EFFECT OF PROHEXADIONE-CA ON SHOOT GROWTH, FRUIT SET AND RETENTION IN 'HASS' AVOCADO IN NEW ZEALAND.

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ABSTRACT

Avocado trees often exhibit a pattern of cropping known as alternate bearing where trees carrying a small crop can have excessive vegetative vigour. This excessive vigour could be considered to competitively inhibit flowering and fruit set through hormonal control. Gibberellins are plant hormones involved with shoot growth. Prohexadione-Ca is a new generation gibberellin biosynthesis inhibitor with low toxicity and persistence in the plant. Reducing shoot growth of New Zealand 'Hass' avocado trees without affecting fruit set or return bloom could be a useful management tool to help maintain a reduced tree size and alter shoot flush timings. Timing and application of prohexadione-Ca was tested over two consecutive seasons using different formulations and active ingredient concentrations of 1% and 1.4%. Shoot growth was greater in 2003 than 2004 while fruit set was greater in 2004 than 2003. Application of prohexadione-Ca at 1.4% active ingredient in 2003 did not affect the growth of spring shoot flush. Shoots treated three times with prohexadione-Ca in 2004 had a lower proportional increase in growth and stopped growing earlier than untreated shoots. There was no difference in fruit numbers or size of fruit between untreated branches and branches treated with prohexadione-Ca. The decrease in shoot growth and earlier cessation of shoot growth could be useful for altering or controlling shoot flushes when there is excessive shoot growth when the trees have light crops. Further research could investigate the effect of prohexadione-Ca on summer/autumn shoot growth with a view to moderating alternate bearing.

Keywords: *plant growth regulator, alternate bearing*

INTRODUCTION

Avocado trees are large vigorous evergreen perennial sub-tropical trees that often produce inconsistent crops of fruit from year to year. The amount of fruit set and carried by an avocado tree to harvest can be high in one year followed by a much reduced crop the following year. Such a pattern of cropping is known as alternate bearing (Whiley, 2002). Flowering and fruiting occurs on new shoots that have grown in the spring and summer/autumn of the previous year (Scora *et al*., 2002). Avocado trees produce vegetative shoots in distinctive flushes according to the Rauh model of tree growth (Scora *et al*., 2002). It has been observed that avocado trees with a small crop have more vegetative growth than avocado trees carrying a large crop (Arpaia *et al*., 1996). A certain amount of shoot growth is required each year to ensure that an avocado tree will have sufficient flowers to set an economic crop. When shoot growth is excessive a large amount of flowering wood is produced that sets a large crop that utilises tree resources preventing the production of adequate flowering wood. This observation has led to the theory that excessive vegetative growth competitively inhibits flowering and fruit set. The mechanism of the inhibitory effect on fruit set has been proposed to be under hormonal control through changes in levels of plant growth regulators such as gibberellins, auxins and abscisic acid. In particular, gibberellins are thought to be key components of shoot growth as they are involved shoot elongation and are synthesized in shoot tips and root tips (Taiz and Zeiger, 1998).

Plant growth regulators that inhibit the development and growth of shoots have been used to reduce the amount of shoot growth and subsequently increase yield. For example, uniconazole (Sunny®) or paclobutrazol (Cultar®) (Khone and Kremer-Kohne, 1989; Whiley, 1994) have been used in Australia and South Africa to control excessive vegetative vigour on summer/autumn flush and are considered to improve the flowering potential of avocado trees. In New Zealand the spring flush is considered to have the greatest flowering intensity (Cutting, 2003) in contrast to Australia and South Africa where the summer flush has the greatest flowering intensity. Such a difference in the timing of the most intense flowering flush in New Zealand compared to the most fruitful shoot flush in other countries suggests that plant growth regulators may have to be applied at different times to prevent excessive vegetative vigour.

Prohexadione-Ca is a new generation gibberellin biosynthesis inhibitor that has low toxicity and persistence in the plant. While not used commercially it has been evaluated in scientific trials on avocados in California (Lovatt, 2005), apples (Greene, 2005), pears (Southwick *et al*., 2004), wine grapes (Lo Giudice *et al*., 2004), and strawberries (Black, 2004). The general effect of prohexadione-Ca has been to reduce shoot growth without affecting fruit set or yield. In avocados prohexadione-Ca applied at the cauliflower stage and full bloom reduced shoot growth by 10-20% depending on the timing of application at specific physiological stages during flowering and fruit set (Lovatt, 2001). Total yield was not affected over the course of a three year trial but an increase in the largest fruit sizes was observed (Lovatt, 2005). Reducing shoot growth of New Zealand grown 'Hass' avocado trees without affecting fruit set or return bloom in the following spring could be a useful management tool to help maintain a reduced tree size and increase the time between tree thinning rounds. To evaluate the effectiveness of prohexadione-Ca in reducing spring shoot growth 'Hass' avocado trees were treated with prohexadione-Ca during flowering and the initial fruit development period. This was the time when the spring flush began. Timing of application and concentration of prohexadione-Ca were tested over two consecutive seasons using different formulations. The results reported in this paper describe the vegetative response and fruit set for New Zealand 'Hass' avocado trees following the application of prohexadione-Ca.

MATERIALS AND METHODS

Twenty, six to seven year old 'Hass' grafted onto 'Zutano' seedling rootstock avocado trees were selected within an orchard block at Te Puna in the Western Bay of Plenty. Five adjacent trees within each of four rows were allocated to one spray treatment. The trees had no visible Phytophthora root rot symptoms and were healthy and managed according to typical industry practice. Two trials were conducted using the prohexadione-Ca products: Apogee® in 2003 and Regalis® in 2004. The same trees but different branches and flowering shoots were used in each year.

Each year 20 branches, identified as having indeterminate flowering shoots at between 0.5m and 1.8m on each tree, were tagged for treatment with prohexadione-Ca. Five branches were tagged at each of the north, south, east and west positions on the tree. Prohexadione-Ca was applied to run-off with a motorised backpack sprayer to each branch when according to a subjective assessment that 50% of the flowers had opened within panicles on a flowering branch and when 90% of the flowers were judged to have opened and also new shoots were starting to emerge from the flower panicles. For the control trees a water only spray was applied at 50% flowering.

There were two trials:
Trial A 2003: Apogee® (27.5% prohexadione-Ca active ingredient) applied at 1.4% active ingredient.

Four treatments were applied:

	Date:
1. Control (water spray)	29/10/03
2. One application at 50% flowering	29/10/03
3. Two applications, one each at 50% and 90% flowering	20/11/03
4. Three applications, one each at 50%, 90% and 2 weeks after flowering	11/12/03

At the time of the first application of prohexadione-Ca on 29/10/2003 shoot lengths of all tagged branches for all treatments were measured to the nearest centimetre from the bud ring of the previous flush to the shoot tip. Thirty-five days after the final application of prohexadione-Ca shoot length was again measured on 15/1/2004 to the nearest centimetre and number of fruit on each tagged branch was recorded. The fruit were between 30mm and 40mm in length when counted.

Trial B 2004: Regalis® (10% prohexadione-Ca active ingredient) applied at 1% active ingredient.

Four treatments were applied:

	Date:
1. Control (water spray)	10/11/04
2. One application at 50% flowering	10/11/04
3. Two applications, one each at 50% flowering and two weeks later	23/11/04
4. Three applications, one each at 50%, two weeks and four weeks later	7/12/04

One week after each spray application, on the 16/11/2004, 2/12/2004 and 14/12/2004 the length of tagged shoots was measured to the nearest millimetre. A fruit count of each tagged branch was conducted on 1/2/2005, 11 weeks after the first application. The fruit were between 30mm and 40mm in length

Shoot lengths were square root transformed before analysis using the One Way analysis of variance of MINITAB version 13.31. Untransformed means are reported in the tables and figures. Percent shoot growth was calculated as the proportional increase in initial shoot length measured on 16/11/2004 for Regalis® treated shoots.

RESULTS

Shoot growth was greater in 2003 than 2004 where the increase in shoot length ranged from 190mm to 1380mm in 2003 and from 5mm to 341mm in 2004. Fruit set was greater in 2004 than in 2003 with the number of fruit on treated branches per tree ranging from 1 to 18 in 2003 and from 2 to 71 in 2004. Application of 1.4% prohexadione-Ca in 2003 did not affect the growth of the spring flush (Figure 1). There was a non-significant trend for shoots treated at the 50% flowering stage only to have the smallest increase in shoot length.

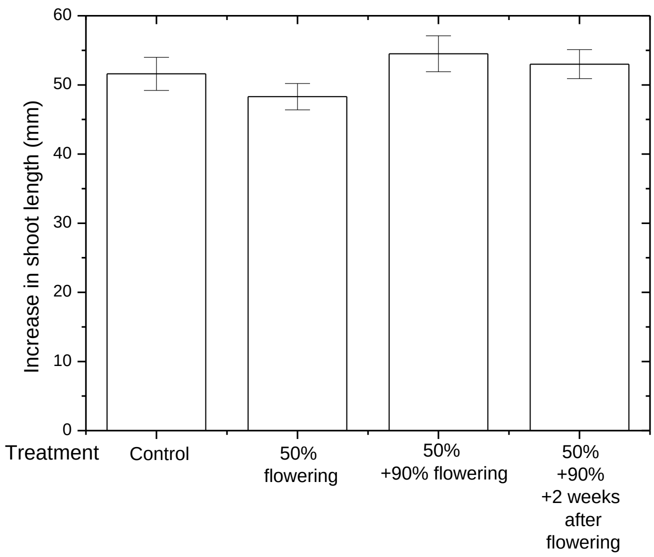

Figure 1. Effect of prohexadione-Ca (applied as Apogee®) on the increase in spring flush shoot length following application onto indeterminate shoots at 50% flowering, 50% and 90% flowering and 50% and 90% and 2 weeks after flowering. The control treatment was a water spray at 50% flowering. Vertical bars represent the standard error of the mean of 20 shoots.

Shoot growth in the spring of 2004 followed an asymptotic pattern with an initial period of rapid growth followed by a slowing of growth to stop sometime after 1/2/2005 (Figure 2). After this time casual observation indicates that a new flush of vegetative growth began. Although there were no apparent differences in shoot growth between treatments the shoots treated 3 times with prohexadione-Ca had almost stopped increasing in length by 1/2/2005. Untreated shoots continued to increase in length while shoots treated once or twice with prohexadione-Ca had a reduced rate of increase compared to the control by 1/2/2005.

shoot growth by about 20% relative to the untreated control (Table 1). Once the shoots slowed in growth the effect of treatment was no longer significant. There was only a small increase in shoot length from mid-December to February for treated shoots while untreated shoots continued to grow (Table 1). The continued growth in untreated shoots suggests shoot growth slowed down earlier in prohexadione-Ca treated shoots.

While there was no statistically significant increase in fruit numbers of branches treated with prohexadione-Ca there was a trend for

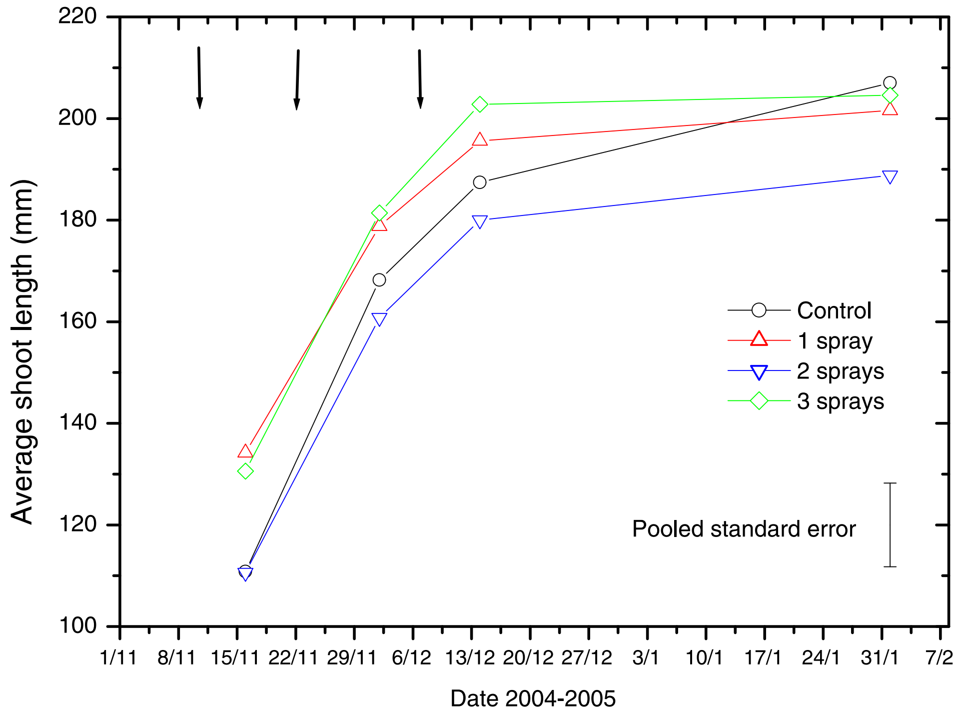

Figure 2. Change in shoot length of ‘Hass’ avocado indeterminate flowering shoots following application of prohexadione-Ca (applied as Regalis®). Arrows indicate the timing of prohexadione-Ca application on 10/11/2004, 23/11/2004 and 7/12/2004.

While the increase in shoot length in absolute terms was not different between treatments, significant treatment effects on the proportional increase in shoot length relative to the initial size of the shoot on shoot growth were found (Table 1). One application of prohexadione-Ca, when the shoots were rapidly increasing in length, reduced

prohexadione-Ca applied twice to increase the number of fruit on branches (Figure 3). Although not significant the trees treated once with prohexadione-Ca had the lowest average numbers of fruit per shoot.

Table 1. Percentage shoot growth following prohexadione-Ca (applied as Regalis®) application to 'Hass' avocado branches at 50% open flower, 2 and 4 weeks later.

	Shoot growth (%)[1]		
Treatment	16 Nov 04 – 2 Dec 04	2 Dec 04 – 14 Dec 04	14 Dec 04 – 1 Feb 05
Control	48.4[2] a[3]	10.6 ab	13.1 a
1 Application	38.9 b	10.0 b	3.0 b
2 Applications		12.8 a	4.0 b
3 Applications			1.9 b

[1]Shoot growth calculated as percentage increase of shoot length for all tagged shoots initially measured about one week after each treatment; [2]Untransformed mean; [3]Means within a column followed by the same letter are not significantly different according to a One-way analysis of variance using a Tukey's family error rate of 5% on square root transformed means.

Fruit numbers from treated shoots did not necessarily reflect the total fruit number of each individual tree. The three times treated prohexadione-Ca treated trees tended to have the most fruit per tree on average (Figure 4a) but had almost the same fruit numbers as the untreated control branches (Figure 4b). There was no difference in the size of fruit between treatments (Data not shown).

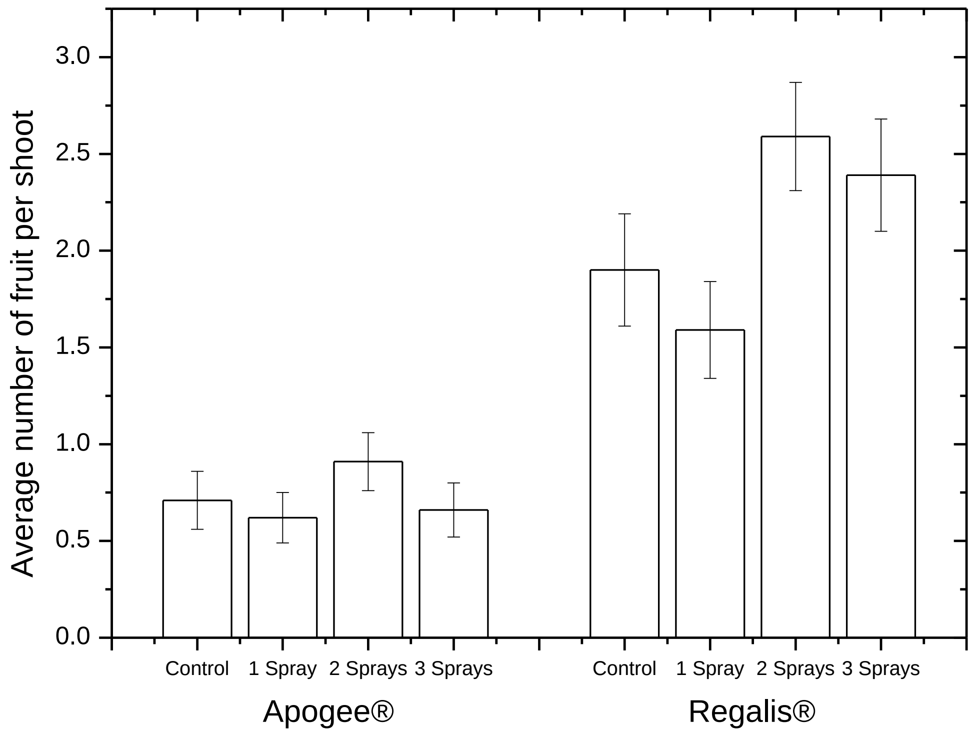

Figure 3. Average number of fruit per shoot on 20 indeterminate flowering branches on each tree seven weeks after final Apogee® application and eleven weeks after final Regalis® application.

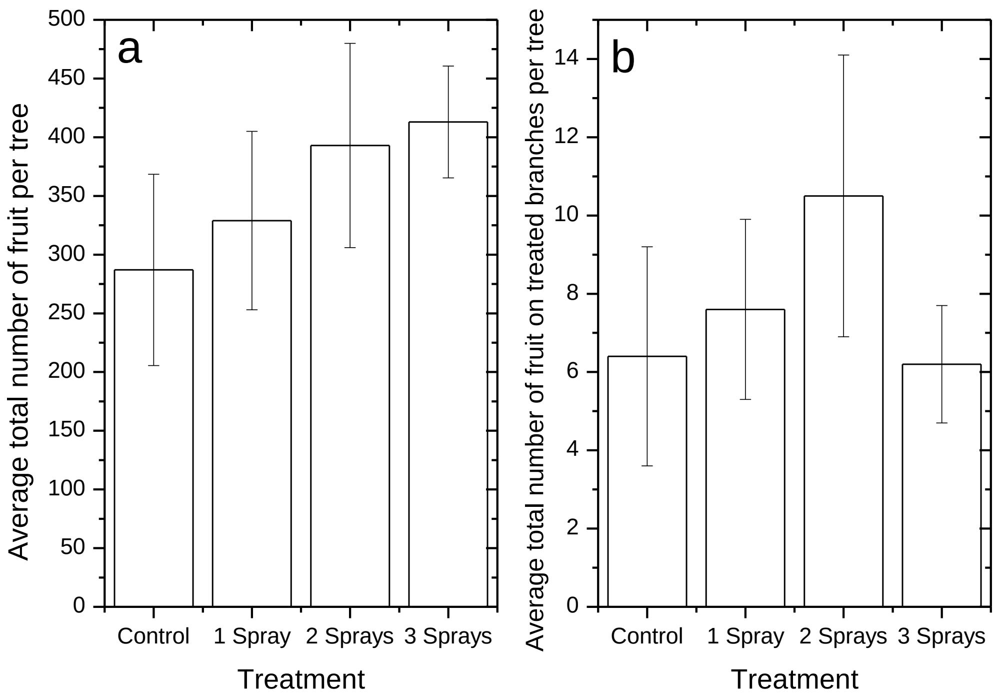

Figure 4. Total numbers of fruit on trees following treatment with Apogee® for a) whole trees and b) treated branches on each tree at harvest on 16/8/2004.

DISCUSSION

A decrease in the percentage shoot length of about 20% in prohexadione-Ca treated branches suggests prohexadione-Ca inhibited shoot growth. The percentage decrease in shoot growth reported here is about half that found for apples (Norelli and Miller, 2004) and avocados (Lovatt, 2005). The most reduction in shoot growth was after a rapid growth phase with the main effect of prohexadione-Ca being to stop shoot growth earlier than the control and suggests prohexadione-Ca has a limited effect on shoot growth. Reducing the vigour of avocado shoots could be useful for altering or controlling shoot flushes when the trees have excessive vegetative vigour in a low crop year. In this trial the prohexadione-Ca was applied to spring flush shoots only. The spring growth typically is followed by a late summer/autumn flush that is still growing and developing at the time when winter starts. The late summer/autumn growth can have a lower flowering intensity than spring growth (Cutting, 2003). Inducing the summer flush to stop earlier could be useful in reducing vegetative growth into winter. It is possible that prohexadione-Ca may also advance the physiological age of the summer/autumn flush thereby improving the flowering intensity in spring. Applying prohexadione-Ca to summer/autumn flush could be investigated in future research projects.

There was more fruit set in 2004 than in 2003 on the same trees indicating that the trees used in this trial were in 2003 in an "off" year and 2004 in an "on" year. Trees that are in an "off" year typically have more shoot growth than trees in an "on" year (Arpaia *et al*., 1996). The difference in the amount of shoot growth in each year was more influenced by the alternate bearing cycle than treatment with prohexadione-Ca. To determine the effect of prohexadione-Ca concentration on the amount of shoot growth treatment of newly developing shoots with different concentrations of prohexadione-Ca is required. The lack of difference between untreated and prohexadione-Ca treated shoots when they were growing rapidly may suggest that application once the growth rate of the shoots has slowed would be the most effective time to inhibit shoot growth. Conversely, maintaining a certain concentration of prohexadione-Ca in the shoots may be required to have most effect on inhibiting shoot growth. To better refine the number and timing of prohexadione-Ca application further research is required.

The trend for increased numbers of fruit on the prohexadione-Ca treated trees may suggest that the prohexadione-Ca effect was translocated throughout the tree or that the location of the trees in the orchard had an influence on tree yield. The treatments were applied to a group of five trees in a row with the rows separated by non-treated trees. Using a randomised block design may have been better as trees for each treatment could have been selected at all locations within the orchard. Therefore, it is not possible to determine if the number of fruit at harvest on the trees was due to the prohexadione-Ca treatment or location within the orchard.

CONCLUSIONS

Prohexadione-Ca applied when shoots were rapidly increasing in length and at the rates of 1% and 1.4% active ingredient decreased shoot growth by 10% to 20% but did not affect fruit set and retention. Shoot growth ceased earlier on prohexadione-Ca treated shoots than untreated control shoots. Although the most effective timing of application and concentration of prohexadione-Ca has not been established the inhibition of shoot growth and early termination of shoot growth may be useful to limit excessive shoot flushes in low crop years. As such further investigation of prohexadione-Ca on shoot growth at the time of fruit set and drop and the summer/autumn flush has merit.

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