DIFFERENCES IN INITIAL FRUIT SET ON DETERMINATE AND INDETERMINATE FLOWERING SHOOTS

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ABSTRACT

Achieving similar yields each year is an important orchard management goal for New Zealand avocado growers. Robust tree management strategies that maximise potential fruit set each year requires a good understanding of avocado tree physiology under New Zealand conditions. One important question we are seeking to answer is: what is the ideal fruiting wood? A study was conducted that surveyed individual shoots for initial fruit set in relation to the characteristics of the flowering structures. The number of fruit in the initial fruit set was related to the 'on' or 'off' flowering status of the tree, shoot type, panicle position, panicle size and total number of panicles down a flowering shoot. The best combination of shoot characteristics that gave the greatest initial fruit set was on shoots consisting of at least 6 panicles (estimated to be about 150 to 200mm long) in the 'on' flowering year, on the very outer edge of the canopy in full sunlight. The initial fruit set in the 'on' flowering year was about twice that in the 'off' flowering year. The proportion of panicles that were determinate down the shoot was greatest in the 'on' flowering year with fewer determinate panicles at each position down the shoot in the 'off' flowering year. The percentage of large panicles was about twice that in the 'on' flowering year compared to the 'off' flowering year for the panicle at the shoot tip. In the 'off' flowering year initial fruit set was about the same on all panicles. Our observations suggest that the spring shoot flush should be about 200mm long. However, restricting shoot length in the 'off' flowering year may not be the only important factor that determines initial fruit set. Further research is required to understand what inhibits initial fruit set in the 'off' flowering year by manipulating shoot growth and fruit numbers up and down. The observations reported here also indicate that in the 'off' flowering year there is an inherently poorer ability to set fruit. The proportion of flowering shoots that was determinate each year differed between orchards suggesting it is possible to manipulate flowering type each year. Once the ideal shoot for fruit set is identified then avocado trees can be manipulated for best shoot growth and consistent yields.

Keywords: *panicle, alternate bearing*

INTRODUCTION

There have been substantial increases in the plantings of Hass avocados in New Zealand during the past 10 years (NZ Avocado Growers' Association Annual Report, 2008). Along with the increased plantings the total avocado crop in New Zealand also increased until the 2003/04 export season where the total crop declined. Since the 2004/05 export season the New Zealand avocado crop has exhibited a strong alternate bearing pattern with the crop doubling then halving again. The alternate bearing pattern for the whole industry is echoed for individual orchards especially in the main growing region of the Western Bay of Plenty. The New Zealand avocado industry exports between 47 to 58% of the total crop each year leading to oversupply and undersupply in export markets. In addition, avocado growers come under financial stress as the alternate bearing pattern affects orchard incomes. Achieving similar yields from year to year is an important orchard management goal for New Zealand avocado growers. To develop robust tree management strategies that control alternate bearing a good understanding of avocado tree physiology under New Zealand conditions is required.

The general nature of how an avocado tree grows, flowers and sets fruit is well known and has been

studied in other countries (Whiley, 2002). The details of how avocado trees grow and develop under New Zealand conditions has been the main focus of the industry research programme over the past four years (Dixon *et al.*, 2007). Although there are many questions to be answered, one important question we are seeking to answer is: what is the ideal fruiting wood? If the ideal fruiting wood could be defined then it would be possible to develop tree management systems that maximise potential fruit set each year. Unfortunately there is little information that describes the ideal avocado fruiting wood. In New Zealand it is thought the best fruiting wood comes from the spring shoot flush (Cutting, 2003). As a first step to identifying the best fruiting wood a study was conducted looking at which shoots had the best initial fruit set in relation to the characteristics of the flowering structures of individual shoots.

MATERIALS AND METHODS

Twenty 'Hass' on 'Zutano' seedling rootstock trees were selected in each of 3 orchards located near Aongatete, Pahoia and Katikati in the Western Bay of Plenty in the years 2005, 2006 and 2007. The trees were large mature trees about 6m to 8m in height and 14 to 20 years old. The trees were managed according to industry norms. The same 20 trees were used each year with new branches selected each year. Three flowering branches facing north and exposed to full sun per tree were randomly selected at between 1.5m and 2.5m height for fruit counts. On each branch the total number of panicles were counted and for each individual panicle the following information was recorded: position on the branch relative to the apical panicle (the apical panicle was classified as position 1), panicle size on a 3 point scale (1 = small, 2 = medium, 3 = large) and if the panicle was determinate or indeterminate (defined as having a vegetative shoot emerging from within the panicle). An 'on' or 'off' flowering year was determined by assessing individual trees for crop load and intensity of flowering. Trees with few fruit and an intense flowering were considered to be in an 'on' flowering, while trees with many fruit and less intense flowering were considered to be in an 'off' flowering. Once about 75% of the total number of flowers had opened the number of fruit on each individual panicle was recorded once or twice a week until the February fruit drop.

The data was analysed using Microsoft Excel 2007.

RESULTS

Initial fruit set

The number of fruit present in the initial fruit set on flowering avocado shoots was related to the 'on' or 'off' flowering status of the tree, shoot type, panicle position, panicle size and total number of panicles down a flowering shoot (Figure 1). In trees in the 'on' flowering, initial fruit set on determinate flowering shoots was about twice that of indeterminate flowering shoots (Figure 1a). The initial fruit set in the 'off' flowering year was similar between determinate and indeterminate flowering shoots (Figure 1a). The initial fruit set in the 'on' flowering year was about twice that in the 'off' flowering year when comparing the same shoot types across years. Average fruit set on panicles at the shoot tip (position 1 in Figure 1b) was about twice the initial fruit set on the second to fourth panicles down the shoot in both the 'on' and 'off' flowering years and was not different between determinate and indeterminate panicles (Figure 1b). Large flowering panicles had the greatest initial fruit set in the 'on' flowering year and showed a consistent trend for the large panicles to have the most fruit (Figure 1c). The greater initial fruit set on large panicles was consistent across the 'on' and 'off flowering years and between determinate and indeterminate panicle types. There was a trend for the average number of fruit per shoot to increase as the number of panicles increased to the sixth panicle. Shoots with more than 6 panicles had similar average numbers of fruit per shoot (Figure 1d). The greatest average fruit numbers were on flowering shoots with 6 or more panicles in the 'on' flowering year (Figure 1d). In the 'off' flowering year the initial fruit set did not differ according to the number of panicles present on a flowering shoot.

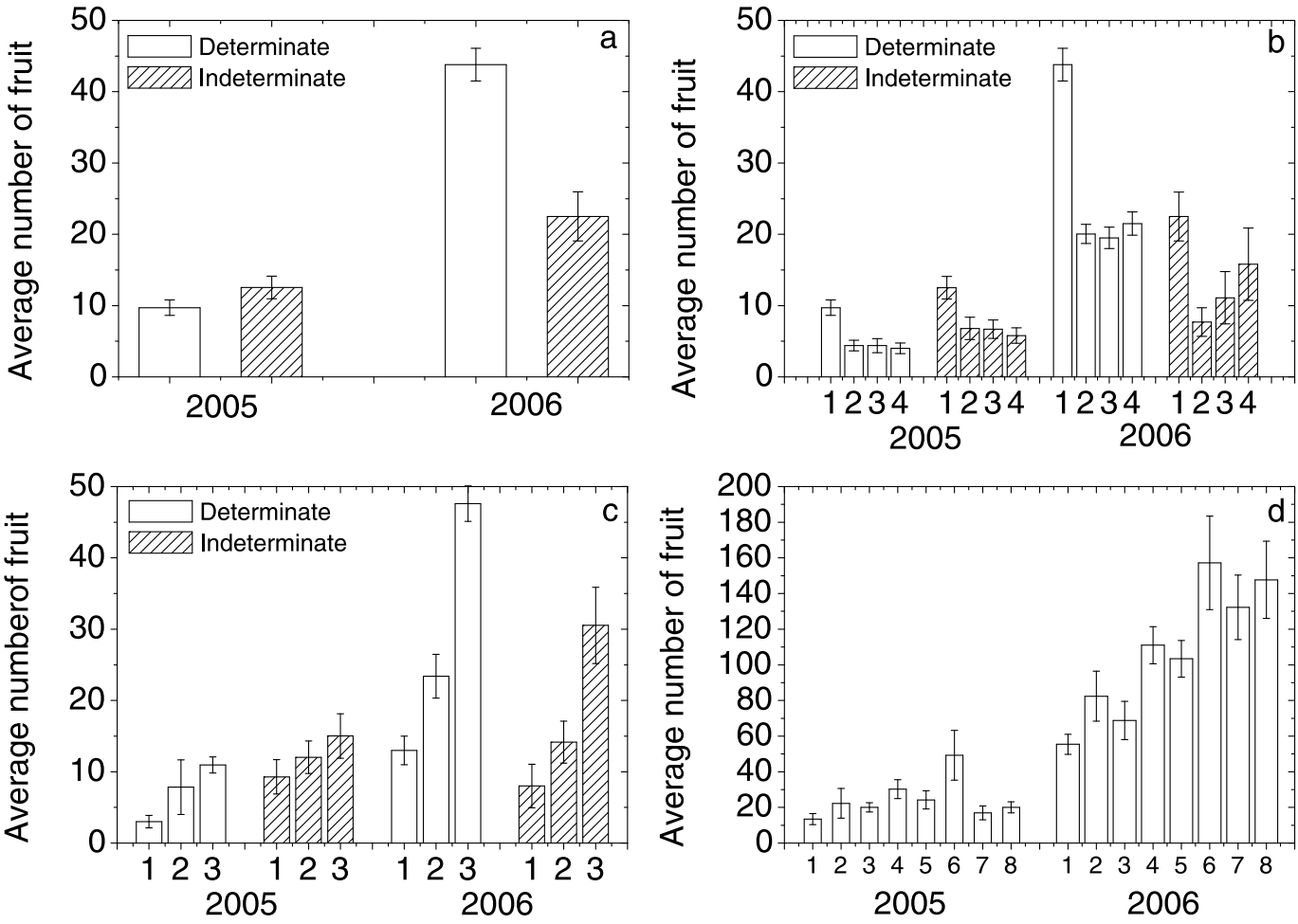

Figure 1. Average number of fruit in the initial fruit set for a) flowering shoot type, b) position down the shoot (1 = apical panicle at the shoot tip), c) panicle size (1 = small, 2 = medium and 3 = large) and shoot type and d) shoot size (1 = shoot with one panicle, 8 = shoot with eight panicles) in a 'off' flowering year 2005 and an 'on' flowering year 2006 for three orchards located near Katikati in the Western Bay of Plenty.

Pattern of fruit drop

The pattern of fruit drop was similar within each flowering year and differed only in magnitude with small panicles having fewer fruit than large panicles (Figure 2). The pattern of fruit drop was not affected by panicle position (data not shown) and whether the panicle was determinate or indeterminate (Figure 2).

Panicle type down the shoot

The type of panicle, determinate or indeterminate, at each position down a flowering branch was related to the 'on' or 'off' flowering status of the tree, panicle position down the branch and the yield following the 'on' flowering year (Figures 3 and 4). The proportion of panicles that were determinate down the shoot to the seventh panicle from the shoot tip was greatest in the 'on' flowering year for the orchard located near Aongatete (Figure 3). There were fewer determinate panicles at each position down the shoot in the 'off' flowering years with the least determinate panicles at the shoot tip (Figure 3). There was a tendency for panicles furthest from the shoot tip to have the greatest proportion of determinacy. In contrast the orchards located near Katikati and Pahoia had similar

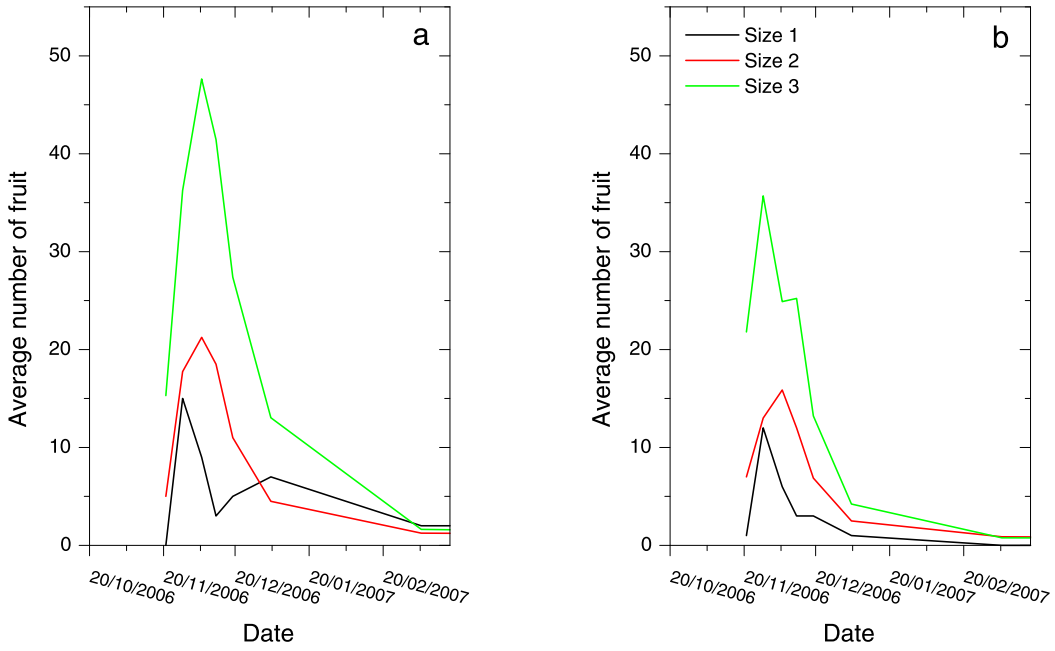

Figure 2. Pattern of fruit drop of the initial fruit set on a) determinate or b) indeterminate panicles of different sizes from one orchard located near Aongatete in the Western Bay of Plenty.

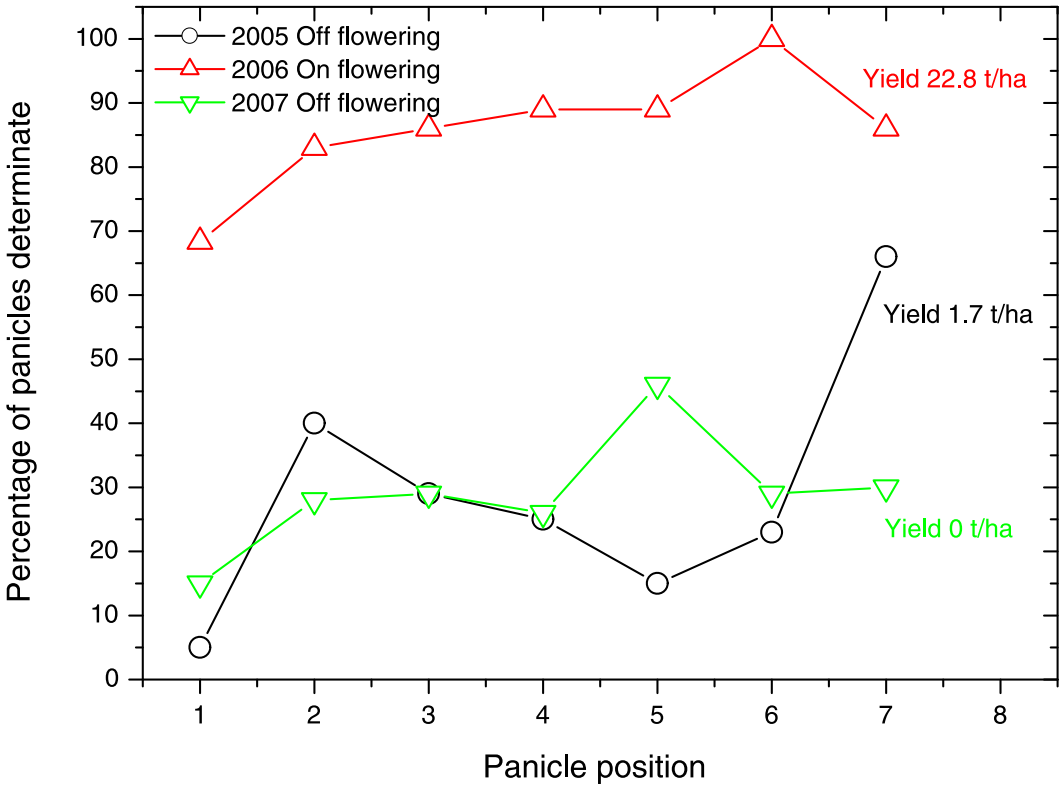

Figure 3. Average percentage of panicles per shoot that were determinate each year according to position down the shoot (1 = apical panicle at the shoot tip) in an orchard located near Aongatete in the Western Bay of Plenty. Yield values are for fruit harvested in the following year.

proportions of determinacy in panicles at each shoot location down the flowering branch during the 'on' and 'off' flowering years (Figure 4). The panicles on the shoot tip had slightly lower proportions of determinacy than panicles further down the shoot. The orchard located near Aongatete had about twice the yield following the 'on' flowering year compared to the orchards located near Katikati and Pahoia (Figures 3 and 4).

Panicle size down the shoot

The size of panicles down a flowering shoot was related to the 'on' or 'off' flowering status of the tree, panicle position on the flowering branch and yield following the 'on' flowering year (Figures 5, 6 and 7). The percentage of large panicles was about twice that in the 'on' flowering year compared to the 'off' flowering year for the panicle at the shoot tip (panicle 1) in trees from the orchard located near Aongatete (Figure 5). The percentage of large panicles at the shoot tip was similar each year on trees in the orchard located near Katikati (Figure 6). The trees in the orchard located near Pahoia had about 15% more large panicles at the shoot tip in the 'on' flowering year than in the 'off' flowering year (Figure 7). The trees in the orchards located near Katikati and Pahoia had a consistent pattern of a greater percentage of large panicles down the flowering shoot in the 'on' flowering year than in the 'off' flowering year (Figures 6 and 7). The percentage of large panicles at positions 2 to 4 on the shoot was less than the percentage of large panicles at the shoot tip. The trees in the orchard located near Aongatete had a similar percentage of large panicles at positions 2 to 4 down the shoot each year (Figure 5).

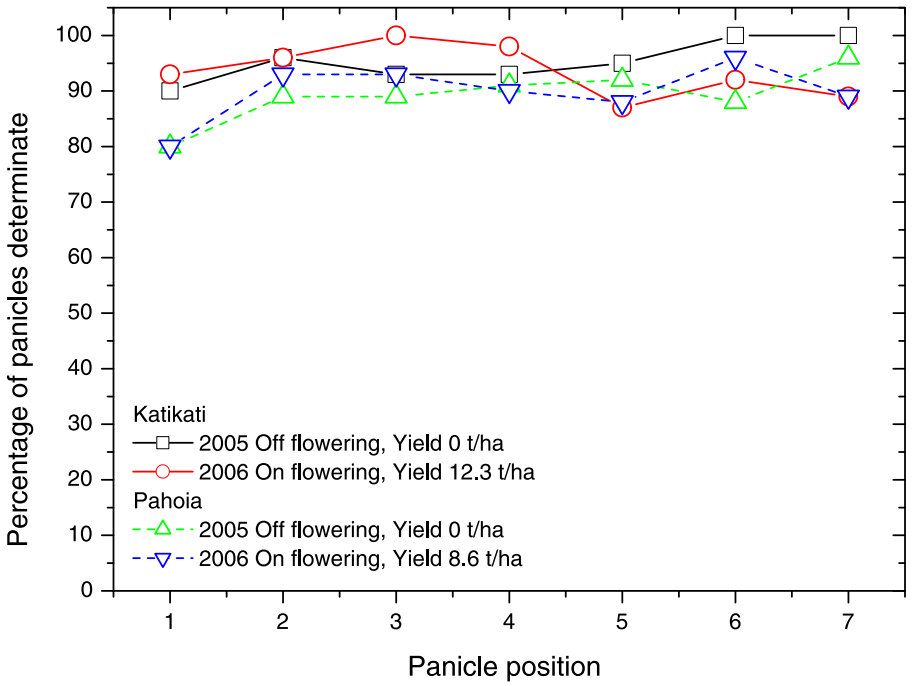

Figure 4. Average percentage of panicles per shoot that were determinate each year according to position down the shoot (1 = apical panicle at the shoot tip) in two orchards located near Katikati and Pahoia in the Western Bay of Plenty. Yield values are for fruit harvested in the following year.

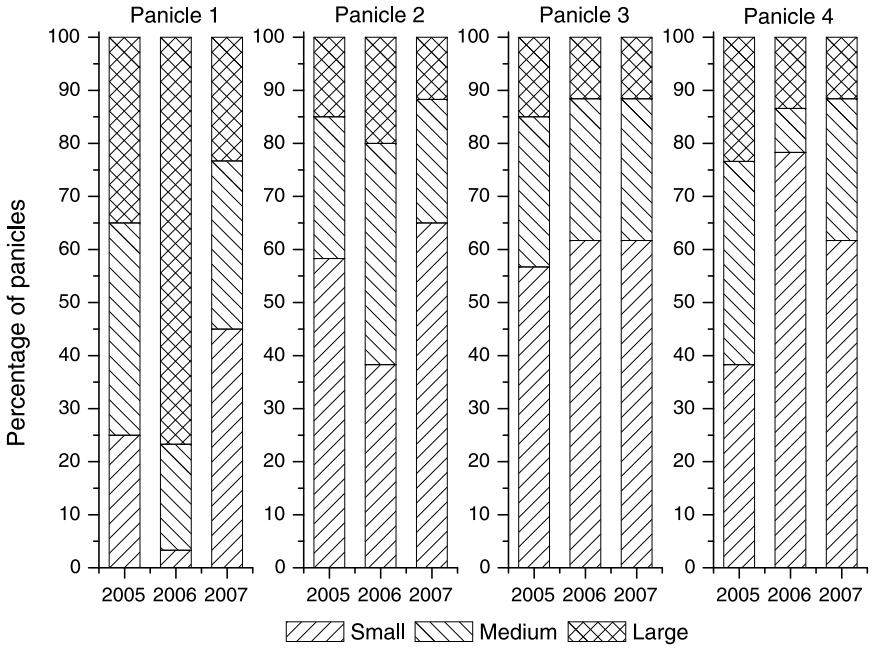

Figure 5. Average proportion of panicles rated as small, medium or large each year according to their position down a shoot (Panicle 1 = apical panicle at the shoot tip) on 'Hass' avocado trees in an orchard near Aongatete in the Western Bay of Plenty.

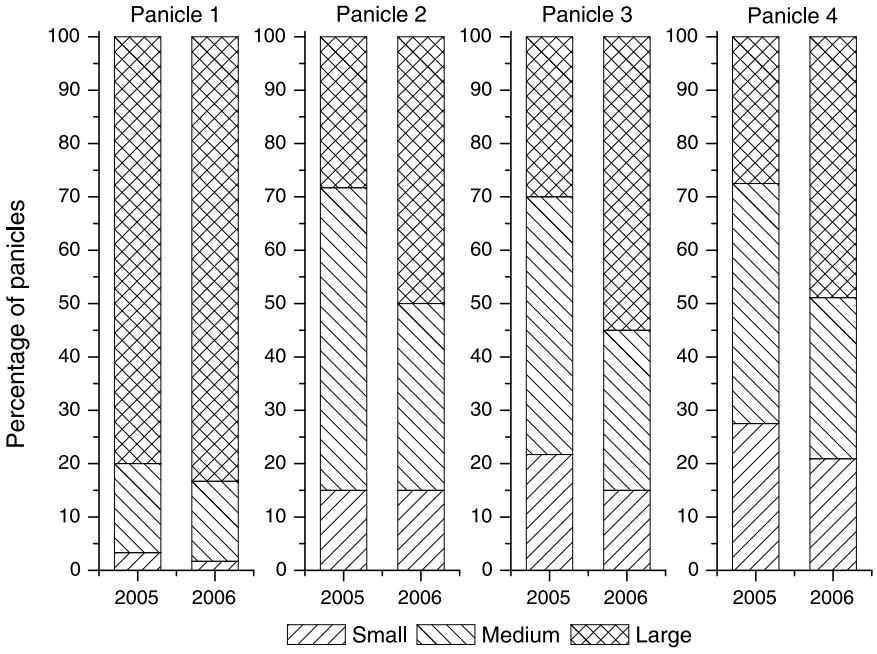

Figure 6. Average proportion of panicles rated as small, medium or large in 2005 and 2006 according to their position down a shoot (Panicle 1 = apical panicle at the shoot tip) on 'Hass' avocado trees in an orchard near Katikati in the Western Bay of Plenty.

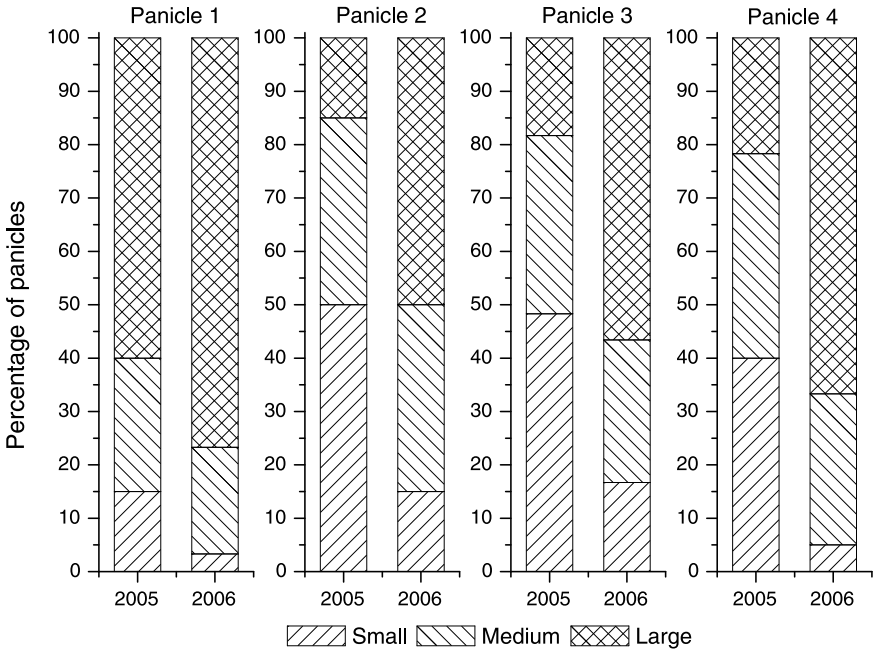

Figure 7. Average proportion of panicles rated as small, medium or large in 2005 and 2006 according to their position down a shoot (Panicle 1 = apical panicle at the shoot tip) on 'Hass' avocado trees in an orchard near Pahoia in the Western Bay of Plenty.

DISCUSSION

The best combination of shoot characteristics that gave the greatest initial fruit set was on shoots 6 panicles long, about 150 to 200mm in length based on casual observations, in the 'on' flowering year. These shoots had the largest panicle size and therefore the most flowers with the greatest proportion of panicles that were determinate. The shoots that had the best initial fruit set, although relatively short, were observed to be commonly on the very outer edge of the canopy in full sunlight. Collectively, the above identifies the best parts of the tree for fruit set are at the tops of trees and on the faces of the tree with exposure to the most sunlight, *i.e.* North and West. In the 'off' flowering year initial fruit set was about the same on all panicles irrespective of the number of panicles down a branch, panicle size and whether they were determinate or indeterminate. Based on the information in this report the ideal amount of spring shoot growth should have only about 6 buds that develop into panicles. This further implies that there will only be about 6 mature leaves associated with the developing flowers. These buds are located from the shoot tip down the branch and will only be present on one year old growth. A shoot length of only about 200mm appears to be relatively short compared to the length of spring shoots often seen on avocado trees in New Zealand at the end of the spring flush in January. The implications of our observations is that the spring avocado shoot flush should be managed for a total spring shoot length of about 200mm as the first step in establishing the ideal tree set up for the best initial fruit set.

That there was little difference in initial fruit set in the 'off' flowering years between panicles of different sizes, the presence of a vegetative shoot in the panicle and position on the shoot may indicate that restricting shoot length in the 'off' flowering year is not the only important factor

determining initial fruit set. Just as important in determining initial fruit set may be competition for nutrients and carbohydrates where a heavy crop on the tree in the 'off' flowering year may reduce the number of large determinate panicles that develop. Experiments where the crop is harvested late have shown that the yield in the following year is reduced (Whiley *et al.*, 1996) it is presumed by depleting the available starch and nutrients or by altering the hormone balance in the new shoots. The observations reported here indicate that there can be fewer determinate panicles that have a lower initial fruit set in the 'off' flowering year. Thus the effect of late harvest on the return crop may also affect the type of flowering shoot that is present in the following spring. The mechanism of how late hanging fruit could determine the flowering shoot type is not known. To identify the major factors that inhibit initial fruit set in the 'off' flowering year further research is required where shoot growth and fruit numbers are manipulated up and down. The results of such research may explain why avocado yields can be variable even though spring shoot growth may only be slightly greater than 200mm. There is also a possible interaction between shoot growth and harvesting strategy, by hanging fruit late, which could further influence initial fruit set.

A major assumption of this study was that initial fruit set is correlated to the final yield of the tree. It is possible that what determines the initial fruit set is not the same as what determines the amount of fruit drop. Previous observations (Dixon *et al.*, 2006) suggest there is no obvious pattern to which fruit survive until harvest. Further research is required to establish the relationship between initial fruit set and fruit drop and between shoot characteristics and fruit set after the fruit drop. While this project attempted to define the characteristics of the ideal fruiting shoot for initial fruit set it has not accounted for what shoot characteristics may be desirable on a whole tree basis. It is possible that in the 'on' flowering year there are more flowering shoots in total on a tree. This is then the reason for a high yield. In the 'off' flowering year there may be fewer flowering shoots that are inherently poorer at setting fruit. This then explains the lower yield. However, the observations reported here also indicate that in the 'off' flowering year there is an inherently poorer ability to set fruit. Therefore to overcome alternate bearing and achieve consistent crops it is important to know not just what kind of shoot growth is needed but also how much shoot growth. This study has taken the approach that it is best to first define what characteristics the ideal fruiting shoot has and then consider whole tree effects. To better understand what leads to a good fruit set individual shoots each year further research following the growth and flowering of shoots over several consecutive years would be required.

This study has been useful in establishing a base of knowledge about avocado shoots and indicates what characteristics of a shoot are desirable. There are many questions that need to be answered before a definitive recommendation can be made about the precise nature of the shoot growth that is needed for consistent crops of avocado fruit. There were large differences in the proportion of flowering shoots that were determinate each year between orchards. Such a finding suggests that it is possible to manipulate the tree into producing more or less determinate panicles each year. It is possible that the high levels of determinate flowering shoots that develop could be determined by as yet undefined nutritional factors, crop load (to get high levels of indeterminate shoots a certain yield threshold may be required), high light levels, climatic factors and position on the tree that may be influencing starch and plant hormone levels in the tree. Further unknown factors are also the type of shoot growth, proleptic or sylleptic, and its effect on initial fruit set. Future research will focus on answering such questions so that the ideal shoot for fruit set can be defined. Once there is an ideal shoot for fruit set then avocado trees can be manipulated in size and shape to best develop ideal shoot growth. By this means the production of avocado fruit on 'Hass' avocado trees in New Zealand can be increased and made more consistent.

CONCLUSIONS

The best combination of shoot characteristics that gave the greatest initial fruit set was on shoots consisting of at least 6 panicles (estimated to be about 150 to 200mm long) in the 'on' flowering year, on the very outer edge of the canopy in full sunlight. Further information required to define the ideal fruiting wood is: the number of determinate and indeterminate shoots each year and the type of shoot growth.

REFERENCES

Cutting, J.G.M. (2003). Research note: Impact of spring and summer flush type on flowering intensity in 'Hass' avocado. *New Zealand Avocado Growers' Association Annual Research Report* **3**: 42-47.

Dixon, J., Lamond, C.B., Smith, D.B. and Elmsly, T.A. (2006). Patterns of fruit growth and fruit drop of 'Hass' avocado trees in the Western Bay of Plenty, New Zealand. *New Zealand Avocado Growers' Association Annual Research Report* **6**: 47-54.

Dixon, J., Elmsly, T.A., Dixon, E.M. and Mandemaker, A.J. (2007). 'Hass' avocado tree phenology 2004-2008 in the Western Bay of Plenty. *New Zealand Avocado Growers' Association Annual Research Report* **7**: 21-29.

Whiley, A.W. (2002). Crop Management. In: *The Avocado: Botany, Production and Uses.* (Whiley, A.W., Schaffer, B. and Wolstenholme, B.N. Eds.) CAB International Wallingford, Oxon, UK. pp. 231-258.

Whiley, A.W., Rasmussen, T.S., Saranah, J.B. and Wolstenholme, B.N. (1996). Delayed harvest effects on yield, fruit size and starch cycling in avocado (*Persea americana* Mill.) in two subtropical environments. II. *The late maturing cv. Hass. Scientia Horticulturae* **66**: 35-49.

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