'HASS' AVOCADO TREE PHENOLOGY 2004 - 2006 IN THE WESTERN BAY OF PLENTY

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ABSTRACT

Casual observation of the growth cycles of shoots, roots and flowers of avocados suggests that important growth events can vary in their timing each year. Differences in phenological events may require orchard management practices to be applied at different times for best results. Trees on two orchards in the Western Bay of Plenty were monitored for three years to establish the variation in phenology. Patterns of shoot and root growth were similar each year but the timing and amount of growth between trees in different orchards and the "on" and "off" years differed. Orchard differences were in the number of shoot flushes, three for orchard 1 and two for orchard 2, possibly due to the use of irrigation on orchard 1. Spring shoot flush started at different times but was about the same duration on both orchards indicating that the trees in the non-irrigated orchard were not limited by soil moisture availability. Spring shoot flush generally ceased growing from mid December to late January. The other major influence on phenological events was whether the trees were in an "on" or "off" year in the alternate bearing cropping cycle. The aspects of the spring flush that were not affected by the alternate bearing cycle were: the start of spring flush, the duration of spring flush and the duration of spring flush after flowering. The trees in an "on" year had reduced growth in shoots and roots compared to trees in the "off" year. Trees in the "off" year had fewer flowers, longer time from flower bud break to the first open flower, a lower percentage of the flowers set fruit and flowering was over a shorter time than trees in the "on" years. That the phenological events vary from year to year and can vary from orchard to orchard indicates that there would be an advantage for avocado growers or orchard managers to more closely follow the growth cycles on their trees.

Keywords: *tree growth cycles, flowering, roots, shoots, weather*

INTRODUCTION

The growth cycles of shoots, roots and flowers of avocados generally defines when orchard management activities occur. For example, many fertilizer programmes are designed to support the growth and development of shoots, roots and flowers. The phenology of avocados has been established in other countries (Arpaia *et al*., 1996; Whiley and Saranah, 1995; Graham and Wolstenholme, 1991) and in the Western Bay of Plenty, New Zealand (Thorp *et al*., 1995). The tree growth cycles of avocados in New Zealand are similar to the growth patterns of avocados in other countries after allowing for the Northern hemisphere season being opposite to that of New Zealand. Casual observation of trees would suggest that important growth events such as flowering and spring shoot growth can vary in their timing each year. These differences may require orchard management practice to be applied at different times each year for best results. To measure changes in the phenology from year to year requires monitoring of trees over a number of years. This is to capture the differences between "on" and "off" cropping years. To gather such information requires tools that describe and measure the tree growth cycle. Such tools could be utilized by avocado growers for monitoring the phenology so that management decisions can then be based on when the tree is in a particular state and there is sufficient time to take corrective action to achieve the best yields from the trees. To evaluate how understanding avocado phenology could be used to achieve regular crops, detailed and accurate descriptions of the phenology is required. Well managed trees on two orchards in

the Western Bay of Plenty were monitored over three years to establish the variation in phenological events each year and to correlate these events with each other and orchard factors. This report describes the first three years of 'Hass' avocado phenology.

MATERIALS AND METHODS

The details of the orchards used in this study and the methods to measure shoot and root growth, flowering and fruit set as well as the temperature and soil moisture are as described previously (Dixon *et al.*, 2005).

RESULTS

Orchard 1

Phenology

Shoot Growth

There were three shoot flush periods each year corresponding to spring, summer and autumn (Figure 1). The first flush was in spring during September/October to mid December/January, the second in summer during January to April and a short period of shoot growth in autumn during April to May (Figure 1). The greatest shoot growth was in spring followed by the summer shoot flush and a weak growth flush in autumn. The amount of shoot flush was greater in 2005 when there was no fruit set than in 2004 and 2006 when there were heavy crops set. On average, the earliest spring flush shoots started growing from early to mid October and grew for about 70 days (Table 1). The length of time individual spring flush shoots grew was variable and generally ranged from as short a time as six weeks up to 14 weeks. The duration of spring shoot growth tended to decrease from 2004 to 2006 with the average duration of the spring flush shorter by about 12 days.

Root Growth

There were at least three periods of root growth each year generally at times when shoot growth was weakest (Figure 1). The timing of root flushes varied each year depending on the timing of the shoot flush. Like shoot flushes the flush of roots could be divided into seasons, the first is spring where there could be one or more flushes of roots. The second was late summer/early autumn and a third winter root flush generally in June or July. The

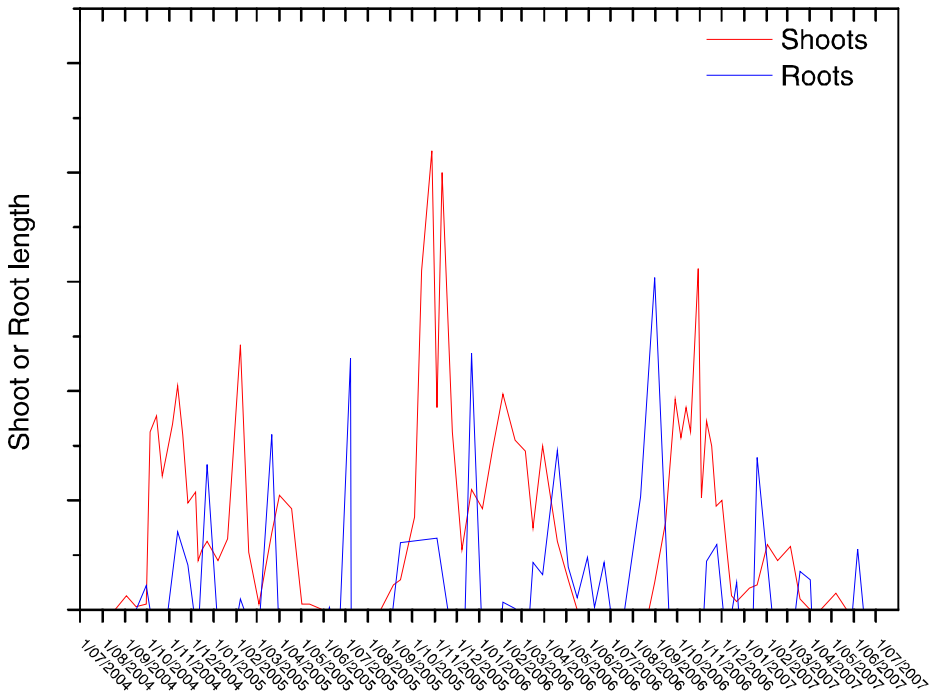

Figure 1. Total shoot and root length of five 'Hass' avocado trees from Orchard 1, 2004 to 2007.

number of root flushes and amount of roots was greatest in the spring of 2006 following a year when there was no fruit on the trees.

Flowering

Over the past three years there has been an obvious alternate bearing pattern on the trees monitored in this study. Fruit set in 2004 and 2006 was very heavy and fruit set in 2005 was absent (Figure 2). Flower bud break varied from year to year with bud break in 2005 and 2006 in early to mid September but in early October in 2004 (Table 2). The time from bud break to the first open flower was about one month in 2004, seven weeks in 2005 and about one month in 2006. Trees in the "on" years took about one month from bud break to first open flowers. In the "off" year the time taken to the first open flower took about seven weeks. Flowering was complete in about two months in 2004 and about three weeks in 2005 but took nearly three months in 2006 (Table 1). Initial fruit set numbers peaked at about the same time as flowering was completed (Table 1). This time was about one month after the peak of open flowers each year (Figure 2). In 2004 the earliest vegetative shoots started to grow at a similar time as the flower bud break. In 2005 and 2006 flower bud break was at least one month before vegetative growth was observed. Total numbers of flowers in the "on" years were of similar high numbers compared to the "off" years. The percentage of flowers that initially set a fruit in an "on" year was between 5 to 9% and maximum fruit number was also similar (Table 2). Determinate and indeterminate shoot types did not have statistically significant different flower numbers or percentage fruit set.

Weather

Air Temperature

The general temperature profile each year was similar with the coldest months from mid-May to August and the warmest months from January to March (Figure 3). The winter weekly average temperature was about 8 to 10°C and in summer the weekly average temperature was around 18 to 20°C. Frosts were possible from June to September and occasionally in October 2004. Frosts were fewer in 2005 but were present from June to September 2005. During the flowering period the temperatures were similar each year but the period of main bloom varied from year to year

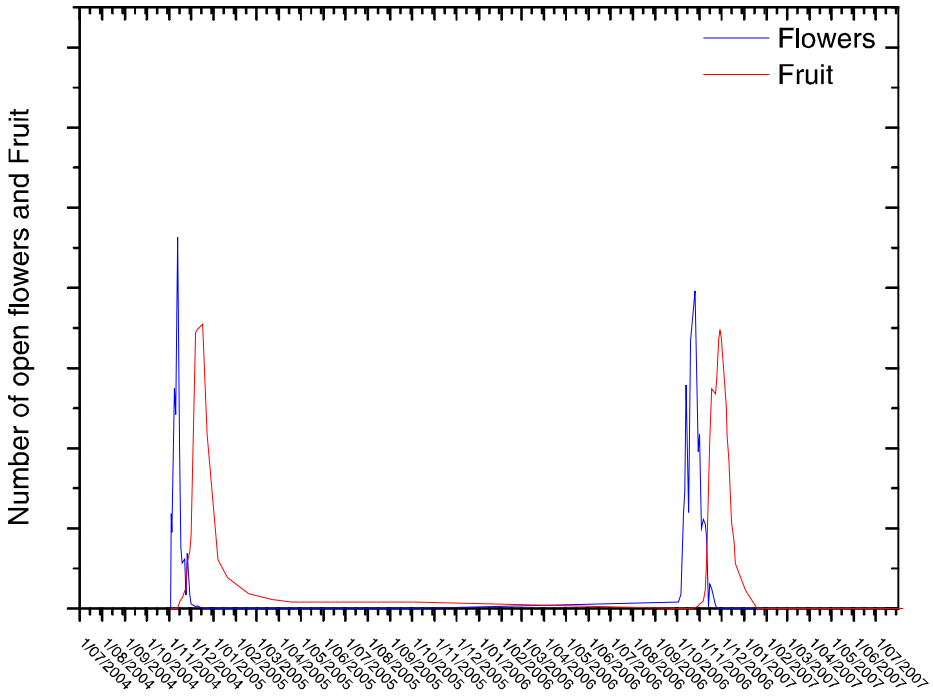

Figure 2. Total number of open flowers and fruit on 10 flowering shoots of 5 'Hass' avocado trees from Orchard 1 2004 to 2007.

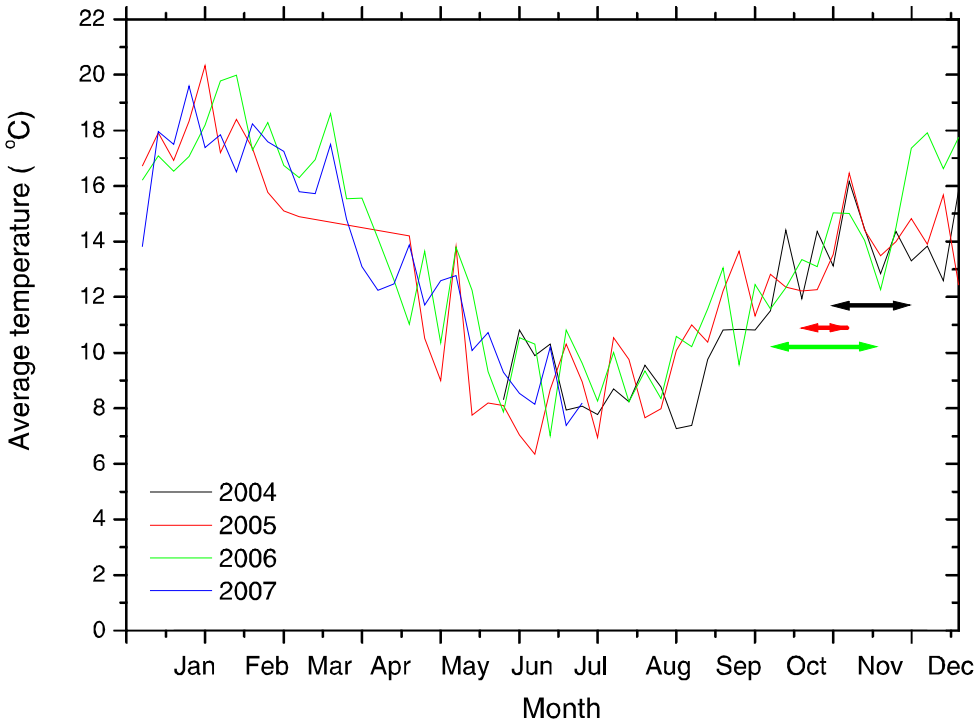

Figure 3. Average weekly shade air temperature for 'Hass' avocado trees in Orchard 1, 2004-2007. The arrows represent the main bloom period each year.

(arrows on Figure 3). The main bloom period was short in 2005 at 3 weeks compared to 5-6 weeks in 2004 and 2006 (Table 1). The first week coincided with cooler temperatures after which the temperature rapidly warmed up.

Soil moisture matrix potential and rainfall

The soil moisture matrix potential tended to be lowest in summer generally reaching about -30 kPa in February or March (Figure 4). There was little difference in soil moisture matrix potential at

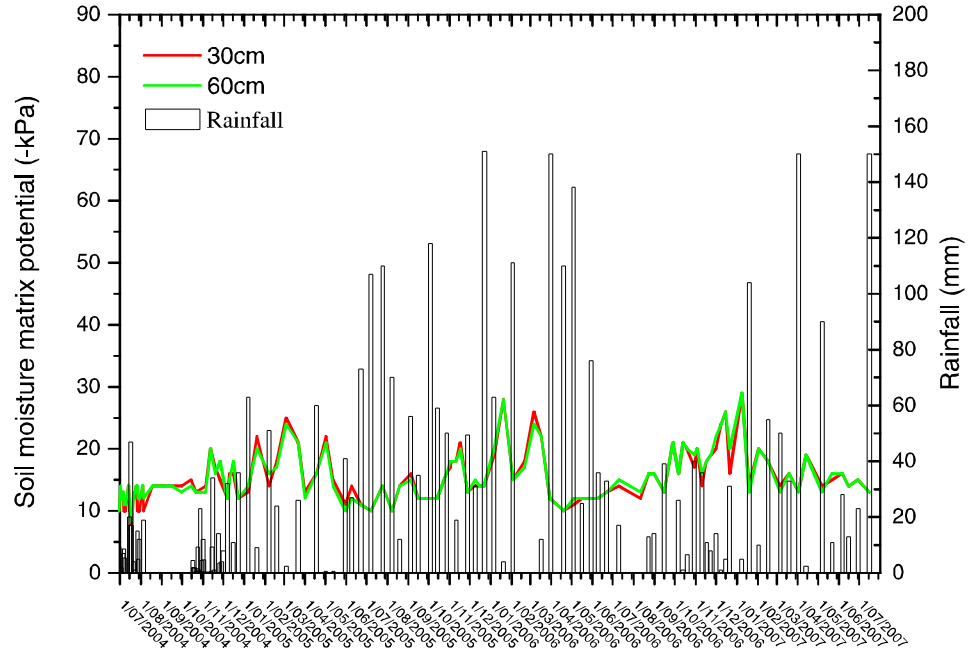

Figure 4. Soil moisture matrix potential at 30 and 60cm and rainfall for Orchard 1 2004-2007. During spring and summer the trees were irrigated with 9.5mm of water per m^2 every 3 to 4 days.

30 or 60 cm depth. As these trees were regularly irrigated at 9.5mm/m^2, the trees were unlikely to have been under water stress. Rain occurred at reasonably regular intervals each year with the longest period where rain was absent of about 6 weeks at different times of the year (Figure 4). There was more rain in July 2005 to June 2006 than in the other two years. The total rainfall from July 2004 to June 2005 was 780mm, from July 2005 to June 2006 was 1557mm and July 2006 to June 2007 was 837mm.

Soil Temperature

The lowest soil temperatures were in June and July where the soil was on average 9°C but was often between 10 to 11°C (Figure 5). From August the soil temperature rose steadily until February when it reached 18 to 20°C. The general pattern of soil temperatures was similar each year.

Orchard 2

Phenology

Shoot Growth

There were two distinct shoot flush periods each year corresponding to spring and summer (Figure 6). The first flush was in spring during September/October to mid December, the second in summer during January to March (Figure 6). The amount of shoot growth in spring and summer was similar. In 2005 the total amount of shoot flush was greater than in 2004 and 2006 with some additional shoot flush in December. On average, the earliest spring flush shoots started growing from mid October and grew for about 70 days (Table 1). The length of time individual spring flush shoots grew was variable and generally ranged from as short a time as six weeks up to 14 weeks. The duration of spring shoot growth while decreased in 2005 was similar in 2004 and 2006.

Root Growth

The number of feeder roots at the soil mulch interface was low in 2004 and 2006, "on" years, and greater in 2005, an "off" year (Figure 6). There were two main periods of root growth each year 2004 and 2006, generally at times when shoot growth was weakest in December and June/July (Figure 6). In 2005 there were several periods of root flush throughout the year. The timing of root flushes varied each year depending on the timing of the shoot flush. The number of root flushes and amount of roots was greatest in the spring of 2005.

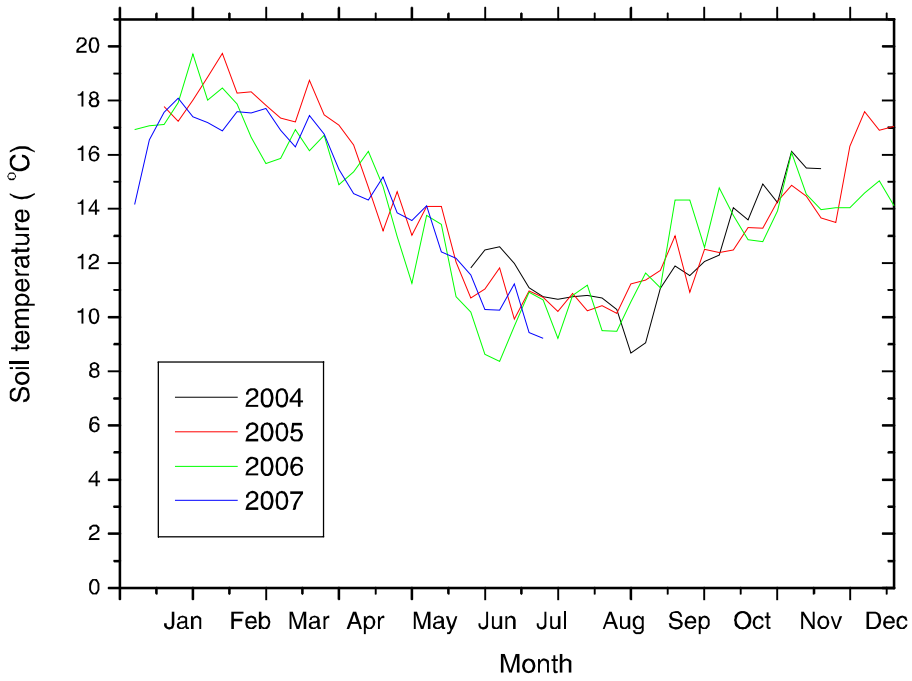

Figure 5. Average weekly soil temperature (100mm depth) for 'Hass' avocado trees in Orchard 1, 2004-2007.

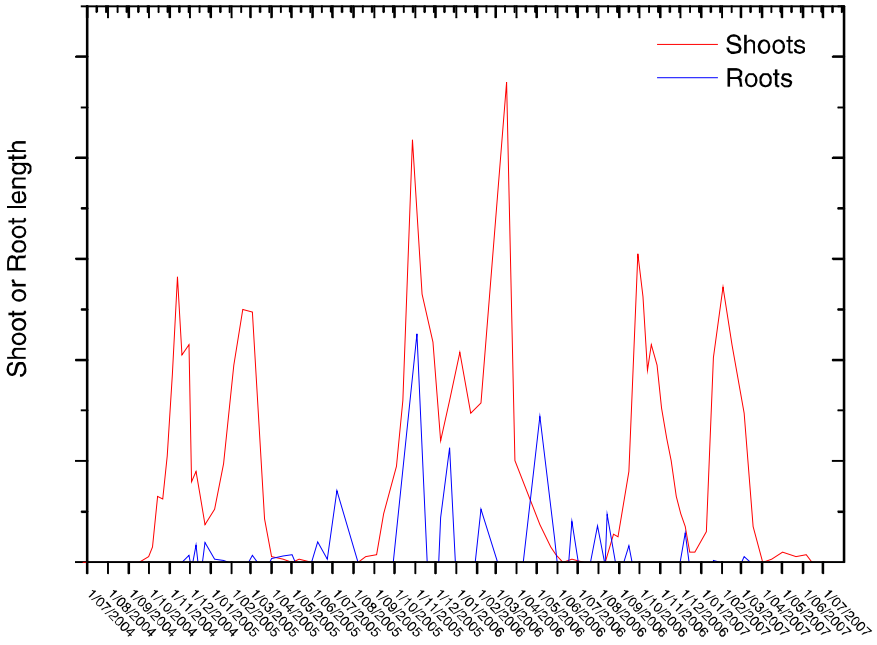

Figure 6. Total shoot and root length of five 'Hass' avocado trees from Orchard 2 2004 to 2007.

Flowering

Over the past three years there has been an obvious alternate bearing pattern on the trees monitored in this study. Fruit set in 2004 and 2006 was heavy and fruit set in 2005 was low (Figure 8). Flower bud break was at about the same time in 2004 and 2005 in early October but was about 20 days earlier in 2006 in mid September (Table 2). The time from bud break to the first open flower was about one month in 2004, two weeks in 2005 and about one month in 2006. Trees in the "on" years took about one month form bud break to first open flowers. In the "off" year the time taken to the first open flower took about two weeks. Flowering

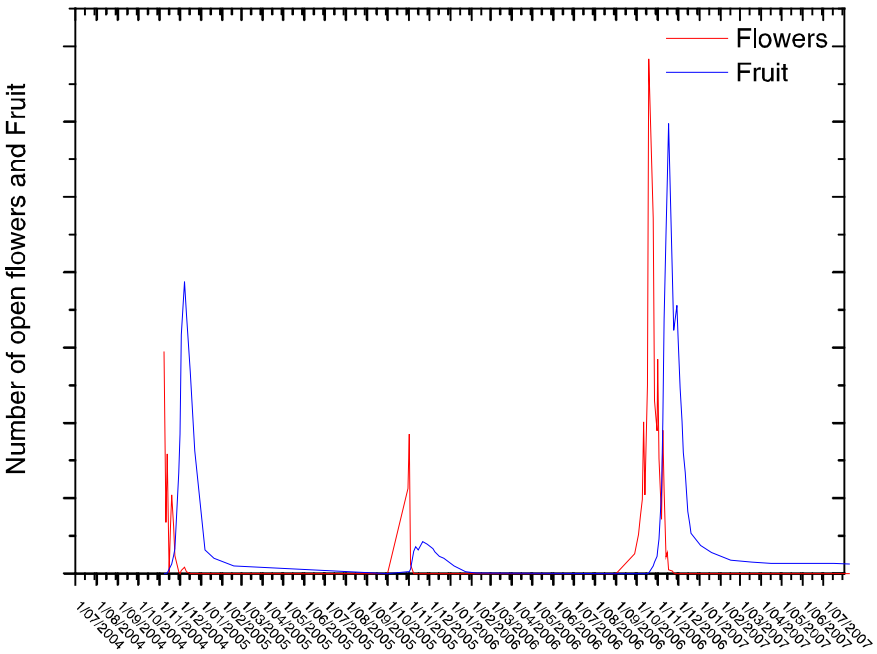

Figure 7. Total number of open flowers and fruit of 5 'Hass' avocado trees from Orchard 2, 2004 to 2007.

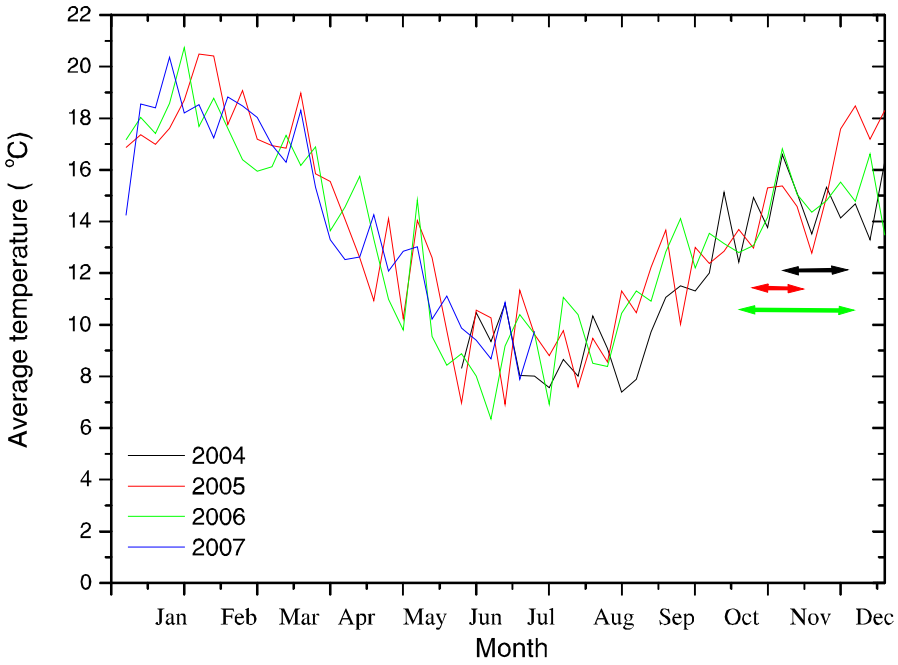

Figure 8. Average weekly shade air temperature for 'Hass' avocado trees in Orchard 2, 2004-2007. The arrows represent the time of open flowers in the main bloom period each year.

was complete in about six weeks in 2004 and about four weeks in 2005 and took seven weeks in 2006 (Table 1). Initial fruit set numbers peaked just before flowering was complete (Table 1). This time was about one month after the peak of open flowers each year (Figure 7). In 2004 and 2005 the earliest vegetative shoots started to grow about 10 days after flower bud break. In 2006 flower bud break was about one month before vegetative growth was observed. Total numbers of flowers was similar each year in indeterminate flowering shoots but was greater in 2006 on determinate flowering shoots (Table 2). The percentage of flowers that initially set a fruit was greater in an "on" year, 2004 and 2006, than an "off" year, 2005 (Table 2). The initial fruit set in 2004 was very high at about 17% compared to 8 to10% in 2006. In 2005 initial fruit set was low at below 5% (Table 2). Determinate and indeterminate shoot types did not have statistically significant different flower numbers or percentage fruit set.

Weather

Air Temperature

The general temperature profile each year was similar with the coldest months from mid-May to August and the warmest months from January to March (Figure 8). The winter weekly average temperature was about 7 to 11°C and in summer the weekly average temperature was around 17 to 20°C. Frosts were possible in 2004 from June to September and occasionally in October. Frosts were fewer in 2005 but were present from June to September 2005. In 2006 frosts were only recorded from June to August. During the flowering period the temperatures were similar each year but the period of main bloom varied from year to year (arrows on Figure 8). The main bloom period was short in 2005 at 3 weeks compared to 5-6 weeks in 2004 and 2006 (Table 1). The first week coincided with cooler temperatures after which the temperature rapidly warmed up.

Soil moisture matrix potential and rainfall

The soil moisture matrix potential was lowest in summer and often exceeded -70 kPa from February to March (Figure 9). The spring of 2006 and summer to autumn of 2007 was very dry with the soil moisture matrix potential less than -50 kPa most of the time (Figure 9). The trees used in this study were not irrigated indicating the trees were likely to have been under water stress. The soil

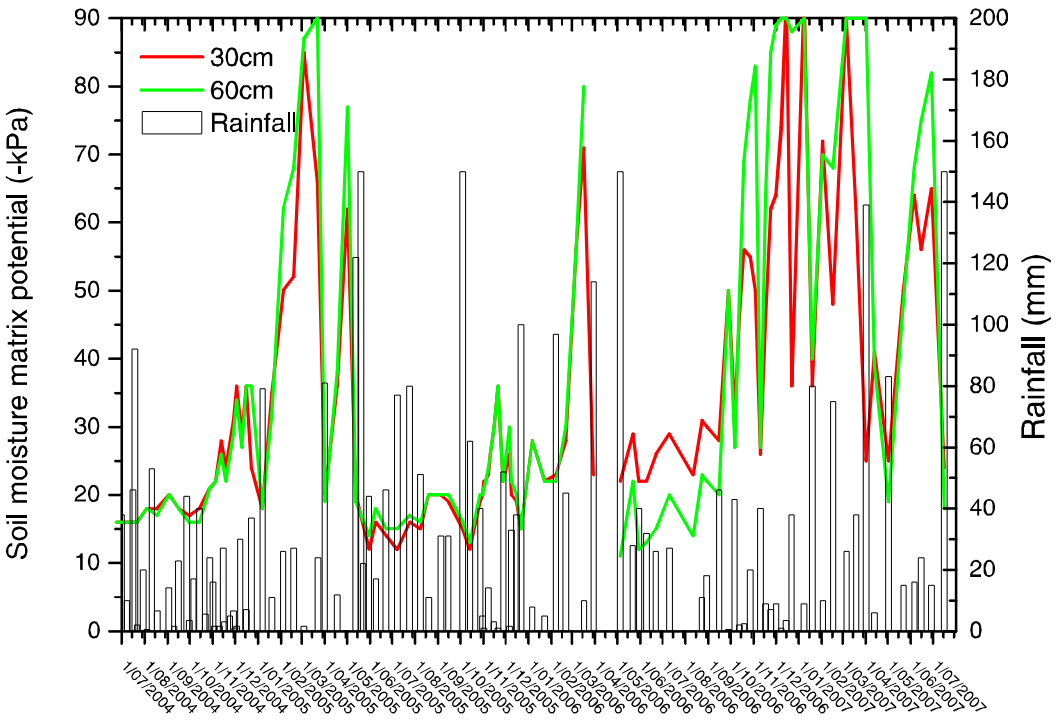

Figure 9. Soil moisture matrix potential at 30 and 60cm and rainfall for Orchard 2 2004-2007. The trees used in this study from this orchard were not irrigated.

moisture matrix potential at 60 cm generally followed the 30 cm soil moisture matrix potential in 2004 and 2005. In 2006 the soil at 60 cm depth generally had a lower soil moisture matrix potential than at 30 cm. Rain was relatively evenly spread throughout each year with the longest period where rain was absent of about 6 weeks at different times of the year (Figure 9). There was less rain in July 2006 to June 2007 than in the other two years. The total rainfall from July 2004

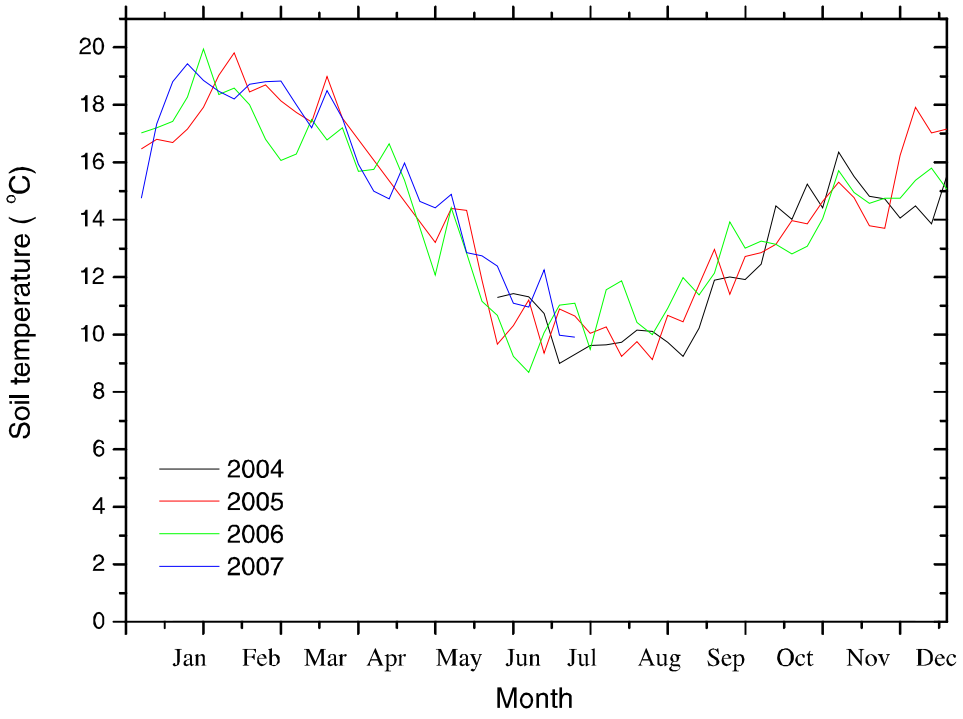

Figure 10. Average weekly soil temperature (100mm depth) for 'Hass' avocado trees in Orchard 2, 2004-2007.

to June 2005 was 1325mm, from July 2005 to June 2006 was 1400mm and July 2006 to June 2007 was 871mm.

Soil Temperature

The lowest soil temperatures were in June and July where the soil was on average 9°C but was often between 10 to 11°C (Figure 10). From August the soil temperature rose steadily until February when it reached 18 to 20°C. The general pattern of soil temperatures was similar each year.

DISCUSSION

The patterns of shoot and root growth were similar each year but there were differences in the timing and amount of growth between trees in different orchards and the "on" and "off" years. The most notable orchard differences were in the number of shoot flushes, three for orchard 1 and two for orchard 2, which may have been due to the use of irrigation. The trees in orchard 1 did not have a period of time in the year when the soil moisture

Table 1. Dates when the phenological events of spring flush and flowering occurred each year and the duration of the flush.

Orchard 1				
Spring flush	**Earliest shoots**	**Growth ceased**	**Duration of flush (days)**	**Range of growing days**
Year				
2004	5/10/2004	25/1/2005	73.5	47-100
2005	14/10/2005	23/12/2005	69.4	48-91
2006	11/10/2006	11/12/2006	61.6	44-79
Flowering	**First flower bud break**	**Average time of first open flowers**	**Flowering complete**	**Peak fruit number**
Year				
2004	6/10/2004	5/11/2004	16/12/2004	13/12/2004
2005	5/9/2005	28/10/2005	11/11/2005	No fruit
2006	15/9/2006	19/10/2006	8/12/2006	29/11/2006
Orchard 2				
Spring flush	**Earliest shoots**	**Growth ceased**	**Duration of flush (days)**	**Range of growing days**
Year				
2004	16/10/2004	22/1/2005	70.7	50-92
2005	13/10/2005	22/1/2006	66.6	43-89
2006	10/10/2006	30/1/2007	73.5	44-103
Flowering	**First flower bud break**	**Average time of first open flowers**	**Flowering complete**	**Peak fruit number**
Year				
2004	6/10/2004	5/11/2004	16/12/2004	8/12/2004
2005	4/10/2005	28/10/2005	28/11/2005	21/11/2005
2006	15/9/2006	16/10/2006	8/12/2006	17/11/2006

Table 2. Average number of flowers, maximum percentage fruit set and fruit number of determinate and indeterminate flowering shoots each year 2004 to 2006.

Orchard 1						
	Number of flowers		Maximum % fruit set		Maximum fruit number	
Year	D[1]	I[2]	D	I	D	I
2004	1074	854	5.6	8.7	38	42
2005	0	0	0.0	0.0	0	0
2006	887	401	8.2	5.7	64	21
Orchard 2						
	Number of flowers		Maximum % fruit set		Maximum fruit number	
Year	D	I	D	I	D	I
2004	260	242	17.4	17.7	45	39
2005	250	313	3.4	1.1	11	4
2006	1071	446	7.9	9.5	85	4

[1]*Determinate flowering shoot,* [2]*Indeterminate flowering shoot*

matrix potential was less than -30 kPa. The trees in orchard 2 tended to experience dry soil conditions (less than -50 kPa soil moisture matrix potential) over the main summer months, January and February, which could limit shoot and root growth (Lahav and Whiley, 2002). There were more roots at the soil mulch interface for orchard 1, this coupled with good soil moisture levels could have led to more growth as the availability of nutrients may have been greater than in orchard 2. This could explain why in orchard 1 there was a third shoot flush in autumn.

The start of the spring shoot flush varied but had about the same duration on both orchards indicating that in spring the trees in the non-irrigated orchard were not limited by soil moisture availability. The reason for the different starting time of the spring flush is not known but may be related to the weather and crop load on the tree over winter. The different times of the year when the spring shoot flush ceased varied from mid December to late January. The observation that the duration of shoot growth can differ has implications for when fertilizer applications need to be reduced or increased. Excessive shoot flush is undesirable and can be induced by fertilizer applications that exceed the trees requirements. Alternatively under fertilizing trees is also possible by stopping the fertilizer applications before shoot growth has stopped. A good spring flush is desirable for good flowering wood in the next spring. To obtain ideal fruiting wood the growth of the spring shoots need to be well supported by good nutrition applied at the right time.

Another major influence on the timing of some phenological events was whether the trees were in an "on" or "off" year in the alternate bearing cropping cycle. The growth of shoots and roots on the trees from spring 2005 through to the spring of 2006 was an example of an "off" year. The "on" years were spring 2004 to spring 2005 and spring 2006 to spring 2007. There were some aspects of the spring flush that were not affected by the alternate bearing cycle. They were: the time when spring shoots started to grow, the duration of the spring shoot growth and the duration of the spring shoot flush once flowering had finished. These are likely to be influenced most by the current nutrient status of the tree and weather conditions during spring rather than the previous phenology of the tree. The trees in an "on" year had reduced growth in shoots and roots compared to trees in the "off"

year. Most notably trees in the "off" year had fewer flowers, the time from flower bud break to the first open flower tended to be longer, a lower percentage of the flowers set fruit and the duration of flowering was much shorter than trees in the "on" years. This was not unexpected as there is a reduction in shoot growth when there is a heavy crop, the "on" year, which in turn leads to fewer flowers. This study has also identified that more than just the number of flowers and amount of shoot growth is affected. Not only are there fewer flowers open for a shorter time but fewer flowers set fruit in the "off" year compared to the "on" year. The reasons for this are not well understood and highlight the need for further research to identify the factors that are lowering the inherent capability of the trees to set fruit in the "off" year.

Recommended orchard management practices can only generalise the timing of when certain activities, like the onset of flowering, begin and end. That they vary from year to year and can vary from orchard to orchard indicates that there would be an advantage for avocado growers or orchard managers to more closely follow the growth cycles on their trees. The differences between orchards in when phenological events happen could also explain why even orchards side by side can appear to need management inputs at different times. A better understanding of how much the time when spring flush starts can change from the previous year should allow avocado growers to better manage their trees.

CONCLUSIONS

The patterns of shoot and root growth were similar each year but there were differences in the timing and amount of growth between trees in different orchards and the "on" and "off" years. Irrigated trees appeared to have three shoot flushes a year compared to two shoot flushes for non-irrigated trees. The greatest differences in phenology were between trees in "on" and "off" years of the alternate bearing cycle. The greatest effect was on shoot growth and flowering where in the "off" year there were fewer flowers and a lower inherent capacity to set fruit.

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