences in flowering time in relation to treatment, inflorescence development on the tagged branches was monitored weekly. The stages of development as described by Oosthuyse (1991) were assigned on each occasion and subsequently transformed to indices ranging in value from 0 to 1. Each index portrayed the stage of inflorescence development on a quantitative time-scale relative to budbreak (0) and the stage characterized by the abscission of flowers and inflorescence axes (1). The indices recorded on July 27 1993 in Tommy Atkins, and on Aug. 6 1993 in Sensation, i.e., when the advanced inflorescences on each cultivar were in full-bloom, were subjected to data analysis.

Shortly after flowering, the number of inflorescences on each tree and the length of the inflorescence on each of the tagged branches was recorded. The number of vegetative flushes arising on each of the tagged branches after the trees were treated and before the trees flowered was also counted (at least one new shoot developed per branch). In addition, the number of leaves on, and the length of the new shoot from which the inflorescence developed on each of the tagged branches were recorded. Three randomly selected leaves were then removed from two of these shoots per tree, and the surface area of each (one side only) was determined using an area meter.

In late November 1993, once fruit drop had ceased, the number of fruits on each tree was counted. At harvest (Tommy Atkins: Dec. 14 1993; Sensation: Jan. 19 1994) the fruits on each tree were individually weighed. On June 30 1994, once postharvest flushing had ceased and before flowering commenced, the height and width of the canopy of each tree was measured.

Tree revenue was ascertained by individually transforming fruit weights to returns after the deduction of packing, shipping and agent costs. Returns (obtained from HM Exporting Co, Tzaneen) for the most lucrative marketing alternatives (fresh export, fresh local or processing) for Sensation and Tommy Atkins mangoes of various sizes were used. The absence of fruit rejection due to superficial markings, disease, insect damage, or atypical shape was assumed.

The data (tree totals or averages) were subjected to analysis of variance, where the sums of squares for treatments was subdivided for reductions due to linear and quadratic components.

RESULTS AND DISCUSSION

The effect of PBZ on growth, flowering and cropping in Sensation is shown in Tables 1 and 2. Number of fruit retained and tree yield were apparently not affected. Aver-

Table 3 *Means and contrast significance levels (P) for number of fruit retained, average fruit weight, tree yield, and tree revenue in Tommy Atkins.*

Paclobutrazol (PBZ) applied (g)	Number of fruit per tree	Average fruit weight (g)	Tree yield (kg)	Tree revenue (Rands)
0.00	14	430	5.7	16.5
0.25	14	381	5.1	14.6
2.50	9	286	2.5	6.2
ANOVA results - ^{x}P values				
Linear	*	*	**	**
Quadratic	ns	ns	ns	ns

^{x}Non-significant (ns), or significant at P < 0.005 (*), 0.01 (**) or 0.001 (***)

Table 4 *Means and contrast significance levels (P) for inflorescence development index, inflorescence number, inflorescence length, number of flushes, new shoot length , number of new shoot leaves, leaf area, and canopy diameter in Tommy Atkins.*

Paclobutrazol (PBZ) applied (g)	Inflorescence development index	Inflorescence number	Inflorescence length (cm)	Number of flushes	New shoot length (cm)	Number of shoot leaves	Leaf area (cm^2)	Canopy diameter (m)
0.00	0.59	65	23.6	1.03	13.0	9.2	40.8	1.26
0.25	0.67	71	13.6	1.04	6.0	9.4	33.9	0.88
2.50	0.65	78	7.6	1.10	2.9	10.0	32.8	0.77
ANOVA results - ^{x}P values								
Linear	ns	ns	***	*	***	ns	*	***
Quadratic	*	ns	***	ns	***	ns	*	***

^{x}Non-significant (ns), or significant at P< 0.005 (*), 0.01 (**) or 0.001 (***)

Fig. 1 *Clustering of the leaves in Tommy Atkins as a result of the pronounced retarding effect of paclobutrazol on internode extension.*

Fig. 2 *Appearance of Tommy Atkins (left) and Sensation (right) inflorescences on trees which received 2.5g of paclobutrazol.*

age fruit weight and tree revenue were increased in direct relation to the rate of PBZ applied. Flowering time was advanced and inflorescence length, new shoot length, and leaf area were reduced in direct relation to the rate of application. Canopy diameter was reduced by PBZ, although the reduction did not appear to differ in relation to the rate of application. Inflorescence number, number of flushes and number of new shoot leaves were not affected.

The effect of PBZ on growth, flowering and cropping in Tommy Atkins is shown in Tables 3 and 4. Number of fruit retained, average fruit weight, tree yield, and tree revenue were reduced in direct relation to the rate of PBZ applied. PBZ advanced flowering time, although the degree of advancement did not appear to differ in relation to the rate of application. Inflorescence length, new shoot length, leaf area, and canopy diameter were reduced by PBZ. In each instance here, the effect of the low rate of application was much greater per `unit' of PBZ applied than that of the high rate of application. The number of flushes produced was increased in direct relation to application rate. Number of inflorescences and number of new shoot leaves were apparently unaffected by PBZ.

The leaves on the new shoots of the treated Tommy Atkins trees were clustered (Fig. 1). Leaf clustering was not observed in Sensation, however. In both the Tommy Atkins and Sensation trees receiving the highest dose of PBZ, the inflorescences were often highly condensed, resembling ice-cream cones (Fig. 2).

PBZ was far more effective in retarding extension and expansion growth in Tommy Atkins than in Sensation. It would appear, therefore, that the cultivars themselves differed greatly in their response to PBZ, especially with regard to shoot extension and leaf expansion. Differences in the effect of PBZ relating to cultivar have not been reported before in mango. Cultivar differences have been found in other perennial crop plants, however (Volz and Knight, 1986; Reynolds *et al.*, 1992).

In mango, soil applications of PBZ have consistently been found to advance flowering time, to increase the number of inflorescences developing, to reduce inflorescence size, internode length, girth growth and leaf size, and to increase tree yield (Kulkarni, 1988; Rowley, 1990; Charnvichit and Tongumpai, 1991; Tongumpai *et al.*, 1991; Burondkar and Gunjate, 1991; 1993; Winston, 1992; Kurian and Iyer, 1993a, 1993b, 1993c; Werner, 1993). Corresponding results were found in the present study concerning flowering time, inflorescence extension, shoot extension, and leaf expansion.

In the foregoing studies, which were performed at geographical locations where environmental conditions for flowering are often inadequately inductive, the yield increases observed were associated with increases in the number of inflorescences initiated. In general, winter conditions in the Northern Province of South Africa are adequately inductive, and hence, a marked enhancement in the number of inflorescences initiated in response to PBZ was not expected.

Following PBZ soil application, Kurian and Iyer (1993a) reported a reduction in the number of new flushes initiated by Alphonso mango trees, whereas increases and reductions were found by Winston (1992) in `Kensington Pride' mango. Inconsistency in this regard was also found in the present study. In Sensation, one new flush was pro-

duced on average, whereas in Tommy Atkins, the number of flushes produced increased slightly with application rate.

Soil applied PBZ has also been reported to reduce the number of nodes or leaves on mango shoots (Kurian and Iyer, 1993a), as well as to suppress apical dominance (Kulkarni, 1988). These findings are not supported by the present study. Furthermore, Werner (1993) found that lateral sprouting in mango was reduced by PBZ. In deciduous fruit trees, it is generally found that the reduction in shoot length caused by PBZ is more due to reduced internode length than to a reduction in the number of nodes formed (Blanco, 1987; Blanco, 1988, Curry, 1988; Forshey, 1991).

PBZ has not formerly been found to effect an increase in fruit size in mango. An increase in fruit size in association with suppressed inflorescence development has been previously observed, however (Oosthuyse, 1993), and possibly relates to a lesser depletion of carbohydrate and other nutrient reserves by inflorescences whose development is suppressed (Monselise and Goldschmidt, 1982; Chauhan and Pandey, 1984).

The leaves on the new shoots of the treated Tommy Atkins trees were clustered. It might be considered that photosynthesis of the leaves on these shoots was reduced owing to mutual leaf shading. A decline in fruit retention resulting from diminished photoassimilate availability has been shown (Chacko *et al.*, 1982).

The objective of increasing fruit size and tree revenue in Sensation by soil application of PBZ was achieved. However, the objective of increasing tree revenue in Tommy Atkins by increasing fruit retention and reducing fruit size was not realized. The contrasting results between the cultivars concerning cropping were apparently related to the extent of the effect of PBZ on extension and expansion growth. It would seem that fruit retention and fruit size were not reduced in Sensation (as opposed to Tommy Atkins) owing to the limited effect of PBZ on vegetative growth in this cultivar.

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