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Paclobutrazol increases fruiting in container grown Pummelo and Barbados cherry

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Five concentrations of paclobutrazol ('Cultar') were applied as a soil drench to container grown pummelo (*Citrus grandis*), grafted on either sour orange (*Citrus aurantium*) or alemow (*Citrus macrophylla*), and Barbados cherry (*Malpighia glabra*). The citrus received between 0.03 and 0.5 g and the cherry between 0.005 and 0.5 g a.i. per container. Paclobutrazol had no effect on the increase in caliper of the pummelo scion and sour orange but it reduced it on alemow. On both rootstocks, 70% of the trees bore fruit in the 0.5 g a.i. treatment compared with 30% in the control and less than 1% in field plantings. Barbados cherry produced 171% more fruit in the highest treatment than in the control. It is concluded that paclobutrazol may be useful in tropical situations to induce flowering by simulating drought conditions when rainfall is abundant

Keywords: Plant growth regulators; Paclobutrazol; Pummelo; Barbados cherry

Introduction

Many plant growth regulators (PGRs) have been applied to plants in attempts to exercise greater control over vegetative plant growth, flowering and fruiting. Within recent years, a new Gibberellic acid (GA) biosynthesis inhibitor, paclobutrazol or PP333 ((2*RS*,3*RS*)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1*H*-1,2,4-triazol-1-yl) pentan-3-ol), has been produced by ICI, England under the trade name 'Cultar' (Anon, 1983). It has effectively reduced shoot growth and/or increased fruiting on temperate fruit trees such as apple (Williams and Edgerton, 1983; Richardson *et al.*, 1986), peach (Erez, 1984), plum (Webster and Quinlan, 1984) and *Prunus* cherries (Webster et al., 1986) and has been tested on tropical guavas (Mohammed et al., 1984) and citrus (Iwahori and Tominaga, 1986).

The pummelo or shaddock, *Citrus grandis* (L.) Osbeck, is a lowland tropical citrus native to Southeast Asia (Hodgson, 1976) and commonly cultivated in the West Indies. It is the largest of the commercial citrus, both in tree and fruit size, with fruits weighing up to 2 kg. Flowering is dependent upon moisture conditions and the pummelo may flower at any time of the year in the tropics (Reuther, 1980). PGRs have been used on citrus to change vegetative characteristics by limiting height and reducing suckering (Wilson, 1983). Fruit peel thickness, fruit size, and eating quality can also be affected by PGR application (Monselise & Goren, 1978).

The Barbados cherry, *Malpighia glabra* L. (= *M. punicifolla* L.), is a small shrubby tree native to the West Indies and South America (Martin et al., 1987). It has achieved some commercial success, notably in Puerto Rico, where it is known as acerola. The

intrinsically high ascorbic acid (AA or Vitamin C) content of the fruits, typically 1% to 4% by weight, has been its most marketable asset (Asenjo and Friere de Guzman, 1946; Mustard, 1946; Martin et al., 1987). The fruits ripen 19 to 21 days after bloom (Jackson and Pennock, 1958) and the trees can flower repeatedly, with little time delay following fruit ripening (Moscoso, 1956; Ledin, 1958). Fruit set is usually low, from 2 to 12% in Hawaii (Yamane and Nakasone, 1961a), but it has been improved by the application of PGRs (Yamane and Nakasone, 1961b). While young trees may flower and set fruit within one year of propagation, field plantings exhibit vigorous vegetative growth, which is often detrimental to flowering and early fruit production.

Day length and temperature are nearly constant in near equatorial lowland tropical areas and changes in water conditions become important in stimulating fruiting. Under consistently rainy conditions, unrestricted vegetative growth often occurs. The application of GA inhibitors offers the possibility of shifting the carbohydrate sink from vegetative growth to fruiting. This paper reports the results of the application of paclobutrazol to container grown pummelo and Barbados cherry.

Methods

Sour orange and alemow rootstocks were transplanted in late 1985 into 30 cm diameter rigid containers, placed on concrete blocks and drip irrigated using two pressure compensating emitters per container. The media consisted of either 60% well rotted sugarcane bagasse and 40% sand; or 40% bagasse, 20% manure and 40% sand. The trees were grown and grafted to a local selection of pummelo between January and March, 1986. The following November, 42 uniform trees, on each rootstock, were selected from a population of over 400 trees. The remaining trees were field planted. Stem calipers of the container trees were measured two to three centimetres above the graft union. Paclobutrazol was applied on December 16 at concentrations of 0, 0.03, 0.06, 0.125, 0.25 and 0.5 g active ingredient (a.i.) to each of seven trees on each rootstock as a soil drench in 500 cm^3 of water. Approximately 60 g of 24-0-18 NPK fertiliser were applied in December and March. The trees were kept weed free and watered. On April 15, 1987, stem calipers were remeasured and the number of trees in each treatment, and in the field planting which bore fruit in excess of 5 cm diameter were recorded.

Similarly sized, nine month old rooted cuttings of Barbados cherry cv. 'Florida Sweet' were transplanted from 20 cm into 30 cm diameter containers in September, 1986. The media was a 60:40 mixture of bagasse and sand. A single row of containers was placed on concrete blocks and irrigated using polyethylene tubing with one pressure compensating emitter per tree. The trees, which had been randomly assigned to position, were divided into six groups of six trees. Each group of trees was treated with paclobutrazol on November 21, 1986. The concentrations used were 0, 0.005, 0.01, 0.05, 0.1 and 0.5 g a.i. per tree and these were applied as a soil drench in 500 cm^3 of water. The trees were fertilised with approximately 60 g of 24-0-18 NPK fertiliser in September, December and March. Attempts were made to avoid any drought stress, but all trees became wilted occasionally as a result of inadvertent water deprivation. New fruits, on each tree, were recorded seven times between January 8 and April 13, 1987. The fruits were not weighed due to constant bird damage as they were ripening. Due to the vigorous, multi-trunked, spur type growth, attempts to accurately measure shoot growth had to be abandoned. However, visual observations were recorded to assess any major differences between treatments.

Results

Fruiting of pummelo on both rootstocks tended to increase with increasing paclobutrazol concentration (Table 1). The response on sour orange was more marked than that on alemow, but on both rootstocks the proportion of trees bearing fruit was greatest at the highest rate of application. Only three of the 400 non-treated field planted trees produced fruit in the same time period.

Over the four month period there was a significantly greater ($P < 0.001$) percentage increase in stem caliper of pummelo on the sour orange rootstock (Table 2). The paclobutrazol had no apparent effect on radial growth on this rootstock but on alemow there was a tendency for reduced growth with increasing treatment concentration. Shoot extension growth was noticeably restricted only at the 0.5 g a.i. treatment.

Cherry fruiting tended to improve with increasing paclobutrazol concentrations (Table 3). Cherry trees receiving the highest level of paclobutrazol (0.5 g a.i.) fruited earliest, most frequently and produced the greatest numbers of fruit. Fruit number was increased 171% over the control.

Cherry tree growth was noticeably restricted at the highest paclobutrazol rate. The trees did not exhibit any shoot growth until March, about four months after application, and all new growth until then was either leaves on extremely short internodes or flowers produced at available growing points.

Discussion

The increased fruit set, and reduced vegetative growth in Pummelo at 0.5 g a.i. paclobutrazol was expected and parallels the results found with cherries and other fruits (Iwahori and Tominaga, 1986; Webster *et al.*, 1986). Some of the control trees also fruited and the response was similar to that at the lower paclobutrazol treatments (Table 1). In the case of the controls, the fruit set appeared to be drought stress related, with flowering occurring sporadically on the larger trees. Since all the plants were grown in the same size containers, container restriction effects cannot be separated from treatment effects in these data.

Since less than one percent of the field planted trees produced fruit within the same period, it suggests that the fruiting of the control plants in containers was due to root restriction and/or associated water stress. The different patterns of caliper increase obtained while using identical scion varieties and similar cultural conditions, indicate differing rootstock sensitivities to paclobutrazol.

Members of a genus would be expected to have similar capacities for producing GA, and to be affected similarly by GA inhibitors. However, if concentration thresholds varied, then the same reduction in GA production could result in different specific growth responses or different changes in carbohydrate sink activities. Thus, it may be inferred that the sour orange rootstocks' demand for carbohydrate was insensitive to the GA synthesis inhibition while in alemow, these changed with paclobutrazol concentration. In consequence, radial growth of the trunk of the pummelo scion was affected only on the latter rootstock.

Overall, citrus was less sensitive to paclobutrazol than cherries. At the highest rate, citrus trees resumed active growth

earlier and the fruiting effects were not as pronounced. However, it appears feasible to apply the chemical to cause a shift towards flower initiation in young vigorous groves and to provide a measure of control over shoot growth.

Table 1 Fruiting response of pummelo to paclobutrazol. The data indicate numbers of trees (out of seven) bearing fruit, four months after treatment.

Treatment (g a.i./ container)	Rootstock		Mean a)
	Sour orange	Alemow	
0.5	5	5	5.0 a
0.25	3	0	1.5 a,b
0.125	2	2	2.0 a,b
0.06	1	1	1.0 b
0.03	1	2	1.5 a,b
0.0	2	2	2.0 a,b.

a) Means followed by the same letter are not significantly different (P >0.05)

Table 2 Increase (mm) and percentage change in caliper of pummelo treated with paclobutrazol. The data are the means of seven trees for each treatment.

Treatment (g a.i./ container)	Rootstock			
	Sour orange		Alemow	
	Increase	% Increase	Increase	% Increase
0.5	5.1	34	1.9	12
0.25	4.9	36	2.3	21
0.125	5.7	51	1.7	13
0.06	4.7	33	3.1	19
0.03	5.4	36	3.6	25
0.0	5.0	33	4.6	30
Mean	5.2	37	2.8	20

The Barbados cherry is an unusual perennial tree crop in that it has a short fruiting cycle. Small changes in carbohydrate allocation, followed by stimulating water and fertiliser application often result in flower flushes. This sensitive carbohydrate shift should be easily manipulated, if not controlled.

The obvious inhibition of growth and concurrent stimulation of fruiting shows a response to paclobutrazol treatment. While the 0.5 g a.i. treatment resulted in substantial control of vegetative growth and increased flowering, the other rates achieved only a mild stimulating effect on fruiting without obvious vegetative effects. Thus, the paclobutrazol may be causing a significant redistribution of carbohydrate only at the highest treatment level.

The means presented in Table 3 may not fully reflect the effect of paclobutrazol. Towards the end of the experiment, there was an increase in fruiting in the control and the lower level treatments which can be attributed, in part, to increasing water stress. Initially, sufficient rooting media existed to allow for rapid growth, resulting in large trees whose roots soon filled the existing container space. This eventually caused water supply to become limiting. Ample water, following this restriction, would have resulted in enhanced flowering.

Table 3 Fruiting response of Barbados cherry to paclobutrazol. The data are the mean number of fruit on six trees average over seven sample dates.

Treatment (g a.i./ container)	Mean number of fruits[a)]
0.5	7.6 a
0.1	4.3 b
0.05	5.5 a,b
0.01	4.1 b
0.005	3.8 b
0.0	2.8 b

a) Means followed by the same letter are not significantly different, ($P > 0.05$).

Similar container grown trees were observed throughout the experimental period in both field plantings and in the experimental containers. The fruiting patterns of all those in containers where root restriction was present showed a tendency toward flower production. However, early stimulation of flowering achieved with paclobutrazol increased flowering without root restriction and may give tropical growers the opportunity to simulate drought conditions when rainfall is abundant.

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