REDUCTION OF INITIAL FRUIT SET THROUGH THE USE OF A CHEMICAL FRUIT SET THINNER ETHEPHON

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ABSTRACT

Alternate bearing of 'Hass' avocado trees is where the amount of fruit set is much greater in an 'on' flowering year than an 'off' flowering year. Reducing fruit numbers in the 'on' flowering year could reduce the amount of alternate bearing. One method is to use a chemical flower or fruit thinning agent. Possible fruit thinning agents for avocados are ethylene via ethephon or ammonium thiosulphate. The correct use of these products on avocados is not known. An experiment was conducted to test if ethephon or ammonium thiosulphate as a chemical flower thinner would be suitable for avocado trees. Further experiments were carried out to establish the correct dose and the best time of application. Ammonium thiosulphate was not effective in thinning avocado flowers. Ethephon consistently reduced initial fruit set by at least 40% when applied at a concentration of 42 ml/L at any time from when 20% to 80% of the flowers had opened. The amount of fruit thinning was temperature dependent, the thinning effect is about twice as strong above 20°C as below 20°C. The next stage of an experimental programme is to apply ethephon to whole trees that are in an 'on' flowering year and to follow the phenology, flowering and yields off the trees over several years. Before ethephon can be recommended for use the residue decay curve and the effect of ethephon applied to mature fruit needs to be determined.

Keywords: Ethrel, Ethin, Thin-it, fruit drop, flowering, avocado

INTRODUCTION

Alternate bearing of 'Hass' avocado trees where a large crop, an 'on' year, is followed by a light crop, an 'off' year, is common in New Zealand avocado orchards. The alternate bearing reduces avocado grower incomes as the orchards over a wide area tend to follow a similar cropping pattern. Bumper crops tend to oversupply the domestic and export markets with fruit leading to low prices returned to the avocado grower. Light crops undersupply the markets and the avocado grower has a low income. The causes of alternate bearing are not well understood but appear to be related to aspects of the tree growth cycle. An obvious feature of a well entrenched alternate bearing cycle is the weak flowering in an 'off' flowering year in association with a strong shoot flush. In the following 'on' flowering year the flowering is heavy and the shoot flush weak. As a consequence the amount of fruit set is much greater in an 'on' flowering year than an 'off' flowering year. A possible mechanism is that the heavy fruit set in the 'on' flowering year competitively inhibits shoot growth leading to fewer flowering sites in the following year. Reducing fruit numbers in the 'on' flowering year could reduce the effects of too much fruit set reducing shoot growth in the following year. To alter the pattern of shoot flushes and therefore the flowering and fruit set potential each year avocado growers need credible treatments to manipulate shoot flushes. One method to change shoot flushes and the amount of fruit set is to flower prune but this can be time consuming and expensive. Another method is to use a chemical flower or fruit thinning agent. Using a chemical spray may be quick and cheap in application to achieve the same effect as pruning. Chemical sprays to reduce excessive fruit set has been used on other crops, most notably apples (Anon, 2009; Weber, 1998), as a method to control alternate bearing caused by over cropping.

A possible fruit thinning agent is the plant hormone ethylene that is involved in many plant processes

to do with growth and senescence, including abscission. Ethrel® (Bayer, Monheim, Germany) or Ethin are plant growth regulators containing 480g/L of ethephon (2-Chloroethanephosphonic acid) as the active ingredient, which is absorbed by plant tissue and metabolised into ethylene that has been used in apple, cherry, citrus and peach orchards to thin fruit or flowers (Anon, 2009). An alternative method of flower thinning is to use a desiccant to 'burn' off the flowers. Thin-it™ is a product containing 782 g/L ammonium thiosulphate, which desiccates and thins blossoms, reducing fruit set in apples (Janoudi and Flore, 2005). The correct use of these products on avocados is not known.

An experiment was conducted to test if ethephon or ammonium thiosulphate as a chemical flower thinner would be suitable for avocado trees. Based on the success of this experiment further experiments were carried out to establish the right amount of chemical thinner and the best time of application to achieve the desired amount of fruit reduction.

MATERIALS AND METHODS

There were three trials conducted over three years. In the first two years the trials were conducted on the same trees on one orchard located in the Katikati area of the Western Bay of Plenty, North Island, New Zealand (37°S, 176°E). In the third year the trial was conducted on another orchard that was a near neighbour to the orchard used in the first two trials.

Year 1 – Selection of a suitable chemical fruit thinner

Six, seven year old, "Hass" on seedling 'Zutano' rootstock trees that were in an 'on' flowering year with greater than 80% determinate flowering branches were used to evaluate the effect on fruit set of two chemical thinning agents, Thin-it™ and Ethrel®. The trees selected were not carrying fruit on the trees when treatments were applied. The chemical thinning agents selected had proven efficacy on apple trees but unknown efficacy on avocado trees. Thin-It™ has as its active ingredient ammonium thiosulphate as a desiccant that can burn off flowers. Ethrel® contains an ethylene producing compound ethephon as the active ingredient. On each tree the same treatment was applied to three randomly selected flowering branches on the northwestern face of each tree. There was a total of 33 flowering branches that received treatments on each tree.

The following treatments were applied when about 50% of the flowers had opened on the 20/10/2006:

- No treatment
- Water spray
- Thin-It™ blossom thinner at recommended rate for apples

The following treatments were applied when about 65% of the flowers had opened on the 27/10/2006:

- No treatment
- Water spray
- Thin-It™ blossom thinner at the label rate for apples
- Ethrel® at 0.5x standard rate, 21 mL/100L (100ppm)
- Ethrel® at standard rate, 42 mL/100L (200ppm)

The following treatments were applied when about 85% of the flowers had opened on the 3/11/2006:

- No treatment
- Water spray
- Thin-It™ blossom thinner at the label rate for apples

Each flowering branch was covered with a clear plastic bag before treatment to prevent cross contamination of chemicals from one branch to another. The chemical thinning agents or water controls were applied to individual branches within the bags using low volume hand pump sprayers to wet the flowers but not to run off. Once the treatment had been applied the bags were carefully removed after shaking off excess liquid into the bag. The bags covered the flowering branches for 10 to 15 minutes when treatments were being applied.

Treatment effects were assessed by counting the number of fruit on each flowering branch on the 16/11/2006, before the drop of the initial fruit set, then on the 6/12/2006, about the time of peak fruit number before the drop of the initial fruit set, and on the 11/1/2007 after the drop of the initial fruit set is complete.

Year 2 – Determining the right concentration of Ethrel®

Five, eight year old, trees in their 'on' flowering year, in the same orchard as used in year 1 that had heavy, >80%, indeterminate flowering were selected for treatment. The trees were not the same as used in the previous year. The fruit from the previous season were commercially harvested prior to applying treatments. Flowering branches were further designated as 'Lower canopy' when the branches were between 0.5m and 2.0m above the ground and as 'Upper canopy' when the branches were between 3.0m and 4.0m above the ground. On each tree three north facing indeterminate inflorescences per treatment per canopy height were randomly selected for treating with Ethrel® or as controls, a total of 30 branches on each tree. Treatments were applied on the 25/10/2007, when about 50-65% of flowers had opened.

The treatments were:

- Water spray as a control
- Ethrel® at 5.25 mL/100 L (0.125 x concentration)
- Ethrel® at 10.5 mL/100 L (0.25 x concentration)
- Ethrel® at 21 mL/100 L (0.5 x concentration)
- Ethrel® at 42 mL/100 L (1.0 x concentration)

Treatments were sprayed to wet but not runoff. Treatments were applied to individual branches using low volume hand pump sprayers using the same method as in year 1. Treatment effects were assessed by counting the number of fruit on each flowering branch on the 6/11/2007 before the drop of the initial fruit set through to the 17/12/2007. In addition the number of abscised panicle stalks and flowers were counted on one tree, 12 days after treatment, for treated and untreated branches. This was to illustrate how flowering branches treated with Ethrel® lost fruit compared to the natural flower and fruit drop.

Year 3 – Determining the right time to apply Ethin

Five, nine year old, trees in their 'on' flowering year, on an orchard neighbouring the orchard used in years one and two were used to evaluate the best time through the flowering period to apply Ethin (480 g/L active ingredient ethephon). The trees selected had heavy, >80%, determinate flowering. The fruit from the previous season were commercially harvested prior to the experiment. On each tree three, northeast to northwest facing, determinate flowering branches per treatment at a canopy height of 1.5 m to 4 m were randomly selected for each Ethin treatment or as controls. There were a total of 30 branches used in the trial on each tree.

Ethin was applied at 42 mL/100L at 15:00 h on five occasions:

- 15/10/2008, about 20% of flowers had opened
- 17/10/2008, about 40% of flowers had opened
- 21/10/2008, about 50% of flowers had opened
- 22/10/2008, about 60% of flowers had opened
- 28/10/2008, about 80% of flowers had opened

Treatments were sprayed to wet but not runoff. Treatments were applied to individual branches using low volume hand pump sprayers using the same method as in year 1. The control treatment was not sprayed. The shade air temperature of trees adjacent to the trial trees was recorded every 30 minutes for the 24 hours of the day the treatment was applied using a Hobo® weather station.

Treatment effects were assessed by counting the number of fruit on each flowering branch on the

7/11/2008, 21/11/2008, 5/12/2008, 22/12/2008, 12/1/2009 and 2/3/2009 covering the period before the drop of the initial fruit set through to after the February drop.

Data Analysis

In Year 1 the fruit counts were analysed as a complete randomised design with treatments nested within trees and in Years 2 and 3 the fruit counts were analysed as a randomised design with treatments nested within trees using the general linear models analysis of variance function of MINITAB version 13.31.

RESULTS

Year 1 – Selection of a suitable chemical fruit thinner

The number of fruit present on avocado flowering branches was not affected by treatment of a spray of water or Thin-it™ onto open avocado flowers at any of the times through the flower opening when treatments were applied (Figure 1).

Ethrel® reduced the average fruit number on individual branches by about 40% when applied at 65% through flower opening at a rate of 42 mL/100L (Figure 2). At a lower concentration of Ethrel the reduction in fruit numbers was less and although not significantly different to the control had a trend indicative of a concentration response. Seventy-six days after treatment the difference between the Ethrel treatment at 42 mL/100L and the control in fruit numbers was no longer significant although Ethrel treated branches continued to have the lowest fruit numbers.

Year 2 – Determining the right concentration of Ethrel

There was a negative relationship between Ethrel concentration and the average fruit numbers per branch (Figure 3a). Ethrel applied at 42 mL/100L reduced the fruit number by 40-50% from the control branches. This was a similar value to the percentage reduction in Year 1. Lower concentrations of Ethrel proportionately reduced

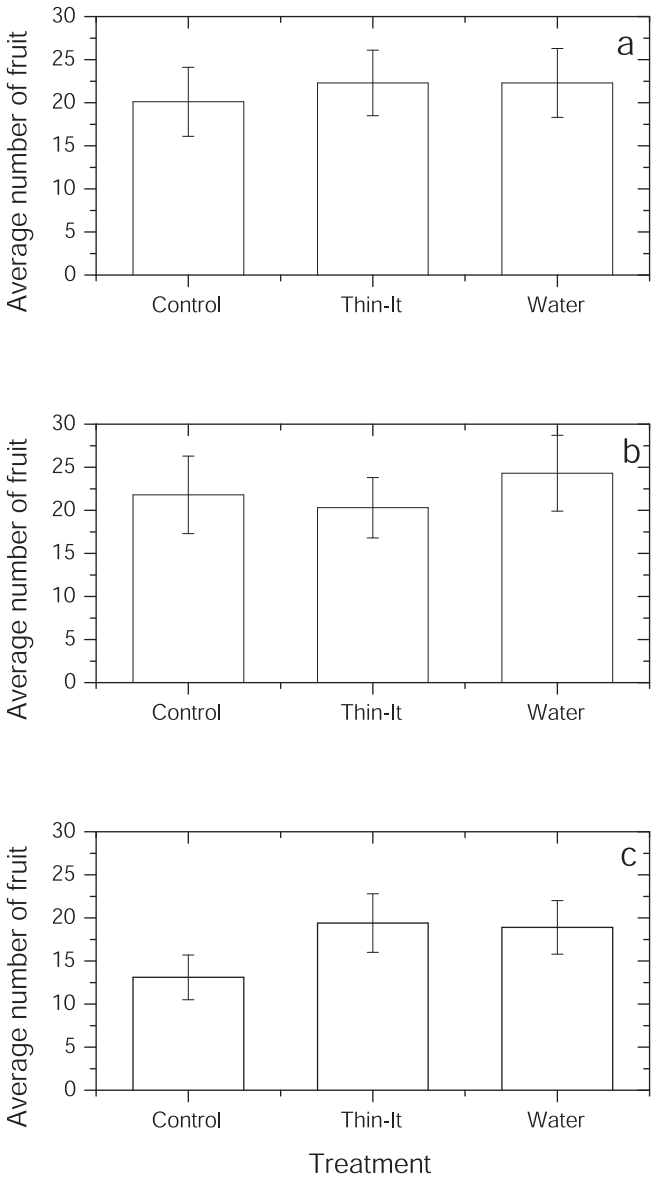

Figure 1. Average number of fruit on an individual branch treated with Thin-It™ or water spray or no treatment (control) in the spring of 2006 when a) about 50% of flowers had opened, b) about 65% of flowers had opened, and c) about 85% of flowers had opened. The vertical bars represent the standard error of the mean.

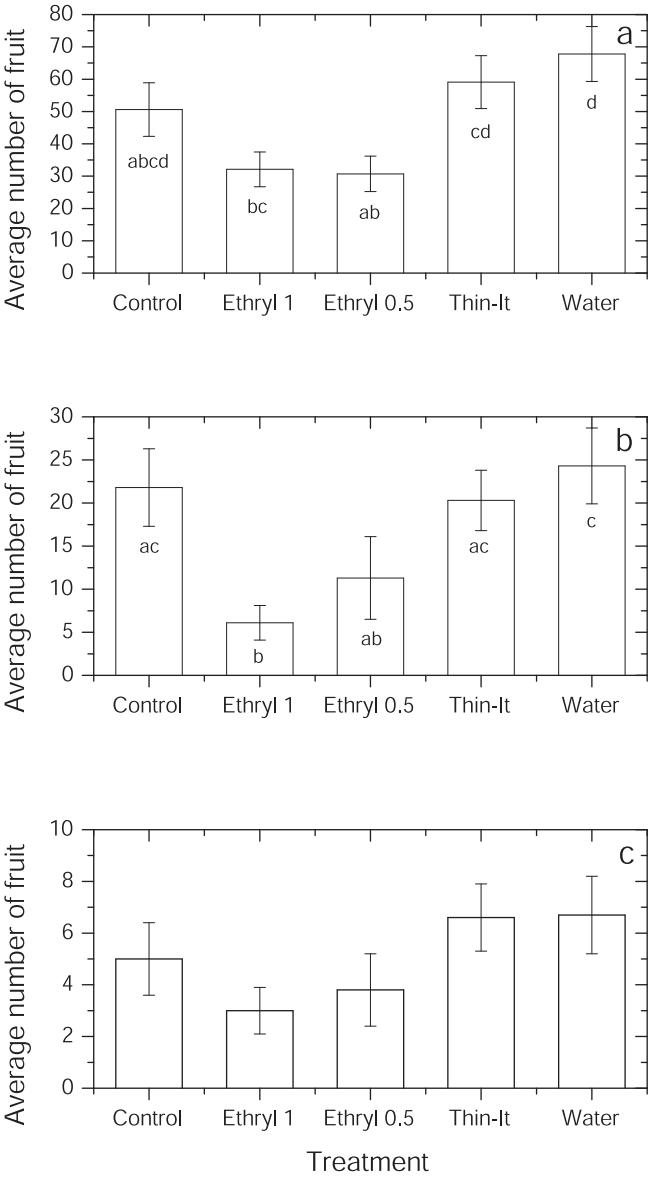

Figure 2. Average number of fruit on an individual branch treated with a flowering thinning agent on 27/10/2006 when about 65% of flowers had opened. The fruit were counted a) 20 days, b) 40 days and c) 76 days after treatment.

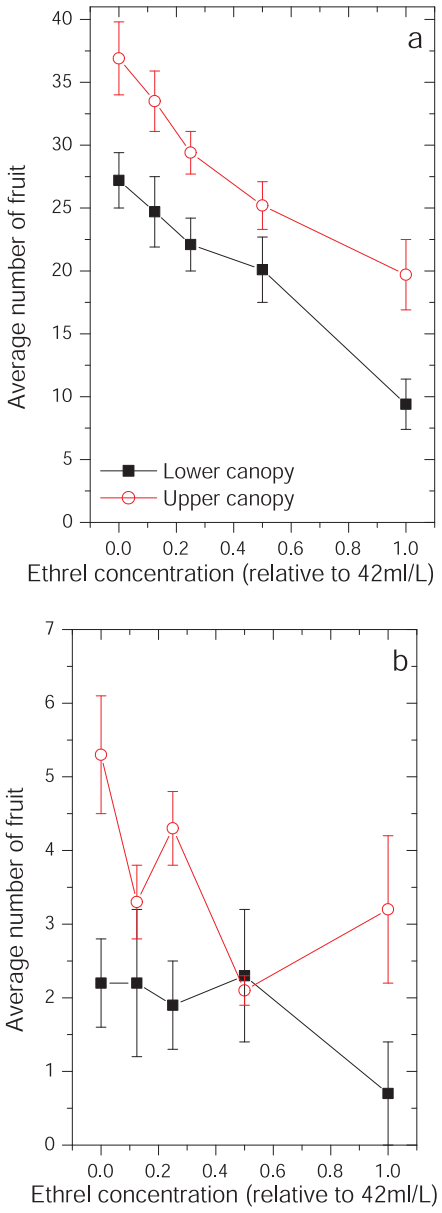

Figure 3. Average number of fruit on individual branches in the Lower or Upper canopy treated with Ethrel on 25/10/2007 at different concentrations assessed a) 32 and b) 53 days after treatment.

the average fruit number by lesser amounts (Figure 3a).

The branches on the Upper canopy set and retained more fruit, across all the treatments, than the branches on the Lower canopy (Table 1 and Figure 3). This effect of Ethrel on reducing fruit numbers on the branches was about the same at each concentration of Ethrel applied (Figure 3a).

The effect of different concentrations of Ethrel and location on the canopy was time bound in that after 53 days from treatment fruit numbers on branches on the Lower canopy were not significantly different to fruit numbers on the Upper canopy (Table 1). Branches on the Lower canopy at the low concentrations of Ethrel had similar fruit numbers with only the 42 mL/100L treatment with lower fruit numbers (Figure 3b). The branches from the Upper

canopy after 53 days treated with Ethrel had fewer fruit than the control branches (Figure 3b).

Ethrel caused abscission of flowers, newly set fruit and panicle stalks in contrast to the water control where panicle stalks were retained and the flowers and newly set fruit abscised (Figure 4). After 12 days, Ethrel® 42ml/100L treated panicles had shed 5.2 ± 2.0 fruit (mean ± standard error of the mean) and 6.7 ± 1.7 flowering stalks. Control fruit treated with water shed 2.6 ± 0.9 fruit and no flowering stalks.

Table 1. Average number of fruit on individual branches 32 and 53 days after treatment with Ethrel on 25/10/2007.

Days after treatment	32		53	
Location on tree	Lower	Upper	Lower	Upper
Average across all treatments	20.7	28.9	1.9	3.6
Significance level	p < 0.001		Not Significant	

Year 3 – Determining the right time to apply Ethin

Ethin was effective in reducing fruit numbers by 42.3% to 81.6% when applied from 20% to 60% of the flower opening (Table 2). The temperature at the time of application was correlated with the percentage reduction in fruit number ($r^2 = 0.914$, $p = 0.011$, $n = 5$). Applying Ethin under cool conditions of <18°C reduced fruit numbers by about 40% compared to applying Ethin at temperatures over 21.5°C which reduced fruit numbers by 70 to 82% (Table 2). There was a significant reduction of fruit numbers between the control and treated branches at each count date from before the fruit drop of the initial fruit set to after the February fruit drop (Table 3).

Figure 4. Examples of flower parts that abscised 12 days after treatment with Ethrel® at 42ml/100L compared to the water control.

Table 2. Treatment date, percentage of flower opening, temperature at time of Ethin application, fruit count at maximum fruit number for control and treated branches and the percentage reduction in fruit number for flowering branches of 'Hass' avocado trees.

Treatment date	Percentage flowered	Temperature (°C)	Fruit count at 21/11/2008 Control	Fruit count at 21/11/2008 Treated	Percentage reduction in fruit number
15/10/2008	20	22.1	40.4	12.2**[1]	69.8
17/10/2008	40	16.0	35.1	20.7*	42.3
21/10/2008	50	22.1	48.6	8.9**	81.6
22/10/2008	60	21.7	45.3	9.5**	78.9
28/10/2008	80	17.5	35.1	19.7[NS]	43.9
		Average	40.9	14.2***	

[1]Significance level for difference between control and treated: * = p < 0.05, ** = p < 0.01, *** = p < 0.001, NS = Not Significant

Table 3. Average fruit count for control and treated branches across all treatment days on individual branches treated with Ethin at 42 mL/100L.

Count date	Control	Treated	Significance
7/11/2008	4.4	0.8	***[1]
21/11/2008	40.9	14.2	***
5/12/2008	15.1	6.8	***
22/12/2008	5.9	2.6	***
12/1/2009	4.6	2.1	***
2/3/2009	1.4	0.8	*

[1]Significance level for difference between control and treated: * = p < 0.05, ** = p < 0.01, *** = p < 0.001

DISCUSSION

Water and ammonium thiosulphate (Thin-it™) were ineffective as a blossom or fruit thinner. Ethephon was an effective fruit thinner consistently reducing initial fruit set by at least 40% when applied at a concentration of 42 ml/L at any time from 20% to 80% of the flowers have opened. That thinning was effective throughout most of the flower opening period suggests that using ethephon is a robust treatment to reduce fruit set. The long application window would allow avocado growers to wait to judge if the fruit set on their trees is excessive and thinning was desirable. The temperature at the time of application of ethephon appears to be important. If ethephon is applied when the temperature is above 20°C the thinning effect is about twice that below 20°C. It is known that the thinning effect of ethephon is temperature dependant in apples (Jones *et al.*, 2000) where more thinning occurs the warmer the temperature. Based on the results reported here ethephon should only be applied when the temperature is below 20°C. If it is desirable to reduce fruit set by about 80% then ethephon could be applied at temperatures above 20°C. The greater the concentration of ethephon the greater was its thinning effect on the avocado flowers and fruit. In the absence of any information for avocados the concentration of ethephon used in the experiments was that recommended for apples of 200ppm. This concentration would be suitable for New Zealand 'Hass' avocado trees when the application temperature was below 20°C. At temperatures above 20°C a lower concentration of ethephon could be used to achieve the same thinning effect as at the cooler temperature. Before ethephon can be recommended as a treatment to reduce avocado fruit set on New Zealand avocado orchards the relationship between ethephon concentration at a range of application temperatures and thinning response needs to be better defined.

The ethephon treatments were applied when there were no mature fruit on the tree and when the newly set fruit were very small. It is not known if

applying ethephon to trees with mature fruit would cause the mature fruit to drop prematurely. There is a potential for there to be ethephon residues on mature fruit for some time after application or for there to be residues to still be present in harvested fruit when the fruit were treated when they were very small. Future studies on ethephon will need to include sampling and analysis of ethephon residues.

The experiments reported here examined the effect of ethephon on individual trees branches rather than on whole trees. It is possible that the thinning response on individual branches affected other branches on the tree that were able to compensate for the changes on individual branches. The next stage of an experimental programme is to apply ethephon to whole trees at a time and concentration identified as the best treatment in the experiments reported here. It is particularly important to determine if using ethephon to reduce fruit numbers in an 'on' flowering year will also lead to better fruit set in the following 'off' flowering year. To do this spring shoot growth measurements are needed in the year the trees are treated and flower bud development then flowering and fruit set in the next spring. The best time to test ethephon would be to use trees flowering heavily in an 'on' flowering year and to follow the phenology, flowering and yields off the trees over several years.

CONCLUSIONS

Ethephon applied to individual branches of heavily flowering 'Hass' avocado trees reduced fruit set by at least 40% at a concentration of 200ppm between 20 to 80% of open flowers and the temperature was below 20°C. Ethephon therefore could be useful as a fruit thinning agent. Before ethephon can be recommended for use the residue decay curve and the effect of ethephon applied to whole trees needs to be determined.

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