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Responses of potted Hass avocado plants to paclobutrazol drenches

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INTRODUCTION

Shoot extension growth is strongly influenced by gibberellins. Since paclobutrazol is a potent inhibitor of gibberellin biosynthesis (Dalziel & Lawrence, 1984; Rademacher, Jung, Graebe & Schwenen, 1984; Hedden & Graebe, 1985) it follows that paclobutrazol should exert its greatest effect on tissues which are rapidly growing and developing at the time of treatment or shortly thereafter (Steffens & Wang, 1986). Accordingly, effective growth control has been obtained in a wide range of plants (Lever, Shearing & Batch, 1982), whether applied to the soil, to a whole plant or to the stem (Quinlan & Webster, 1982; Williams & Edgerton, 1983).

There has been extensive research on pome and stone fruit crops, with relatively less done on evergreen fruit trees (Wolstenholme, Whiley & Saranah, 1989). Pleasing results from field trials conducted on avocados have resulted in paclobutrazol recently being registered as a soil drench for tree growth control. This trial evaluates the responses of potted avocado plants to paclobutrazol drenches, with special reference to morphology, dry matter partitioning and leaf mineral element concentration.

MATERIALS AND METHODS

A randomised block design was used with 112 Hass on Duke 7 avocado plants. Four-tree plots received one of four concentrations of paclobutrazol, and were replicated seven times. Each plant was randomly assigned to a plot, and treatments similarly assigned to the plots.

Plants in polythene sleeves received from Westfalia nursery, Duivelskloof, were re-potted into 10 litre volume plastic bags containing a 1:3 sand to FRIT-enriched, pasteurised pine bark medium and allowed to grow for about four months. Each plant received dilute nutrient feed (N,P,K) administered daily through a microjet irrigation system of spray stakes. During this period of establishment under glasshouse conditions and natural daylight, no branching was permitted, to encourage maximum growth from one growing point. The trees were kept erect with wire stakes. At the end of the spring vegetative growth flush, each plant was treated with its assigned concentration of paclobutrazol mixed into 250 ml water, poured evenly over the surface of the medium, which had previously been saturated with water to ensure uniform penetration of the chemical. Treatment A (control) plants received only 250 ml water each. Treatment B, C and D plants received, in addition, 1,25, 2,5 and 5,0 ml Cultar® per m^2 canopy area, respectively. Canopy area was calculated as average stem height multiplied by average estimated canopy width. Date of application was August 23, 1988.

Initial measurements of stem height, diameter and leaf number were taken after treatment, followed by subsequent measurements of stem height and diameter, taken at approximately two-week intervals until harvest at 111 days after treatment (DAT). Subjective visual observations were also made during these times. Harvest coincided with the hardening off of the second vegetative growth flush.

At the conclusion of the experiment (December 12, 1988), measurements were taken of stem height, measured from medium surface to apical bud; diameter, measured approximately 3cm above the graft union; leaf area, using a LI-COR 3100 leaf area meter, and leaf number. The soil medium was washed from the roots and the plants were separated into leaf, stem and root components. The fresh mass of each component was recorded, followed by oven-drying at 60°C to constant mass for dry mass determination. Dried leaf material was analysed for N, P, K, Ca, Mg and B, by Outspan Laboratories, Verwoerdburg.

Leaf chlorophyll *a* and *b* contents were determined by placing 0,50 cm leaf discs into 80 per cent acetone and reading the absorbance at 645 and 663 nm (Arnon, 1949) respectively, once all the chlorophyll appeared to have dissolved (48 hours).

Results were analysed by means of analysis of variance, and significance calculated using LD at 5 per cent and 1 per cent.

RESULTS

Shoot growh reduction due to paclobutrazol, remained non-significant for up to 57 days, after which the control (treatment A) was always significantly different from the paclobutrazol treatments (Figure 1). At harvest, trees in treatment A were significantly taller than in treatment B which was, in turn, significantly taller than both C and D, whose heights were relatively similar.

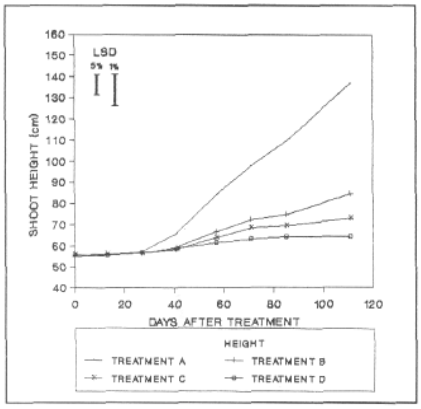

Fig 1 Hass avocado shoot growth inhibition response, after treatment with different concentrations of paclobutrazol applied as a drench.

Internode length decreased as shoot growth inhibition increased. However, stem diameter data suggest that an increase in girth relative to height, was occurring (Table 1).

TABLE 1 Responses of Hass avocado plants growth for 11 days in 10 ℓ of 1:3 sand:bark (v/v), to different concentrations of paclobutrazol applied as a soil medium drench

Parameter	Paclobutrazol (mℓ Cultar® / m² canopy area)				
	A 0	B 1,25	C 2,50	D 5,00	SIG
Plant height (cm)	136,4a	84,5b	73,0bc	64,3c	★★
Internode length (cm)	10,1a	7,3b	5,1b	3,5b	★
Stem diameter (mm)	11,9a	8,68b	8,2b	8,12b	★★
Total LA (cm²)	5691a	878b	847b	796b	★★
Leaf no	114,4a	42,4b	39,0b	29,1b	★★
Branches/plant	12,4a	7,2b	6,2bc	4,4c	★
Leaf DM/plant (g)	53,9a	27,8b	26,9b	22,9b	★
Stem DM/plant (g)	41,2a	16,9b	15,1b	13,9b	★★
Root DM/plant (g)	46,2a	38,1a	25,7b	23,36b	★
Root:Shoot ratio	0,49a	0,85c	0,62b	0,63b	★
Leaf chlorophyll *a* (Absorbance 645 nm)	0,612b	0,702a	0,649b	0,673b	★
Leaf chlorophyll *b* (Absorbance 663 nm)	1,436	1,558	1,607	1,439	NS

Means within rows followed by the same letter not significantly different by LSD at 5 per cent (★) and 1 per cent (★★). NS = non-significant.

Leaf area (LA), leaf number, leaf-and stem dry mass (DM), all decreased with increasing paclobutrazol concentrations, the control being significantly different from the paclobutrazol treatments. The trend in root DM was similar, but the decrease between A and B roots was not significant. Dry mass data were used since fresh masses showed a similar trend.

Branching, which was first detected 41 DAT and was predominantly on control plants, progressively decreased with increasing paclobutrazol concentration. Flowering began 16 days later on B treatment plants. At 71 DAT, there were 0, 6, 11 and 10 plants with flowers in treatment A, B, C, and D respectively. Panicle expansion was progressively inhibited with increasing paclobutrazol concentrations, and at the highest concentration, the flowers were closely associated with the stem, often located under the extremely curled leaves (Figure 2). Some fruit were set, growing to pea size before termination of the experiment.

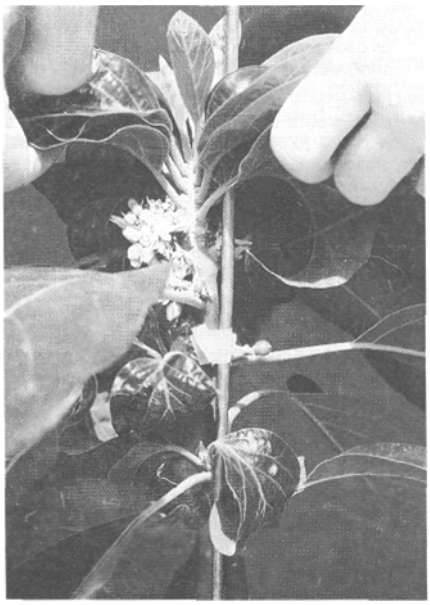

Fig 2 Treatment D Hass avocado plant, showing small, curled leaves with "bubbled" lamellae, short internodes, flower position and developing fruitlets.

Aphids were observed on control plants only at 85 DAT, and were sprayed with Mercaptothion (125 ml/ 100 ℓ).

The root:shoot ratio of treated plants was significantly larger than the control (Table 1). Treatment B had the highest root shoot ratio, with C and D being significantly lower, but similar to each other.

Leaf chlorophyll a content (represented by absorbance values) was significantly higher in treatment B leaves than A, C and D, being lowest in the control. Chlorophyll *b* showed no significant trends, although the highest concentration was in treatment C.

Mineral element trends (Table 2) reveal that leaf N levels were significantly higher in control plants than treated plants. Amongst the paclobutrazol treatments, treatment D was highest on average. The overall level was high. P had a non-significant, tenuous trend to decrease with increasing paclobutrazol concentration. Leaf K decreased as concentration increased, with the control concentration being significantly higher than B, C or D, which were not significantly different. No trends were detected in leaf Ca levels, but treatment B had the highest level, and treatment C the lowest. The leaf Mg level was significantly higher in D plants than the others, with the control being lowest on average. The only significant response to boron was a reduction in leaf concentration at the highest paclobutrazol treatment.

TABLE 2 Hass avocado leaf nutrient content as affected by soil-application of paclobutrazol to plants growing in 1:3 sand:bark (v/v) in a glasshouse

Element	Paclobutrazol (*ml* Cultar®/*m²* canopy area)				
	A	B	C	D	SIG
	0	1,25	2,50	5,00	
N (%)	3,334a	2,740b	2,824b	3,031b	★★
P (%)	0,334	0,314	0,314	0,310	NS
K (%)	1,783a	1,516b	1,473b	1,450b	★★
Ca (%)	1,506	1,663	1,453	1,591	NS
Mg (%)	0,447a	0,499a	0,476a	0,573b	★★
B (mg/kg)	59,1ab	63,4a		51,3b	★

Means within rows followed by the same letter not significantly different by LSD at 5 per cent (★) and 1 per cent (★★). NS = non-significant.

DISCUSSION AND CONCLUSIONS

Reduced shoot growth, typically expressed by the shortening of inter-nodes, is one of the most widely reported morphological responses to paclobutrazol for both deciduous and evergreen plants (Wample & Culver, 1983; Stang & Weis, 1984; Bausher & Yelenosky, 1986; Early & Martin, 1988, Kohne, 1988). In this trial, the same response was observed. Eight weeks elapsed before significant differences in shoot growth became apparent. This lag period was possibly the result of chemical application coinciding with a root flush that followed the first shoot flush. Chemical intercepted by the roots may have been drawn preferentially to active sites of growth in the roots and only later transported upwards in any significant quantity, into the shoot. Alternately, the chemical could have moved into the shoot immediately, with inhibition only becoming apparent once active shoot growth resumed.

About this time, leaves appearing on new stem growth of treated plants had reduced LA, abaxially curled midribs, a darker green colour and 'bubbled' lamellae, consistent with previous reports (Wample & Culver, 1983; Kohne & Kremer-Kohne, 1987; Wolstenholme, Whiley, Saranah, Symonds, Hofman & Rostron, 1988). At the high concentrations, while the leaves generally appeared darker green, chlorophyll *a* and *b* readings reflected little significant change in chlorophyll content (Table 1). This may suggest that at harvest, some degree of etiolation has occurred, due to differential shoot growth producing shading. Since Mg is the central atom in chlorophyll (Devlin, 1975), the high Mg content found in treatment D leaves (Table 2) could mean that some shade-induced alteration to chloroplasts had occurred.

Soon after the onset of new growth, flowering was observed on treated plants. Reproductive buds may have been induced by paclobutrazol, either directly by a lowered gibberellin concentration in cells, or indirectly by modifying the root: shoot ratio through a shift in assimilate partitioning. Further indication of altered partitioning is possibly given by the slight, general tendency for stem girth to increase relative to height (Table 1), as well as the fact that control plants had many branches and no flowers, while treated plants had fewer branches and produced flowers. This agrees with Anon (1984), who regards the diversion of assimilates to flower bud production as the major effect of paclobutrazol, aside from growth inhibition. Nonetheless, it is uncertain why a greater proportion of plants did not flower.

Possibly then, the high root: shoot ratio obtained in B treatment plants (Table 1) is associated with these plants flowering first. This large ratio may result from some measure of root growth stimulation; especially since shoot growth was not excessively inhibited. However, stimulation observed in citrus plants, in response to relatively low concentrations of paclobutrazol, resulted in accelerated shoot growth (Bausher & Yelenosky, 1986). The difference may result from the different application methods, as the citrus trees were sprayed. In any event, the fact that such young plants were induced to flower is indicative of the powerful growth retardant effects of paclobutrazol.

Leaf N levels increased with increasing paclobutrazol concentration, in agreement with previous reports for deciduous crops (Atkinson & Crisp, 1982; 1983; Ráese & Burts, 1983), except that paclobutrazol treatment levels were below control levels (Table 2). The overall high levels detected could be the result of the regular supply of liquid fertilizer to the plants, as well as that in the pre-enriched bark medium, leading to luxury uptake by the plants (Tisdale, Nelson & Beaton, 1985).

Decreasing K trends reflect the typical response found in apple crops subjected to paclobutrazol (Swietlik & Miller, 1985). Since a general tendency in plants is for Ca and Mg ions to compete with K for entry into plants (Tisdale, Nelson & Beaton, 1985) if leaf concentrations reflect this relationship the K levels may be associated with the general Mg levels, which tended to rise. Calcium, however, followed no trend, but the high level in treatment B leaves may be the result of the relatively larger rootsystem in these plants. P levels remained particularly uniform indicating a clear lack of response to paclobutrazol. Boron showed no clear trend, but was low in treatment D plants. Since flowering was most intense in this treatment, the low B level observed may partially reflect a loss due to flowering.

The varied responses of the leaf elements could be partially accounted for by the different leaf development stages at harvest, since paclobutrazol resulted in delayed bud break, so that C, and especially D treatment leaves were younger than the A and B treatment leaves.

This trial clearly reveals that paclobutrazol effectively controlled vegetative growth, encouraged flowering and induced typical morphological responses in potted Hass avocado plants. Application rates were higher for treatments C and D than recommended for avocado plants, in order to compensate for the high bark content of the medium, which being organic, was expected to bind the compound (Williams & Edgerton, 1983). Lower paclobutrazol concentrations may well have clarified differences between the treatments themselves, which in this instance were often non-significant. A physiological study of gibberellin and carbohydrate levels would possibly provide more information, to enable more effective utilization of paclobutrazol and other new anti-gibberellin growth inhibitors. This work is in hand.

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