Flower manipulation with Ralex to increase fruit size and even out alternate bearing of citrus

Dr Tahir Khurshid
NSW Department of Primary Industries

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Flower manipulation with Ralex® to increase fruit size and even out alternate bearing of citrus

Tahir Khurshid

Know-how for Horticulture™

NSW DEPARTMENT OF PRIMARY INDUSTRIES

Project CT03026: Flower manipulation with Ralex® to increase fruit size and even out alternate bearing of citrus

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This report describes the results of the bud responses of navel orange trees to a new plant growth formulation (Ralex®) in terms of flower suppression to adjust early crop load to optimise fruit size at harvest.

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September 2005

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Media Summary

Fruit size is the most important production issue facing citrus growers in domestic markets and particularly in export markets. Market returns are directly linked to fruit size with most markets preferring fruit in the larger size classes. Crop load manipulation can be used to overcome smaller fruit size and alleviate the problems of alternate bearing. Ralex®, a gibberellic acid (GA_3) based formulation (a product of Valent BioSciences) offers a means of crop load manipulation via flower suppression. Bud responses to different Ralex® rates and timings for flower suppression were studied for two seasons. Experiments were carried out on Washington navel, Navelina, Bellamy (Washington) navel and Barnfield navel trees. Ralex® was applied to individual trees in an "on-flowering" year 2003 at four different rates (0 ml, 100 ml, 150 ml, or 200 ml/100 L) and at five different timings ranging from early May to late July during first and second sensitivity peaks. The sensitivity peaks refer to the ability of developing buds to be influenced by treatments.

The results indicated that higher rates of Ralex® caused flower reduction by targeting the leafless inflorescence. The best rate identified was 150 ml/100 L when applied around mid June. This rate produced a higher percentage of fruit in large (77-87 mm) size class at harvest compared to the control treatment. Ralex® treatments were also applied to a new set of individual trees in an "off-flowering" year at four different Ralex® rates (0 ml, 100 ml, 150 ml, or 200 ml/100 L) and at three different timings ranging from late May to late June targeting the buds during first sensitivity peak. Results indicated a strong reduction in flowering, although there were not any fruit size benefits at harvest when Ralex® was applied in an "off-flowering" year.

There were no biennial bearing effects found after Ralex® use after two years of study. Ralex® effects on fruit skin colour were also assessed in a different set of trials in early, mid and late maturing cultivars. So far there was no colour delay indicated when Ralex® was applied around late May or early June periods at a 50% skin colour stage. There was an indication of effect on fruit firmness when fruit were observed visually, but these effects need further investigation as they were not part of this project. Some of the results have been published in scientific journals and conference proceedings. Results of the project have been extensively reported at Cittgroup meetings, field day, farm walks and in national and international conferences.

<u>Key outcomes:</u>

1. Ralex® can be applied at 150 ml/100 L around mid June (approx. 4-6 weeks) before bud break. Therefore, the use of Ralex® in first sensitivity peak is recommended.

2. Investigations on fruit colour trials revealed no skin colour delay affects at harvest with Ralex® use if applied during late May-June periods or at 50% colour stage.

3. Ralex® gave positive effects on skin colour with higher percentage of yellow coloured fruit compared to untreated fruit. Ralex® effects for rind quality needs urgent attention for further research.

4. Ralex® application can eliminate alternate bearing problem across two growing seasons. Return fruit size data indicated the potential benefits of Ralex® treatment. Final yields were very similar across two years.

5. Results of this project did not suggest any benefits of fruit size increases at harvest after Ralex® application in an "off-flowering" year. Therefore, Ralex® application is not recommended in an anticipated "off-flowering" year.

6. A permit (PER8269) is now in place (22 June 2005- 30 September 2007) for a limited use of Ralex® for research purposes. Sumitomo Chemical Australia can be contacted to obtain further information.

Technical Summary

Fruit size is the most important production issue facing citrus growers in domestic markets and particularly in export markets. Market returns are directly linked to fruit size with most markets preferring fruit in the larger size classes. Crop load manipulation can be used to overcome smaller fruit size and alleviate the problems of alternate bearing. There are a range of crop load management practices available which are being used by the citrus growers. However, flower suppression (not flower thinning) is one of the management strategies that can be used very early in the season. Flower suppression is possible 4-6 weeks before bud break and in this way carbohydrate budgets can be saved instead of getting consumed in the flower development and fruit set processes. However, flower suppression has not been used for crop load manipulation in navel oranges. The aim of this project was to use flower suppression as one of the management strategies to manipulate flowering very early in the season and to enhance the pack out of large size fruit at harvest. Ralex® (GA_3-based formulation, a product of Valent BioSciences) was used as a tool to perform the task of flower manipulation in this project.

Ralex® application in "on-flowering" year:
Bud responses to different Ralex® rates and timings for flower suppression were studied for two growing seasons. Experiments were carried out on Washington navel, Navelina, Bellamy (Washington) navel and Barnfield navel in an anticipated "on-flowering" year. Ralex® was applied to individual trees in 2003 at four different Ralex® rates (0 ml, 100 ml, 150 ml, or 200 ml/100 L) and at five different timings (6 May, 20 May, 4 June, 18 June, or 21 July). The reason for five applications was to cover the first and second sensitivity peaks. The data indicated that higher rates were able to cause flower reduction by reducing the leafless inflorescence up to 50%. The best rate identified was 150 ml/100 L when applied around mid June under Sunraysia conditions. This rate produced 30%-60% of fruit in large (77-87 mm) size class at 2004 harvest in different cultivars. These trees were left untreated for another year and return flowering and yield data was recorded for another season. The results indicated that there were no biennial bearing in fruit yield across two years. This was due to higher percentage of leafy inflorescences which remained stable for two years after 2003 Ralex®application.

Ralex® application in "off-flowering" year:
Ralex® treatments were also tested in an anticipated "off-flowering" year. Ralex® treatments were applied at four different Ralex® rates (0 ml, 100 ml, 150 ml, or 200 ml/100 L) and at three different timings (20 May, 15 June, or 30 June) to target the buds during the first sensitivity peak. Results indicated a strong reduction (> 50%) in flowering with 150 ml/100 L applied in mid June. However, flower reduction did not produce fruit of larger size at harvest. In addition to that a higher percentage of vegetative shoots were produced in spring. Based on these results Ralex® is not recommended for flower suppression in an anticipated "off-flowering" year.

Ralex® effects on alternate bearing and fruit colour:
In this project the experimental trees which received Ralex® application in 2003 were left untreated for a second year to assess the return flowering behaviour and their subsequent effects fruit size responses for another year. This exercise was regarded as important to

evaluate the possible alternate bearing effect after Ralex® use. In Washington navel, fruit yield were higher by 26% due to higher percentage of large sized fruit in 2005, even though it was an "off-flowering" year. In 2005 growing season climatic conditions were optimum. Fruit set was better due to lower flower number and optimum fruit growth also played a key role on this site. There was no alternate bearing effect evidenced after Ralex® use. The return year (2005) produced slightly more (4%) large sized fruit than 2004, while yields were higher in 2005 by 20% compared to 2004. No obvious alternate bearing effects were noticed across two growing seasons in fruit yields.

A separate set of experiments were also conducted to assess the effects of Ralex® use on colour delay in navel oranges. A range of early, mid and late maturing navel cultivars Early Ryan, Washington navel, Bellamy (Washington) navel, Lane Late and Barnfield navel were selected. Ralex® was applied to individual fruits at different stages of colour development. At harvest the percent surface colour (soft green, hard green, yellow or orange) of individual fruit was recorded subjectively. Results indicated no colour delay effects when Ralex® was used at 50% colour stage and this colour stage coincided with May-June periods. June is a recommended period for Ralex® use to suppress flowers.

Key Outcomes:

1. Ralex® can be applied at 150 ml/100 L around mid June (approx. 4-6 weeks) before bud break. Therefore, the use of Ralex® in first sensitivity peak is recommended.

2. Investigations on fruit colour trials revealed no colour delay at harvest with Ralex® use if applied during late May-June periods or at 50% colour stage.

3. Ralex® application can eliminate alternate bearing problem across two growing seasons. Return fruit size data indicated the potential benefits of Ralex®. Final yields were very similar across two years.

4. Study in this project did not suggest any benefits of fruit size increases at harvest after "off-flowering" year application. Ralex® application is not recommended in an anticipated "off-flowering" year.

5. A permit (PER8269) is now in place (22 June 2005-30 September 2007) for a limited use of Ralex® for research purposes. Sumitomo Chemical Australia can be contacted to obtain further information.

6. A part of the data has been published in scientific journals and conference proceedings. Results of the project have been extensively reported at Cittgroup meetings, field day, farm walks and in national and international conferences.

Future research:

1. Results indicated a positive effect of Ralex® on skin colour. Higher percentages of the treated fruits were in yellow colour (a sign of improved rind quality) at harvest. Ralex® effects for rind quality need further research.

2. Ralex® may substitute for May/June GA_3 application without delaying the colour at harvest. Further research is needed to explore this possibility.

1. General Introduction

Project Background

Fruit size is an imperative crop management issue for citrus growers, packers and marketers. Fruit size is the single most important factor determining market returns. Although exact requirements vary between markets, in most domestic and export markets there is an obvious preference for fruit in larger size counts. Small fruit has limited demand and is difficult to sell in domestic and especially in export markets, i.e. USA. Depending on cultivar, as little as 10-30% of the crop can reach the desired large (> 72 mm) size range in heavy crop years, while 30-60% of the crop can fall into the unwanted small (<65mm) size category. Although in light crop years up to 60-80% of the crop of Washington navel and late navel varieties can reach the preferred size range with negligible production of small fruit, overall yields are low. Due to changes within the citrus industry, diverting large volumes of small fruit to juice outlets, especially navel oranges, is not a viable alternative. So it is essential to manipulate crop load to ensure favourable fruit size outcomes, and reasonable yields.

Crop manipulation is one of the management strategies used to adjust crop load at various phenological stages during the growing season. Flower suppression (not flower thinning) is the first and most important management strategy in the growing season which can be used to control crop load very early in the season around May-July before the emergence of the flowers occur.

Gibberellic acid (GA_3) has been widely reported to be an effective inhibitor of flowering in citrus (Davenport, 1983; Davenport, 1990; Guardiola et al., 1982; Koshita et al., 1999; Stover and Albrigo, 2001). Therefore, GA_3 can be used as a management tool to adjust crop load via flower suppression. In addition to potential effects on crop load through reduced flower numbers, GA_3 application also results in an increased proportion of leafy inflorescences and vegetative shoots (Iwahori and Oohata, 1981). Leafy inflorescences can bear larger size fruit than leafless inflorescences (Khurshid and Bevington, 2001). On the other hand, vegetative shoots can provide potential flowering sites for next season's flowering. Previously, GA_3 has been used to reduce the number of purely generative shoots or leafless inflorescences in citrus (Garcia-Luis et al., 1988). Gibberellin has also been reported to reduce flowering by suppressing bud sprouting (Garcia- Luis et al., 1986). However, GA_3 is not consistent in flower suppression and its use is not viable because it delays rind colour and interfere with the harvest.

Ralex® is a GA_3-based formulation and it has been used in other fruit crops for flower suppression. Ralex® is an important formulation that makes it synthetically different from a simple GA_3 solution. In Chile, Ralex® has been reported to reduce peach flowering by 50% and enhance fruit size (Lemus, 1998). In South Africa, Ralex® has been used to reduce bud density in 'Sunlite' nectarines (Coetzee and Theron, 1999). However, to our knowledge Ralex® has never been used to suppress flowers in navel oranges.

Fruit size in navel oranges is a major issue for the citrus industry in export markets as mentioned earlier. Year to year variability in fruit load is responsible for poor fruit size in an "on-flowering" year, while in an "off-flowering" year small numbers of large sized fruit are produced. This project will provide the citrus industry with the recommendations to optimise the use of Ralex® for crop load manipulation at an early stage of flower initiation or differentiation. This will allow growers to even out the alternate year cropping pattern, thereby providing a reliable annual production of optimum size fruit.

The aim of this project was to use the growth regulator Ralex® to adjust fruit load very early in the season of heavy crop years (referred to as an "on-flowering" year). The term "off-flowering" is used to refer to the year following a heavy crop load. Flower suppression will prevent diversion of the tree's carbohydrate resources to large numbers of smaller fruit, instead allowing fewer fruit to achieve optimum commercial sizes. The adjustment of the early fruit load by reducing flower numbers in an "on-flowering" year will also have a strong carryover effect of more bud development for the following "off-flowering" year, thus evening out the crop load between years. Timing of Ralex® applications is known to be critical, so in the experiments carried out during this project Ralex® was applied at different growth stages to identify the most appropriate timings and application rates.

Project Objectives:

The main objectives of this project were to identify the most effective Ralex® rate and time of application for flower suppression and its effects on yield and fruit size at harvest. Crop load manipulation in one year can interfere with next year's crop and hence cause the problem of alternate bearing. In addition to that Ralex® may delay fruit colour development if applied earlier in the season. Therefore, the project objective considered the issue of alternate bearing and colour delay effects before the final recommendation for Ralex® use could be made. Keeping in view these mentioned factors the expected outcomes sought from the project were as follows.

- **Refined recommendations for Ralex® use to manipulate flowering in citrus**

Currently there is no available information on Ralex® use to form a basis for firm recommendations for flower suppression and fruit size optimisation in navel oranges. The data generated from the current study will form the basis for Ralex® use in specified navel cultivars studied in this project.

- **Modification of product label recommendations for use of this product for oranges**

Ralex® is registered in Australia for its use in mandarins. Valent BioSciences is seeking label change for its use in navel oranges. The data generated from the study carried out in this project will be available to Valent BioSciences for product registration.

- **A better understanding of the Ralex® use on the return flowering and alternate bearing pattern**

Reducing fruit crop in the current year can increase crop next year causing a problem of alternate bearing. Alternate bearing has been widely documented in oranges and in a range of other fruit crops. The issue of alternate bearing was assessed in the course of this project in Ralex® treated versus untreated trees.

- **To determine the likely colour delay issues with Ralex® use on the current crop**

Generally Gibberellic acid (GA_3) application has the ability to delay rind colour development from days to weeks depending on time of application and concentration of GA_3. GA_3 application during colour break can delay rind colour up to 2-3 weeks.

However, GA_3 application at later stages will have minimum effects on rind colour delay (Ken Bevington, pers. comm.). Ralex® is a GA_3 based formulation (40 g/L GA_3) and it may delay rind colour if used during first or second sensitivity peak between May-July periods. Colour delay effects were also assessed in this project.

2. Ralex® application in "on-flowering" year and its effect on subsequent flower suppression, yield and fruit size distribution in navel oranges

Introduction:

Gibberellic acid (GA_3) has been widely reported to be an effective inhibitor of flowering in citrus. Properly timed application of GA_3 can reduce flowering by causing the reversion of floral buds to vegetative shoots (Lord and Eckard, 1987). The primary effect of GA_3 on flowering is to reduce the number of purely generative shoots or leafless inflorescences produced (Garcia-Luis et al., 1988). Thus in addition to potential effects on crop load through a reduction in flower number, GA_3 application can also result in an increased proportion of leafy inflorescences if applied during high bud sensitivity period.

There are generally two peaks of bud sensitivity to GA_3 that have been identified in citrus (Guardiola et al., 1982). The first peak coincides with floral initiation which occurs in May-June in the southern hemisphere. The second peak of sensitivity coincides with floral differentiation of floral primordia and occurs just before or at bud burst in July. The application of GA_3 to the buds must be made prior to irreversible commitment to flowering to be effective (Lord and Eckard, 1987). Once the bud has gone past sepal formation stage during the second sensitivity peak, the reversion of flowering primordia to vegetative primordia is not possible.

Ralex® is a GA_3-based formulation that can be used for flower suppression (not flower thinning) in citrus. Preliminary trials in Queensland on mandarins have shown that Ralex® can significantly reduce flowering by 62% in 'Imperial' and by 68% in 'Honey Murcott' mandarins when applied at a rate of 200 ml/100 L between June and July (Peter Wishart, pers. comm.). At the present time, Ralex® is the only GA_3-based formulation registered in Australia for flower suppression in citrus. Currently, this registration only applies to mandarins but registration is being sought for oranges. Ralex® has not been tested previously for flower suppression in navel oranges under Sunraysia growing conditions. The objective of this experimental program was to undertake an assessment of the effectiveness of Ralex® for regulating flowering in navel oranges and to evaluate its subsequent effects on yield and fruit size distribution at harvest.

Materials and Methods:

The experimental program was started in an anticipated "on-flowering" year. On-flowering year was determined due to the lower fruit number/tree in the experimental block. A range of experiments were conducted in 2003 on different navel cultivars. These experiments were conducted at the Agricultural Research and Advisory Station, Dareton on 14-year-old Bellamy/*Poncirus trifoliata* and on 10-year-old Navelina/Troyer citrange and at a commercial grower's property at Dareton on 38-year-old Washington navel/Sweet orange trees. Ralex® treatments (control, 100 ml, 150 ml or 200 ml/100 L) were applied to the trees during the first and second sensitivity peaks. Ralex® was applied in 2003 at five different timings (6 May, 20 May, 5 June, 15 June and 21 July). Six single tree replicates were allocated to each treatment giving a total of 120 trees for Washington navel and 120 trees for Navelina navel. In Bellamy navel (a nucellar selection of Washington navel) trees were sprayed with four Ralex® treatments (control, 100 ml, 150 ml or 200 ml/100 L) on 15 June or 21 July 2003 (estimated to coincide with the two periods of sensitivity). Five single tree replicates were allocated to each treatment giving a total of 40 trees. All trees were individually sprayed with a hand-held sprayer to the point of run-off. Ralex® was applied around mid-day on a sunny and calm day. Maximum temperature at the time of spray application was 13-15 ^{0}C.

Data Collection and statistical analysis:

Methodology for data collection:

Flowering data in Washington navel, Navelina and Bellamy navel trees were recorded during September 2003 (the year of Ralex®application). Different type of inflorescences (see definition below) and vegetative shoots were recorded. Total number of inflorescences and vegetative shoots were counted in 0.5 X 0.5 m^2 (0.125 m^3) cubic counting frame at the mid point of the canopy. The counting frame was placed four times around the tree canopy. Data on return (next year) flowering was also recorded during September 2004 by using the above procedure. All experimental trees received normal irrigation and nutrition according to the commercial orchard practices applied in this district during the course of this project.

Definition of terms:

There are different types of inflorescence found on a citrus tree. (1) Leafless inflorescence - one or many flowers and no leaves. Leafless inflorescences are not a desirable type because it produces a smaller sized fruit than leafy inflorescence or solitary terminal inflorescence. (2) Leafy inflorescence - this type consists of many flowers and many leaves. Fruit born of this type has a larger fruit than leafless inflorescence (3) Solitary terminal inflorescence - this type has only one flower and many leaves. Fruit born on this type usually grows larger than leafless or leafy inflorescences. (4) Vegetative shoots - this is not a type of inflorescence but it is a well defined vegetative shoot (spring flush) which is a potential site for next year flowering (Figure 2.1).

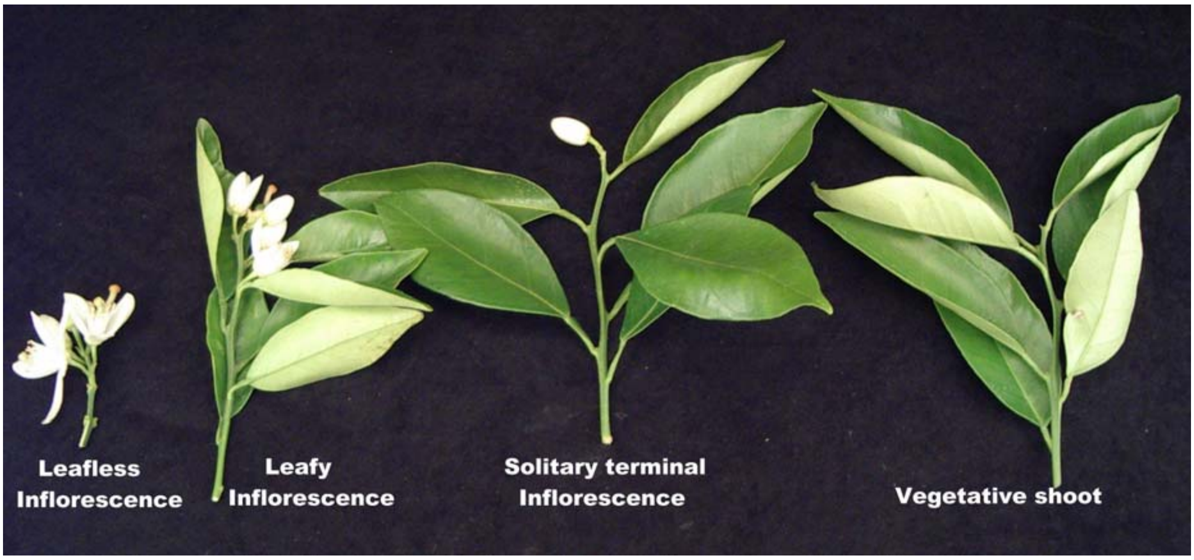

Figure 2.1: Different types of inflorescences and vegetative shoot, born on an orange tree

Harvest and fruit size distribution:

Harvest of individual trees was carried out in 2004 and 2005. Total fruit weight, number of fruit per tree and fruit size distribution was recorded on each experimental tree at harvest for two consecutive years using a commercial grader (Colour Vision Systems Pty. Limited). Fruit were sorted into five size classes based on fruit diameter (mm). The size classes were <65 mm (>138 fruit/carton), 65-67 mm (138-125 fruit/carton), 69-72 mm (113-100 fruit/carton), 75-77 mm (88 fruit/carton) and >77 mm (<80 fruit/carton).

Statistical analysis:

The total number of leafless inflorescences, leafy inflorescences, solitary terminal inflorescences and vegetative shoots was recorded in each counting frame. Then the percent contribution of each inflorescence type and vegetative shoots was calculated and subjected to analysis of variance (ANOVA) using the statistical software package Genstat 8. Treatment means were tested with least significant differences (LSD) at 5% level of significance. For the purpose of this report the data for leafy inflorescences and solitary terminal inflorescences (both leafy types) were pooled and referred to as mixed inflorescences. The data presented below are for leafless inflorescences, mixed inflorescences and vegetative shoots for the three different experiments.

Results:

Experiment 1: Washington navel

Trees in this trial were 38-year old and had an average height of 3 meters. Most of the trees in the Sunraysia district are larger and older.

Flowering and Yield components 2003/2004 season

Flowering components:

Leafless Inflorescences: The data indicated that there was a significant effect of different Ralex® timings in reducing the leafless inflorescences (Table 2.1).

Table 2.1: Effect of different Ralex® rates and timing of application on different inflorescence types and vegetative shoots in Washington navel orange trees for 2003

	Treatments	Percent leafless inflorescences	[A]Percent mixed inflorescences	Percent vegetative shoots
Timings	6 May	45.9	30.4	23.7
	20 May	38.8	30.7	30.5
	4 June	42.0	30.0	27.8
	18 June	43.9	29.9	26.1
	21 July	45.6	33.9	20.5
	Lsd (5%)	**5.8**	**ns**	**5.1**
Rates	Control	50.7	30.2	19.1
	100 ml/100 L	39.0	31.7	29.2
	150 ml/100 L	41.1	30.6	28.3
	200 ml/100 L	42.2	31.5	26.3
	Lsd (5%)	**5.1**	**ns**	**4.6**
Timings*Rates		***	ns	***

[A]Percentage of total (leafy and solitary terminal) inflorescences

***P<0.001; ns, not significant

Lsd (Least significant difference) is used to compare the treatment means within the columns

Ralex® applied on 20 May reduced the leafless inflorescences by 13% compared to the average value of all other application times (Table 2.1). Generally all Ralex® rates were effective in reducing leafless inflorescences by 20% as compared to control (Table 2.1).

There was a significant interaction effect across Ralex® (timings*rates). The data suggested that Ralex® at 100 ml/100 L rate was able to reduce the leafless inflorescences by 30% as compared to control when applied on 6 May (Table 2.2). At the later dates of 20 May, 4 June or 18 June, the higher rates (150-200 ml/100 L) were required to be able to control flowering when compared to their respective controls. However, the highest (51%) flower reduction was achieved with 200 ml/100 L rate on 20 May treatment. Ralex® applied at the later date of 21 July was not effective in reducing the inflorescence number (Table 2.2).

Table 2.2: Interaction effect of Ralex® (Timing*Rates) on percent leafless inflorescences in Washington navel trees for 2003

	Control	100 ml/100 L	150 ml/100 L	200 ml/100 L
6 May	50.7	35.4	48.4	49.1
20 May	57.2	34.9	35.4	27.8
4 June	52.2	39.9	36.9	39.4
18 June	52.3	43.7	35.2	44.4
21 July	41.2	41.4	49.5	50.2
Lsd (5%) **11.5**				

Mixed inflorescences: There were no significant effects of Ralex® timings or rates on reducing mixed inflorescences (Table 2.1).

Vegetative shoots: Vegetative shoots are potential sites for next year flowering and it is expected that Ralex® would convert the flowering inflorescences to vegetative shoots in order to decrease the overall flowering. Ralex® rates on average significantly increased the number of vegetative shoots by 46% compared to control (Table 2.1). There was a significant timing effect on vegetative shoots. Ralex® treatments applied in May/June generally had more vegetative shoots as compared to treatments applied on 21 July (Table 2.1). A significant interaction effect across Ralex® (timings*rates) suggested that Ralex® at 100-150 ml/100 L had more vegetative shoots when applied in May/June period as compared to 21 July application. The highest percentages of vegetative shoots were obtained with Ralex® @ 200 ml/100 L applied on 20 May (Table 2.3).

Table 2.3: Interaction effect of Ralex® (Timing*Rates) on percent vegetative shoots in Washington navel trees for 2003

	Control	100 ml/100 L	150 ml/100 L	200 ml/100 L
6 May	18.1	32.5	22.4	21.9
20 May	12.9	34.9	30.6	43.4
4 June	22.1	29.6	35.2	24.5
18 June	14.5	28.7	34.4	26.7
21 July	28.1	20.1	18.8	14.9
Lsd (5%) **10.3**				

Yield components:

The data indicated that the Ralex® timing effect was not significant on fruit size increase for 2004 harvest. Ralex® rate at 150 ml/100 L had a significant increase on fruit size distribution by 9% (Table 2.4). An interaction effect which was not significant suggested that there was a 20% increase in the fruit size (77-87 mm) compared to control when Ralex® was applied on 20 May 2003 (data not presented). It still indicates a trend for an increase percentage in the export class oranges. This increase was also evidenced by a significant effect of fruit weight (209.3 g) with medium Ralex® rate as compared to 200.9 g in control trees (Table 2.4). Overall these results indicated that flower suppression with Ralex® use in "on-flowering" years lead to an increase in fruit size without any yield losses.

Table 2.4: Effect of Ralex® application in 2003 on percent large fruit size, fruit yield/tree and mean fruit weight of Washington navel oranges for 2004

	Treatments	Percent large fruit size (77-87 mm)	Fruit yield/tree (kg)	Mean Fruit weight (g)
Timings	6 May	55	77.0	206.5
	20 May	58	80.0	210.5
	4 June	54	77.7	201.3
	18 June	54	78.3	205.4
	21 July	55	76.5	204.9
	Lsd (5%)	**ns**	**ns**	**ns**
Rates	Control	52	73.7	200.9
	100 ml/100 L	55	81.2	205.4
	150 ml/100 L	57	77.1	209.0
	200 ml/100 L	56	79.6	207.6
	Lsd (5%)	**3.9**	**ns**	**5.7**
Timings*Rates		ns	ns	ns

ns, not significant

Lsd (Least significant difference) is used to compare the treatment means within the columns

Flowering and Yield components 2004/2005 season

Flowering components:

Return flowering behaviour, return fruit yield and fruit size distribution was recorded in Washington navel for 2004/2005 season. These trees did not receive any further Ralex® application after winter 2003.

In Washington navel trees the total flowering percentage was determined irrespective of any specific type of inflorescences for the following year after Ralex® application (Table 2.5). There were no significant differences found among any timings or Ralex® rates as compared to control on percentage inflorescences the year following application (Table 2.5).

Table 2.5: Effect of different Ralex® rates and timing of application in 2003, on percent flowering and vegetative shoots in Washington navel orange trees for 2004

	Treatments	[A]Percent inflorescences	Percent vegetative shoots
Timings	6 May	21.9	65.1
	20 May	20.0	66.2
	4 June	20.2	64.6
	18 June	21.0	67.1
	21 July	19.6	65.0
	Lsd (5%)	**ns**	**ns**
Rates	Control	20.0	66.8
	100 ml/100 L	21.2	65.8
	150 ml/100 L	21.5	65.2
	200 ml/100 L	19.5	64.5
	Lsd (5%)	**ns**	**ns**
Timings*Rates		ns	**

[A]Percentage of total inflorescence (leafless, leafy and solitary terminal)
**P<0.01; ns, not significant
Lsd (Least significant difference) is used to compare the treatment means within the columns

Yield components:

The data from return crop harvested in June 05 indicated that there were no significant differences in proportions of bigger fruit for Ralex® timings or Ralex® rates applied 2003. Fruit yield/tree effect was significant for Ralex® application timings, but effects varied inconsistently with time of applications (Table 2.6). In terms of Ralex® rates the only significant rate was 200 ml/100 L as compared to control for yield increases of 14%. There was an overall increase of 23 percent yield in 2005 for 150 ml/100 L rate. This was not significant enough to constitute an alternate bearing problem as fruit yield was higher due to heavier fruit in 2005 as compared to fruit weight of 2004 @ 150 ml/100 L.

Table 2.6: Effect of Ralex® application in 2003 on percent large fruit size (77-87 mm), fruit yield and mean fruit weight of Washington navel oranges for 2005

	Treatments	Percent fruit size (77-87 mm)	Fruit yield/tree (kg)	Mean Fruit weight (g)
Timings	6 May	56	99.6	222.6
	20 May	58	105.5	224.2
	4 June	56	94.1	229.6
	18 June	58	101.1	228.7
	21 July	55	90.1	234.2
	Lsd (5%)	**ns**	**8.6**	**ns**
Rates	Control	56	93.2	229.1
	100 ml/100 L	56	97.7	226.0
	150 ml/100 L	58	95.4	233.4
	200 ml/100 L	56	106.2	223.1
	Lsd (5%)	**ns**	**7.7**	**5.7**
Timings*Rates		ns	ns	ns

ns, not significant
Lsd (Least significant difference) is used to compare the treatment means within the columns

Experiment 2: Navelina navel

Navelina is an earlier maturing cultivar than the Washington navel cultivar. Trees in this trial were 10-year-old at the time of Ralex® application with an average height of 2 meters.

Flowering and Yield components 2003/2004 season

Flowering components:

Leafless Inflorescences: Data collected on leafless inflorescences indicated a significant timing effect and leafless inflorescences were decreased by 16% for May/June application as compared to July application (Table 2.7). The data indicated that there was a significant effect of Ralex® rates in reducing leafless inflorescences by 29%, 31% and 42% for 100 ml, 150 ml and 200 ml/100 L rate respectively as compared to the control (Table 2.7).

Table 2.7: Effect of different Ralex® rates and timing of application on different inflorescence types and vegetative shoots in Navelina orange trees for 2003

	Treatments	Percent leafless inflorescences	[A]Percent mixed inflorescences	Percent vegetative shoots
Timings	6 May	31.1	39.3	29.6
	20 May	31.8	39.2	29.0
	4 June	32.7	37.9	29.4
	18 June	34.9	38.1	26.9
	21 July	39.1	41.7	19.2
	Lsd (5%)	**3.84**	**2.7**	**3.8**
Rates	Control	45.5	37.9	16.6
	100 ml/100 L	32.2	41.2	26.5
	150 ml/100 L	31.4	38.3	30.3
	200 ml/100 L	26.6	39.4	34.0
	Lsd (5%)	**3.11**	**2.4**	**3.39**
Timings*Rates		*	**	*

[A]Percentage of total (leafy and solitary terminal) inflorescences
*P<0.05; **P<0.01; ns, not significant
Lsd (Least significant difference) is used to compare the treatment means within the columns

An interaction effect suggested that Ralex® (100-150/100 L) was better to reduce flowering in May/June as compared to 21 July application; however, the effects of 200 ml/100 L applied on 6 May was stronger in reducing leafless inflorescences (Table 2.8).

Table 2.8: Interaction effect of Ralex® (Timing*Rates) on percent leafless inflorescences in Navelina navel trees for 2003

	Control	100 ml/100 L	150 ml/100 L	200 ml/100 L
6 May	45.7	29.6	31.5	17.5
20 May	42.6	28.9	30.6	24.9
4 June	43.7	30.8	30.8	25.4
18 June	48.7	34.8	28.1	28.3
21 July	46.9	36.9	35.7	36.8
Lsd (5%) **7.0**				

Ralex® treatment at 200 ml/100 L applied on 6 May significantly reduced leafless inflorescences by 62% as compared to control. Ralex® in this trial was less effective when applied on 21 July. A similar effect was previously indicated in Washington navel trees (experiment 1).

Mixed inflorescences: Timing of Ralex® applications had a significant effect and the latest date 21 July had more mixed inflorescences compared to May/June timings. Generally, mixed inflorescences were slightly higher in Ralex® treated trees as compared to control (Table 2.7). A significant interaction effect for Ralex® (timings*rates) suggested that Ralex® at 100 ml/100 L rate was able to increase mixed inflorescences in early and late May applications (Table 2.9). Mixed inflorescences were also increased with 100 ml/100 L and 150 ml/100 L rates applied on 18 June. After 18 June Ralex® rates did not have any significant effects on increasing the mixed inflorescences.

Table 2.9: Interaction effect of Ralex® (Timing*Rates) on percent mixed inflorescences in Navelina navel trees in 2003

	Control	100 ml/100 L	150 ml/100 L	200 ml/100 L
6 May	37.6	41.5	38.4	39.7
20 May	38.3	45.6	34.4	38.6
4 June	38.8	39.7	34.7	38.3
18 June	34.4	41.4	40.1	36.6
21 July	40.5	38.1	44.2	43.9
Lsd (5%) **5.4**				

Vegetative shoots: Generally vegetative shoots were significantly increased with May/June application of Ralex® as compared to July application. There was a significant linear increase in vegetative shoots with Ralex® rates (Table 2.7). A significant interaction effect for Ralex® (timings*rates) suggested that Ralex® at 200 ml/100 L rate as compared to control was able to produce larger numbers of vegetative shoots when applied on 6 May (Table 2.10).

Table 2.10: Interaction effect of Ralex® (Timing*Rates) on percent vegetative shoots in Navelina navel trees for 2003

	Control	100 ml/100 L	150 ml/100 L	200 ml/100 L
6 May	16.7	28.9	30.1	42.8
20 May	19.2	25.5	35.1	36.5
4 June	17.5	29.5	34.5	36.3
18 June	16.9	23.8	31.8	35.2
21 July	12.5	24.9	20.1	19.2
Lsd (5%) **7.6**				

Yield components:

Percent large fruit size (77-87 mm, diameter): Fruit harvest was carried out in June 2004 for each experimental tree for its yield per tree, mean fruit weight and fruit size distribution. Data in Table 2.11 indicated that there was a significant effect of Ralex® rates on percent fruit size (77-87 mm) at harvest. Ralex® at 150 ml/100 L gave an increase in fruit size by 26% as compared to control. A significant interaction effect indicated (data not presented) that trees produced 61% large sized fruit compared to control with 150 ml/100 L applied on 18 June.

Fruit yield per tree (kg): Effect of Ralex® timing did not alter the total yield/tree. However, yield was significantly increased by 22% with 150 ml/100 L rate of Ralex® application as compared to control (Table 2.11).

Mean fruit weight (g): Individual fruit weight was generally increased by 10 g with 150 ml/100 L rate as compared to control (Table 2.11). However, this fruit gain was 33 g with 150 ml/100 L when applied on 18 June as indicated by a significant interaction effect (data not shown).

Table 2.11: Effect of Ralex® application on percent large fruit size (77-87 mm), yield/tree and meanl fruit weight of Navelina oranges for 2004

	Treatments	Percent fruit size (77-87 mm)	Fruit yield/tree (kg)	Mean Fruit weight (g)
Timings	6 May	44	49.5	187.0
	20 May	40	48.9	182.9
	4 June	46	53.2	187.5
	18 June	47	48.3	190.3
	21 July	46	44.6	187.5
	Lsd (5%)	**ns**	**ns**	**ns**
Rates	Control	38	44.5	179.5
	100 ml/100 L	47	45.2	188.5
	150 ml/100 L	48	54.4	190.7
	200 ml/100 L	46	51.5	189.5
	Lsd (5%)	**7.1**	**5.9**	**7.5**
Timings*Rates		**	ns	**

**P<0.01; ns, not significant

Lsd (Least significant difference) is used to compare the treatment means within the columns

Flowering and Yield components 2004/2005 season

Flowering components:

Return flowering behaviour, return fruit yield and fruit size distribution was recorded in Navelina navel for 2004/2005 season. These trees did not receive any further Ralex® application after winter 2003.

Leafless inflorescences: The return flowering data was collected in Navelina orange trees in September 2004. The data analysis indicated that the percentage of leafless inflorescences was not significantly affected by Ralex® timings (Table 2.12). However, Ralex® rates at 100 ml/100 L caused a significant reduction in leafless inflorescences. The interaction effect (timings*rates) was significant for leafless inflorescences. Ralex® at 150 ml/100 L applied on 18 June reduced the leafless inflorescences by 62% as compared to its control (Table 2.13) suggesting a carry over effect from last treatment.

Mixed inflorescences: An increased in mixed inflorescences was indicated for the first Ralex® application and for the two last Ralex® application dates (Table 2.12). Ralex® rates had no effects on percent mixed inflorescences. A significant interaction effect suggested no differences between control and Ralex® applied on 18 June.

Vegetative shoots: Vegetative shoots were reduced in trees treated in 2003 with first application of Ralex® on 6 May compared to 20 May and 4 June Ralex® applications. However, Ralex® rates did not have any effect on percent vegetative shoots (Table 2.12). It was remarkable to notice that leafless inflorescences were much lower in 2005 compared to 2004, however, there were no difference found in mixed inflorescences across two years.

Table 2.12: Effect of different Ralex® rates and timing of application in 2003 on different inflorescence types and vegetative shoots in Navelina orange trees for 2004

	Treatments	Percent leafless inflorescences	[A]Percent mixed inflorescences	Percent vegetative shoots
Timings	6 May	8.9	33.4	57.8
	20 May	7.2	27.6	65.2
	4 June	6.0	26.6	67.2
	18 June	7.6	31.4	60.9
	21 July	7.7	31.9	60.4
	Lsd (5%)	**ns**	**5.3**	**6.2**
Rates	Control	6.7	32.7	60.6
	100 ml/100 L	6.3	29.1	61.5
	150 ml/100 L	8.3	29.2	64.6
	200 ml/100 L	8.8	29.7	62.5
	Lsd (5%)	**2.0**	**ns**	**ns**
Timings*Rates		***	***	***

[A]Percentage of total (leafy and solitary terminal) inflorescences
***P<0.001; ns, not significant
Lsd (Least significant difference) is used to compare the treatment means within the columns

Table 2.13: Interaction effect of Ralex® (Timing*Rates) on percent leafless inflorescences in Navelina navel trees for 2004

	Control	100 ml/100 L	150 ml/100 L	200 ml/100 L
6 May	6.7	9.8	9.3	9.7
20 May	6.8	4.2	11.7	6.2
4 June	4.8	0.8	9.4	9.0
18 June	10.5	7.0	4.0	8.8
21 July	4.5	9.4	6.8	10.2
Lsd (5%) **4.7**				

Yield components:

Percent large fruit size (77-87 mm, diameter): Harvest of all experimental trees was carried out in late May 2005. The data from return crops indicated that there were no significant differences in the percentage larger fruit size for different Ralex® timings.

However, Ralex® rates had a significant effect and the 100 ml/100 L rate increased the percent of larger fruit by 13% as compared to control (Table 2.14), which was a reflection of decreased leafless inflorescence for the same treatment (Table 2.12).

Fruit yield per tree (kg): Fruit yield/tree was not affected with Ralex® application timings. However, Ralex® rates at 150-200 ml/100 L rates gave a slightly higher yield (Table 2.14). This was not surprising as trees had more fruit with smaller size. Fruit number were 295/tree for 150-200 ml/100 L treatment as compared to control and 100 ml/100 L were 250 and 219 fruit/tree respectively (data not shown). A significant interaction effect (timings*rate) indicated an increase of 67% yield with 150 ml/100 L Ralex® when applied on 18 June (Table 2.15).

Mean fruit weight (g): There were no effects on mean fruit weight for Ralex® timings applications as observed in fruit size and yield data (Table 2.14). However, Ralex® at 100 ml/100 L did have heavier fruits as compared to control.

Table 2.14: Effect of Ralex® application on percent large fruit size (77-87 mm), fruit yield/tree and mean fruit weight in Navelina oranges for 2005

	Treatments	Percent fruit size (77-87 mm)	Fruit yield/tree (kg)	Mean Fruit weight (g)
Timings	6 May	35	49.2	182.2
	20 May	37	47.3	182.5
	4 June	39	48.6	200.8
	18 June	39	48.6	183.6
	21 July	40	42.8	195.2
	Lsd (5%)	**ns**	**ns**	**ns**
Rates	Control	40	44.7	188.8
	100 ml/100 L	45	41.3	205.1
	150 ml/100 L	37	52.4	184.2
	200 ml/100 L	29	50.8	177.9
	Lsd (5%)	**7.4**	**6.4**	**13.9**
Timings*Rates		***	*	***

[A]Percentage of total (leafy and solitary terminal) inflorescences
*P<0.05; ***P<0.001; ns, not significant
Lsd (Least significant difference) is used to compare the treatment means within the columns

Table 2.15: Interaction effect of Ralex® (Timing*Rates) application on fruit yield (kg)/tree in 2005 for Navelina oranges

	Control	100 ml/100 L	150 ml/100 L	200 ml/100 L
6 May	30.3	37.8	32.7	39.5
20 May	45.3	42.3	25.7	33.8
4 June	32.7	62.8	30.5	28.0
18 June	31.8	44.7	53.5	24.0
21 July	57.7	37.8	43.7	20.3
Lsd (5%) **16.5**				

Experiment 3: Bellamy navel

Trees in this experiment were 15-year-old and had an average height of 2.3 meters. Ralex® was applied at two timings in this trial, which matched the last two timings of Washington navel and Navelina cultivars for Ralex® applications.

Flowering and Yield components 2003/2004 season

Flowering components:

Leafless Inflorescences: Data collected on leafless inflorescences indicated that there was no significant Ralex® application timing effect. There was a significant Ralex® rate effect on leafless inflorescences, these were significantly reduced from 30%-56% with 100 ml/100 L, 150 ml/100 L or 200 ml/100 L respectively as compared to the control (Table 2.16).

Table 2.16: Effect of different Ralex® rates and timing of application on different inflorescence types and vegetative shoots in Bellamy (Washington) navel orange trees for 2003

	Treatments	Percent leafless inflorescences	[A]Percent mixed inflorescences	Percent vegetative shoots
Timings	18 June	48.0	33.1	18.8
	21 July	44.7	34.0	21.3
	Lsd (5%)	**ns**	**ns**	**ns**
Rates	Control	68.7	22.6	8.8
	100 ml/100 L	48.4	33.4	18.2
	150 ml/100 L	38.3	39.0	22.7
	200 ml/100 L	30.2	39.3	30.5
	Lsd (5%)	**9.8**	**6.98**	**8.7**
Timings*Rates		ns	ns	ns

[A]Percentage of total (leafy and solitary terminal) inflorescences
ns, not significant
Lsd (Least significant difference) is used to compare the treatment means within the columns

Mixed inflorescences: Data collected on mixed inflorescences suggested a significant increase in mixed inflorescences with 100-200 ml/100 L applications of Ralex® compared to control (Table 2.16).

Vegetative shoots: Generally vegetative shoots were significantly increased with Ralex® rates from 100-200 ml/100 L. There was a linear increase in vegetative shoots with increasing Ralex® rates as compared to control (Table 2.16).

Yield components:

Ralex® was applied only at two different times in this trial which matched the last two application timings for Washington navel and Navelina oranges. Fruit were harvested during July 2004.

Percent large fruit size (77-87 mm, diameter): Percent large fruit size in this trial was significantly higher for the 21 July treatment. Percent large fruit size was also higher at

200 ml/100 L as compared to control (Table 2.17). In this experiment Ralex® at 200 ml/100 L treatment had a slightly higher percentage of large sized fruit than 150 ml/100 L. This was due to reduced leafless inflorescences. Both treatments had similar leafy inflorescences but the difference was obviously due to less leafless inflorescences. This sugges the importance of flower quality and its effect on fruit size at harvest.

Fruit yield per tree (kg): Ralex® timings and Ralex® rates effects failed to show any significant differences for fruit yield/tree, however, 150 ml/100 L treatment has 8% higher yield than control (Table 2.17).

Mean fruit weight (g): Ralex® timings and Ralex®rates did not show any significant differences in mean fruit weight (Table 2.17).

Table 2.17: Effect of Ralex® application on percent large fruit size (77-87 mm), yield/tree and mean fruit weight of Bellamy (Washington) navel oranges for 2004

	Treatments	Percent fruit size (77-87 mm)	Fruit yield/tree (kg)	Mean Fruit weight (g)
Timings	18 June	38	87	188
	21 July	47	82	192
	Lsd (5%)	**7.5**	**ns**	**ns**
Rates	Control	34	83	185
	100 ml/100 L	40	86	194
	150 ml/100 L	38	90	189
	200 ml/100 L	58	79	192
	Lsd (5%)	**10.6**	**ns**	**ns**
Timings*Rates		ns	ns	ns

ns, not significant
Lsd (Least significant difference) is used to compare the treatment means within the columns

Flowering components 2004 season

The return flowering data for Bellamy navel trees treated with Ralex®in 2003 was recorded in September 2004. The data indicated that there were no differences of Ralex® timings or rates of these previous treatments on either percent leafless or mixed inflorescences or percent vegetative shoots (Table 2.18).

The flowering data across two years suggested a strong alternate flowering in leafless inflorescences. However, no difference was noticed in mixed inflorescences across 2003 and 2004. This effect of Ralex® not affecting the percent mixed inflorescences for the two consecutive years may have contributed to high percentage of large sized fruits. The lack of timing effect was simply due to only two times of applications not far apart from each other to cause any major difference. There was not any interaction effects found on percent leafless inflorescences, mixed inflorescences or vegetative shoots.

Table 2.18: Effect of different Ralex® rates and timing of application in 2003 on different inflorescence types and vegetative shoots in Bellamy navel orange trees for 2004

	Treatments	Percent leafless inflorescences	[A]Percent mixed inflorescences	Percent vegetative shoots
Timings	18 June	7.84	36.7	55.5
	21 July	8.14	32.8	59.1
	Lsd (5%)	**ns**	**ns**	**ns**
Rates	Control	7.92	35.4	56.8
	100 ml/100 L	7.50	34.5	58.1
	150 ml/100 L	7.85	34.6	57.6
	200 ml/100 L	8.67	34.6	56.9
	Lsd (5%)	**ns**	**ns**	**ns**
Timings*Rates		ns	ns	ns

[A]Percentage of total (leafy and solitary terminal) inflorescences
ns, not significant
Lsd (Least significant difference) is used to compare the treatment means within the columns

Relation between flower reduction and fruit size across the three experiments:

In the three experiments it became obvious that reduction in leafless inflorescences did result in an increase in bigger fruit size. This was believed to be due to two reasons. Firstly, the application of Ralex® reduced the overall number of flowers and indirectly led to adjustment in crop load. Second, Ralex® was able to suppress a specific type of inflorescence (Leafless) and thus leave behind a reasonable proportion of leafy inflorescences. This effect enhanced the flower quality. The question remains as to how much suppression of leafless inflorescences was required to optimise the pack out of large sized fruit.

To quantify the effect of flower reduction and fruit size a relationship between leafless inflorescences and large fruit size class (77-87 mm) was established using the data from the three cultivars. For both timing and rate factors the average effect of leafless inflorescences for all Ralex® treatments (100-200 ml/100 L) was calculated by comparing it to the control treatments. Then for both timing and rate factors the average effect of percent fruit number in large size class (77-87 mm) for all Ralex® treatments (100-200 ml/100 L) was calculated by comparing it to the control treatment.

A model was developed by using linear regression analysis. Reduction in percent leafless inflorescence was used as an independent variable and increase in the percent of fruit in the large size (77-87 mm) was used as a dependent variable. These values were derived by using the regression equation (Figure 2.2).

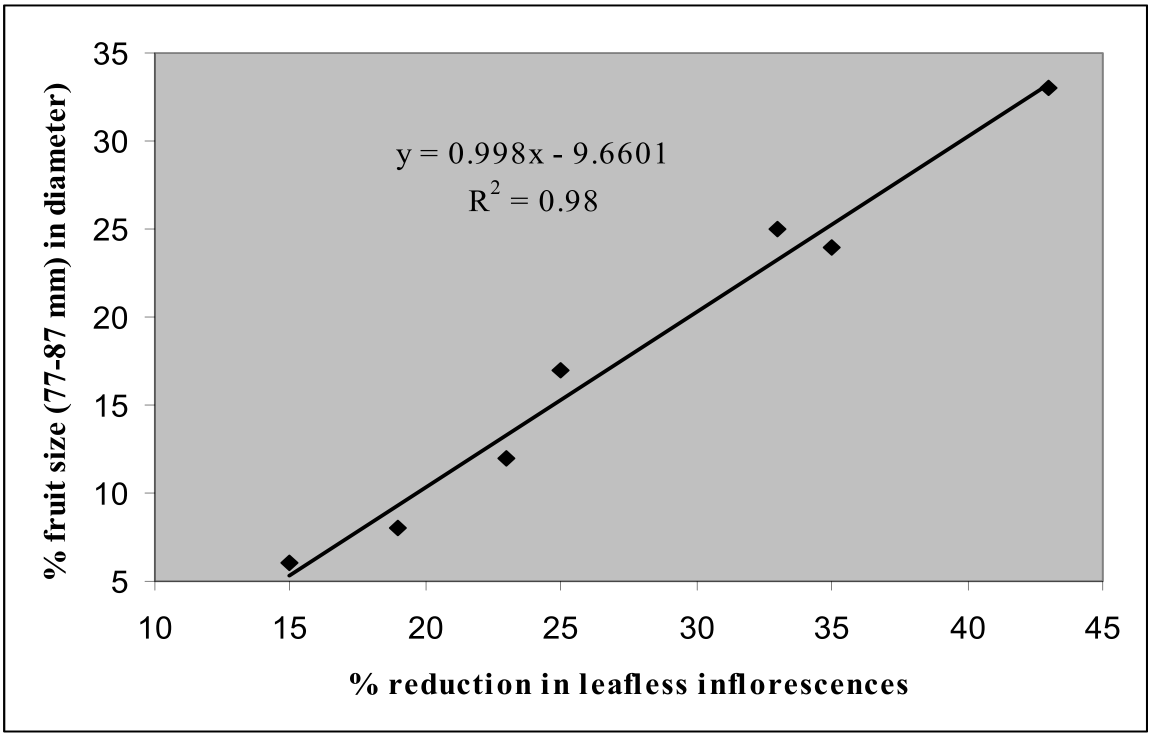

Figure 2.2: Relationship between reduction in leafless inflorescences versus percent increase in large (77-87 mm) fruit size at harvest ($R^2 = 0.98^{***}$)

The amount of reduction required to obtain a desirable percentage of large size fruit is shown in Table 2.19. The data in this table suggested that 20% reduction in leafless inflorescences was required to obtain 11% increase in fruit of the desire size class. A maximum of 50% reduction in leafless inflorescences can result in 40% increase in the desired fruit size. Once the reduction in leafless inflorescence has passed beyond 50% mark then it may decrease the average fruit yield/tree. This can happen with Ralex® application in an anticipated "off-flowering" year (see Chapter 3)

Table 2.19: Percentage increase in fruit size class (77-87 mm) due the percent reduction in leafless inflorescences

Percent reduction in leafless inflorescences	Percent increase in fruit size (77-87 mm)
20	11.2
30	20.3
40	30.3
50	40.2

Discussion:

Ralex® was applied to individual trees in an anticipated "on-flowering" year at different times to determine the most effective time of bud responses to this new formulation. Results from winter application of Ralex® suggested that it was possible to control number of leafless inflorescences when applied early in the season. This reconfirms that there is a first gibberellin sensitivity peak which occurs in May or probably the first week of June. First sensitivity peak normally occurs in May-June and coincides with that of flower induction, in which a flowering promoter probably is translocated from leaves to the buds (Augusti et al., 1981). Figure 2.3 shows a general comparison between Ralex® treated and untreated trees. The effectiveness of flowering depends on bud sensitivity and it has been previously suggested that buds are more sensitive to gibberellins in “off-flowering” year than in “on-flowering” years (Garcia-Luis et al., 1988). However, in our recent experiments the data suggested that flower reduction was possible in an expected “on-flowering” as well as in “off-flowering” year. However, fruit size benefits were only evident when Ralex® was applied in an anticipated “on-flowering” year. This indicated Ralex® as a more effective product than GA_3 for flower suppression in navel oranges. Ralex® seems to have a better formulation which is more effective and consistent in flower suppression than GA_3.

The response of buds can also be dependent on different seasons or different cultivars. Tree age may also be responsible to add further complexity to seasonal and cultivar effects. However, tree age effects were not quantified in this project and warrants further research.

In this project Ralex® was able to control flowering and enhance fruit size in an “on-flowering” year. It was also demonstrated that Ralex® reduces flowering mostly by reducing the leafless inflorescences and by increasing vegetative shoots. In these trials, the magnitude of reduction was lower in bigger (older trees) as compared to the younger trees. Washington navel trees were 38-year-old and the response of the buds grown on these trees were lesser to Ralex® application. However, flowers can still be reduced in older trees by applying Ralex® earlier or with higher rates. In this instance it was still possible to have a fruit size increase of 9% with early application of 150-200 ml/ 100 L of Ralex® treatment. In Navelina which was a younger cultivar tested in this project, the buds responded well to Ralex® when applied earlier.

The later applications either had no effect or had lesser effect in suppressing flowering. For instance in Navelina the best dates for suppressing leafless inflorescences and to increase fruit size occurred with Ralex® at 150 ml/100 L when applied on 18 June 2003. This period of 18 June may still fall within first sensitivity peak as Navelina bud break was 25 July, 2003. Navelina normally break their buds later than Washington navel bud break which was 18 July, 2003 in our trials. It is also possible that due to earliness of bud break Washington navel might have missed the bud sensitivity period and did not respond that well compared to Navelina. Therefore, a calendar date for Ralex® application should be used with caution with a prior knowledge of average bud break times for a particular cultivar.

Our study suggested that Ralex® application 4-6 weeks before bud break would be a desirable option for flower suppression and fruit size benefits at harvest. In this study the buds at the second sensitivity period were either less responsive or not did not respond at all when Ralex® was applied in July (a putative second sensitivity peak).

This contradicts the earlier reports that there is a second sensitivity peak which occurs during flower differentiation stage (Iwahori, 1978) and which is sensible to Ralex® or GA_3. One of the reasons for this was that it may be possible that in Australia we do not have a second sensitivity peak or it might be very short. This makes perfect sense because one will think that it will be easier to suppress the flowers when they are in their initiation stage in May/June rather than the later differentiation stage in July. In late July while the differentiation occur it may be possible that a large number of buds have passed the stage of sepal formation.

Once the sepal formation is completed it is not possible to revert the floral inflorescence into vegetative shoot (Lord and Eckard, 1987). At the flower differentiation stage most of the buds are not at the same stage of development and the responses could vary on a larger scale in terms of cultivars and vegetative flush types. Generally, there are three distinct vegetative flushes such as spring flush, summer flush or autumn flush occurs on a citrus tree in Australia. Buds born on these flushes are at the different age at the time of flower initiation. It is not clear that how the bud age respond to plant growth regulators such as GA_3 or Ralex®.

The previous literature also suggested that the second sensitivity peak window in citrus is very narrow (Guardiola et al., 1982). It is also possible that buds of Washington navel trees have missed the sensitivity peak between 18 June and 21 July period, as Ralex® was not applied between these two dates.

Figure 2.3: Comparison of the Ralex® treated and untreated navel tree

Phenological events can play an important role in the bud behaviour. Phenological data collection is underway for the last few years at Agricultural Research and Advisory Station, Dareton for a range of navel oranges and these cultivars were also included in this project (Khurshid, 2005).

It was noticed that bud break (onset of second sensitivity peak) timings vary across different cultivars and across growing years. However, it is easy to track down the differences across cultivars based on the available phenological data. In our trials the bud break in Washington navel trees was 10 days earlier than Navelina trees. This difference in bud break timing may have been well responsible for the bud responses to Ralex® application. Therefore, Ralex® application should be based on bud break timing. However, if bud-break timings do not vary across growing seasons by more than 3-4 days then flower suppression effects can still be achieved with a proper calendar date as mentioned earlier. Every grower must keep a good record of phenological stages of their blocks for the effective use of plant growth regulators and fertilisation program. Four articles on phenology have been published in Australian Citrus News, to make growers aware of this need and assist them to implement it.

Return Flowering:
In this project the experimental trees which received Ralex® application in 2003 were left untreated for a second year to assess the return flowering behaviour and subsequent effects fruit size responses for another year. This exercise was regarded as important to evaluate the possible alternate bearing effect after Ralex® use. In Washington navel fruit yield was higher by 26% due to higher percentage of large sized fruit in 2005, although it was an "off-flowering" year. In 2005 growing season better climatic conditions and better fruit set with lower flower number and optimum fruit growth also played a key role at our experimental site. There was no alternate bearing effect evidenced after Ralex® use. The return year (2005) produced slightly more (4%) large sized fruit than 2004, while yields were higher in 2005 by 20% compared to 2004. There was no obvious alternate bearing noticed between two years in Ralex® treated trees. It also suggests that Ralex® may not be necessary to use every year. The use of Ralex® in an "off-flowering" year and its subsequent effects on flowering behaviour and fruit size distribution is discussed in next Chapter 3.

In Navelina trees the return flowering data suggested a strong alternate bearing in spring 2004 for leafless inflorescences. However, there was no alternate bearing was noticed in mixed inflorescences across 2004 and 2005. This return flowering behaviour produced 67% large sized fruit in 2005 with Ralex® applied at 150 ml/100 L on 18 June 2003. Bellamy navel cultivar followed a similar trend to Washington navel and Navelina trees.

The overall conclusion from the three experiments reported here is that Ralex® can effectively reduce the number of leafless inflorescences, increase the percentage of large size fruit at harvest and can overcome alternate bearing cycles.

3. Ralex® application in "off-flowering" year and its effect on subsequent flower suppression, yield and fruit size distribution in navel oranges

Introduction:

Ralex® is a GA_3-based formulation that can be used for flower suppression in citrus. Preliminary trials in Queensland on mandarins have shown that Ralex® can significantly reduce flowering in 'Imperial' and 'Honey Murcott' mandarins when applied at a rate of 200 ml/100 L between June and July. At the present time, Ralex® is the only GA_3-based formulation registered in Australia for flower suppression in citrus. Currently, this registration only applies to mandarins but registration is being sought for oranges.

The trials reported in this chapter are based on Ralex® application in expected "off-flowering" year (2004). These experiments were designed to determine the bud responses to Ralex® in terms of flower suppression followed by an assessment of yield and fruit size distribution of Washington navel and Navelina navel oranges 2004.

An additional experiment was included to assess the Ralex® effects on a late maturing cultivar Barnfield which was in an anticipated "on-flowering" year. Flowering data is presented for Branfield navel oranges after 2004 Ralex® application. The inclusion of Barnfield was seen as an opportunity to test the bud responses to Ralex® in an "on-flowering" year and to validate the previous findings described in Chapter 2.

Materials and Methods:

A range of experiments were conducted in 2004 on different navel cultivars. These experiments were conducted at the commercial grower's property at Dareton on 39-year-old Washington navel/Sweet orange, 11-year-old Navelina/Troyer citrange and 14-year-old Barnfield navel/*Poncirus trifoliata* rootstock. Ralex® treatments (control, 100 ml, 150 ml or 200 ml/100 L) were applied to the trees during the first sensitivity peak in 2004. Ralex® was applied to individual trees with a hand-held sprayer to the point of run-off at three different timings (20 May, 15 June or 30 June). Six single tree replicates were allocated to each treatment giving a total of 72 individual trees for Washington navel Navelina or Barnfield navel. Ralex® was applied around mid-day on a sunny and calm day. Maximum temperature at the time of spray application was 13-15 ^{0}C.

Data Collection and statistical analysis:

<u>Methodology for data collection:</u>

Flowering data in Washington navel, Navelina and Barnfield navel trees were recorded during September 2004 (the year of Ralex®application). Different types of inflorescences and vegetative shoots as described in chapter 2 were recorded. Total number of inflorescences and vegetative shoots were counted in 0.5 X 0.5 m^2 (0.125 m^3) cubic counting frame at the mid point of the canopy. The counting frame was placed four times around the tree canopy. All experimental trees received normal irrigation and nutrition according to the commercial orchard practices applied in this district during the course of this project.

Definition of terms:
There are different types of inflorescence found on a citrus tree. (1) Leafless inflorescence - one or many flowers and no leaves. Leafless inflorescences are not a desirable because it produces a smaller sized fruit than leafy inflorescence or solitary terminal inflorescence. (2) Leafy inflorescence - this type consists of many flowers and many leaves. Fruit born on this type is larger than leafless inflorescence. (3) Solitary terminal inflorescence - this type has one flower and many leaves. Fruit born on this type grows larger than leafless or leafy inflorescences. (4) Vegetative shoots - this is not a type of inflorescence but it is a well defined vegetative shoot (spring flush) which is a potential site for next year flowering (see Figure 2.1)

Harvest and fruit size distribution:
Harvest of individual tree was carried out in 2005. Total fruit weight, number of fruit per tree and fruit size distribution was recorded on each experimental tree at harvest with a commercial grader (Colour Vision Systems Pty. Limited). Fruit were sorted into five size classes based on fruit diameter (mm). The size classes were <65 mm (>138 fruit/carton), 65-67 mm (138-125 fruit/carton), 69-72 mm (113-100 fruit/carton), 75-77 mm (88 fruit/carton) and >77 mm (<80 fruit/carton).

Statistical analysis:
The data on total number of leafless inflorescences, leafy inflorescences, solitary terminal inflorescences and vegetative shoots was recorded in each counting frame. Then the percent contribution of each inflorescence type and vegetative shoots was calculated and subjected to analysis of variance (ANOVA) using the statistical software package Genstat 8. Treatment means were tested with least significant differences (LSD) at 5% level of significance. For the purpose of this report the data for leafy inflorescences and solitary terminal inflorescences (both leafy types) were pooled and referred to as mixed inflorescences. The data presented below are for leafless inflorescences, mixed inflorescences and vegetative shoots for the three different experiments.

Results:
In previous experiments (described in Chapter 2) Ralex® was applied in 2003 at five different dates in Washington navel or Navelina trees. In experiments described in this chapter, Ralex® was applied to the trees at three different times to cover the first sensitivity peak. This decision was based on the outcome of the results from 2003 Ralex® application in Washington navel and Navelina trees.

Experiment 1: Washington navel
Trees in this trial were 39-year-old and had an average height of 3 meters. Most of the trees in the Sunraysia district are larger and older. Trees from this trial were in an anticipated "off-flowering" year in spring 2004. A set of uniform and healthy trees were selected which have not received Ralex® in the past. A set of new experimental healthy and uniform trees were selected from the same blocks (used for experiments described in Chapter 2) of Washington navel and Navelina cultivars.

Flowering and Yield components 2004/2005 season

Flowering components:
Leafless Inflorescences: Data analysis of Washington navel tress indicated that there was not any significant effect of Ralex® timings on leafless inflorescences. However, there was

a significant decrease of 36% with 150 ml/100 L Ralex® treatment as compared to control (Table 3.1).

Table 3.1: Effect of different Ralex® rates and timing of application on different inflorescence types and vegetative shoots in Washington navel trees for 2004

	Treatments	Percent leafless inflorescences	APercent mixed inflorescences	Percent vegetative shoots
Timings	20 May	18.0	48.2	34.0
	15 June	21.8	47.0	31.2
	30 June	17.6	44.0	38.4
	Lsd (5%)	**ns**	**ns**	**ns**
Rates	Control	22.3	45.4	32.4
	100 ml/100 L	18.1	45.9	36.0
	150 ml/100 L	14.3	46.7	39.0
	200 ml/100 L	21.8	47.6	30.7
	Lsd (5%)	**6.1**	**ns**	**ns**
Timings*Rates		*	*	***

APercentage of total (leafy and solitary terminal) inflorescences
*$P<0.05$; ***$P<0.001$; ns, not significant
Lsd (Least significant difference) is used to compare the treatment means within the columns

A significant interaction effect suggested that 150 ml/100 L treatments were effective in reducing the leafless inflorescences by 45% when applied on 15 June as compared to control (Table 3.2).

Table 3.2: Interaction effect of Ralex® (Timing*Rates) on percent leafless inflorescences in Washington navel trees for 2004

	Control	100 ml/100 L	150 ml/100 L	200 ml/100 L
20 May	15.4	19.3	10.1	27.1
15 June	29.3	17.7	16.1	24.1
30 June	22.3	17.4	16.7	14.2
Lsd (5%) **10.5**				

Mixed inflorescences: There were no significant effects of Ralex® timings or Ralex® rates on reducing or increasing mixed inflorescence (Table 3.1).

Vegetative shoots: Vegetative shoots are potential sites for next year flowering and it was expected that Ralex® would convert the flowering inflorescences to vegetative shoots in order to decrease the overall flowering. Ralex® timings effects or Ralex®rates, on an average had no significant effect on vegetative shoots as compared to control. However, vegetative shoots were higher by 22% with Ralex® at 150 ml/100 L as compared to control (Table 3.1). A significant interaction effect for Ralex® (timings*rates) indicated that Ralex® at 100-150 ml/100 L rate had twice as much vegetative shoots than the control trees when applied on 15 June (Table 3.3).

Table 3.3: Interaction effect of Ralex® (Timing*Rates) on percent vegetative shoots in Washington navel trees for 2004

	Control	100 ml/100 L	150 ml/100 L	200 ml/100 L
20 May	39.1	26.3	45.9	24.6
15 June	20.0	41.8	40.7	22.3
30 June	38.1	39.9	30.4	45.2
Lsd (5%) **15.1**				

Yield components:

Harvest of individual trees was carried out in June 2005 to assess yield, mean fruit weight and fruit size distribution. The harvest data for 2005 Washington navel crop suggested that there were no Ralex® timing or rate effects for fruit size distribution, mean fruit yield/tree or mean fruit weight (Table 3.4). There were also no significant interaction effects for the above mentioned variables (Table 3.4). However, there was a clear indication that Ralex® at 150 ml/100 L rate produced 10% more fruit in large size class (77-87 mm). This effect was also evidenced by average higher yield per tree and fruit were heavier for this treatment (Table 3.4). There were not any interactions effects found for percent fruit size, yield/tree or mean fruit weight.

Table 3.4: Effect of Ralex® application on percent large fruit size (77-87 mm), fruit yield/tree and mean fruit weight of Washington navel oranges for 2005

	Treatments	Percent fruit size (77-87 mm)	Fruit yield/tree (kg)	Mean Fruit weight (g)
Timings	20 May	63.7	89.8	220.2
	15 June	63.6	92.6	224.1
	30 June	69.8	87.1	232.4
	Lsd (5%)	**ns**	**ns**	**ns**
Rates	Control	63.1	93.8	218.8
	100 ml/100 L	66.1	81.8	226.8
	150 ml/100 L	69.1	94.9	232.3
	200 ml/100 L	64.6	88.9	224.4
	Lsd (5%)	**ns**	**ns**	**ns**
Timings*Rates		ns	ns	ns

ns, not significant
Lsd (Least significant difference) is used to compare the treatment means within the columns

Experiment 2: Navelina navel

Trees in this trial were 11-years-old at the time of Ralex® application and had an average height of 2 meters. Trees were generally in "off-flowering" year. Data on flowering was collected in September/October 2004 and fruit were harvested in May 2005.

Flowering and Yield components 2004/2005 season

Flowering components:

Leafless Inflorescences: Data collected on leafless inflorescences indicated that there was no significant timing effect when Ralex® was applied between 20 May and 30 June. The data did indicate a very strong effect of Ralex® rates on leafless inflorescences. Ralex® reduced the leafless inflorescences by 89% and 88% with 150 ml/100 L and 200 ml/100 L respectively as compared to control (Table 3.5). There was no significant interaction effect indicated on the percent leafless inflorescences. It is worth noticing that even the control trees were low in percent leafless inflorescences for this cultivar. It seems to highlight that it was a very "off-flowering" year.

Table 3.5: Effect of different Ralex® rates and timing of application on different inflorescence types and vegetative shoots in Navelina orange trees for 2004

	Treatments	Percent leafless inflorescences	[A]Percent mixed inflorescences	Percent vegetative shoots
Timings	20 May	2.47	10.3	87.3
	15 June	2.11	12.2	85.8
	30 June	3.01	16.4	80.6
	Lsd (5%)	**ns**	**3.8**	**4.5**
Rates	Control	6.32	23.3	70.51
	100 ml/100 L	2.42	9.7	87.9
	150 ml/100 L	0.65	8.3	91.1
	200 ml/100 L	0.74	10.6	88.7
	Lsd (5%)	**1.9**	**4.4**	**5.2**
Timings*Rates		ns	ns	ns

[A]Percentage of total (leafy and solitary terminal) inflorescences
ns, not significant
Lsd (Least significant difference) is used to compare the treatment means within the columns

Mixed inflorescences: There was no significant effect of Ralex® timings on reducing the mixed inflorescences. Ralex® rates had a significant effect on reducing mixed inflorescences. All Ralex®treatment reduced the percent mixed inflorescences compared to control (Table 3.5). On this occasion the stronger rates was 150 ml/100 L which reduced the mixed inflorescences by 64% as compared to control (Table 3.5). No significant interaction effect was found.

Vegetative shoots: Generally vegetative shoots were significantly increased with May application as compared to June application (Table 3.5). There was a significant increase in vegetative shoots with Ralex® rates (Table 3.5) and 150 ml/100 L treatment had increased the percent vegetative shoots by 29% as compared to control. No significant interaction effect was found.

Yield components:

Percent large fruit size (77-87 mm, diameter): Fruit harvest was carried out in May 2005 for each experimental tree for its yield per tree, mean fruit weight and fruit size distribution. Data in Table 3.6 indicated that there was no significant effect of Ralex® timings or Ralex® rates on percent fruit size (77-87 mm) increase at harvest. However, Ralex® (average of all rates) increased the percent of bigger fruit size by 12% compared to control (Table 3.6). On this instance Ralex® at 200 ml/100 L alone had an increase of 20% as compared to control.

Table 3.6: Effect of Ralex® application on percent large fruit size (77-87 mm), fruit yield/tree and mean fruit weight of Navelina oranges for 2005

	Treatments	Percent fruit size (77-87 mm)	Fruit yield/tree (kg)	Mean Fruit weight (g)
Timings	20 May	49	21.6	246.8
	15 June	54	28.7	238.8
	30 June	48	36.5	225.0
	Lsd (5%)	**ns**	**6.4**	**ns**
Rates	Control	46	42.3	194.6
	100 ml/100 L	52	27.8	230.9
	150 ml/100 L	48	23.5	257.6
	200 ml/100 L	55	22.2	264.4
	Lsd (5%)	**ns**	**7.4**	**25.9**
Timings*Rates		ns	ns	ns

ns, not significant
Lsd (Least significant difference) is used to compare the treatment means within the columns

Fruit yield per tree (kg): Effect of Ralex® timing and rates were both significant for fruit yield per tree. Fruit yield were lower with 20 May application when compared to 30 June application. This was due to a very low flower number this year as it was an "off-flowering" year. Ralex® (average of all rates) managed to decrease the yields by 42% as compared to control (Table 3.6).

Mean fruit weight (g): Individual fruit weight was linearly increased by with increasing Ralex® application rates from 100 to 200 ml/100 L as compared to control (Table 3.6). Ralex® application at 200 ml/100 L rate had heavier fruit weight as reflected due to lower fruit number (87) compared to control (222).

Experiment 3: Barnfield navel

Trees in this trial were 14-year-old and had an average height of 2.1 meters. Tree density was 621 trees/ha. Barnfield is a late maturing cultivar and exhibits strong alternate bearing. Ralex® was applied due to its anticipated "on-flowering" year which was apparent from lower fruit number per tree in 2004 season and intense vegetative growth flush from previous year.

Flowering components 2004 season

Flowering components

Leafless Inflorescences: Data collected on leafless inflorescences indicated that there was a significant Ralex® application timing effect. Early treatment applied on 20 May reduced the leafless inflorescences by 23% as compared to the latest (30 June) application. There was a significant Ralex® rate effect and leafless inflorescences were significantly reduced from 36%, 42% and 52% with 100 ml/100 L, 150 ml/100 L or 200 ml/100 L respectively as compared to the controls (Table 3.7).

Table 3.7: Effect of different Ralex® rates and timing of application on different inflorescence types and vegetative shoots in Barnfield navel trees for 2004

	Treatments	Percent leafless inflorescences	[A]Percent mixed inflorescences	Percent vegetative shoots
Timings	20 May	21.58	45.7	32.8
	15 June	26.99	53.2	20.0
	30 June	27.85	56.7	15.4
	Lsd (5%)	**4.8**	**5.0**	**5.6**
Rates	Control	37.70	51.0	11.3
	100 ml/100 L	24.15	53.8	22.0
	150 ml/100 L	21.76	50.8	27.4
	200 ml/100 L	18.28	51.6	30.1
	Lsd (5%)	**5.5**	**ns**	**6.4**
Timings*Rates		ns	**	ns

[A]Percentage of total (leafy and solitary terminal) inflorescences
**P<0.01; ns, not significant
Lsd (Least significant difference) is used to compare the treatment means within the columns

Mixed inflorescences: Data collected on mixed inflorescences suggested that the early application had reduced the mixed inflorescences by 14% and 19% compared to 15 June and 30 June treatment respectively (Table 3.7). However, Ralex® rates did not have any effect on mixed inflorescences. A significant interaction effect (timings*rates) indicated that any Ralex® rate applied on 15 or 30 June had no effect on mixed inflorescences. However, the only treatment which reduced the mixed inflorescences was 150 ml/100 L applied on 20 May (Table 3.8).

Table 3.8: Interaction effect of Ralex® (Timing*Rates) on percent mixed inflorescences in Barnfield navel trees for 2004

	Control	100 ml/100 L	150 ml/100 L	200 ml/100 L
20 May	52.8	47.9	35.7	46.2
15 June	50.3	53.7	54.8	53.4
30 June	49.9	59.8	62.0	55.2
Lsd (5%) **9.9**				

Vegetative shoots: Generally vegetative shoots were higher with 20 May Ralex® application by 64% and 112% for 15 June and 30 June respectively (Table 3.7). Vegetative shoots were significantly increased with Ralex® rate from 100-200 ml/100 L. There was a significant linear increase in vegetative shoots with increasing Ralex® rates as compared to control (Table 3.7).

Discussion:

The main experiments in 2004 were designed to apply Ralex® in an anticipated "off-flowering" year. Trees on two trial sites Washington navel and Navelina were in "off-flowering" year. These experiments were designed to test if Ralex® was required to suppress the flowers in an anticipated "off-flowering" year to gain the benefits of fruit size increase at harvest.

In Washington navel different Ralex® application timing did not cause any significant differences on any type of inflorescences or vegetative shoots. This reconfirms some of the effects observed when Ralex® was applied in "on-flowering" year. Similar results of application timings on leafless inflorescences were also indicated in Navelina cultivar, further strengthening this outcome. However, in both cultivars leafless inflorescences were significantly reduced with 150 ml/100 L Ralex® treatment. The percentage of mixed inflorescences was not affected by Ralex® timing in Washington navel but did have a reduction in Navelina cultivar. In the 2003 application there was a slight reduction in leafy inflorescences when applied in May/June period in Navelina trees.

One of the reasons could be that Wahington navel trees were bigger and probably higher rates or earlier application would have been required to have an effect on mixed inflorescences. However, Navelina trees were much younger and smaller and probably early applications would have caused the reduction of these inflorescence type.

The aim of the project was not to eliminate mixed inflorescence type which normally bear initial bigger fruit size.

Mixed inflorescences were unaffected by Ralex® timings or rates in an "on-flowering" year as previously mentioned in chapter 2. In fact in Bellamy navel trees a slight increase in mixed inflorescences was observed. Although in 2003 and 2004 trees had a different status in terms of crop loads, Ralex® application results were very consistent to what was found in previous experiments.

Apart from a positive affect of Ralex® application "off-flowering" year on reducing leafless inflorescence there were no real benefits on producing fruit of large size at harvest. These findings suggested that Ralex® application in an "off-flowering" year had no practical benefits. In our previous study hand thinning in an “off-flowering” year did not show any benefits in fruit size increase at harvest (Bevington and Khurshid, 2002), which is consistent with the current results.

Barnfield navel was included in 2004 application program and this cultivar was in an anticipated “on-flowering” year. The inclusion of Barnfield into 2004 experimental program provided an opportunity to repeat Ralex® application for the second consecutive year in “on-flowering” trees that had not received Ralex® in the past. Results obtained from Barnfield trial were very useful to evaluate the bud responses to Ralex® applications. The medium rate of Ralex® application was very effective in eliminating the leafless inflorescences which paralleled the results of Washington navel and Navelina navel for 2003 application. It was also found that the June application period was very helpful in reducing leafless inflorescences and increasing mixed inflorescences. Mixed inflorescences bear bigger fruit than leafless type.

This study based on the results from 2004 application in Washington navel and Navelina trees concluded that Ralex® application had a positive effect on suppressing flowers in “off-flowering” year but flower suppression in “off-flowering” year did not result in percentage of large sized fruit at harvest. Therefore, Ralex® use in an “off-flowering” year is not recommended.

4. Effects of Ralex® on colour development in navel oranges

Introduction:

In previous chapters Ralex® use for flower suppression is described in detail. The data generated in this project has indicated that Ralex® can be use efficiently to suppress flowers in first sensitivity peak. First sensitivity peak normally occurs in May-June period. During this stage fruit of different cultivars are in different stages of colour development. For example, early maturing cultivars like Navelina may have more rind colour in May than other types under Sunraysia conditions. At the same time late maturing cultivar such as Branfield or Lane Late normally has less rind colour. Therefore, a comprehensive colour trial was required to assess if Ralex® use may have any effects of colour delay on an existing crop when applied at specific stage of colour development.

Ralex® is a GA_3-based formulation and GA_3 is widely to known to have its effects in delaying fruit colour (Greenberg and Goldschmidt, 1989; Marur et al., 1999). The senescence-delaying regulator GA_3 inhibits the effect of ethylene on chlorophyllase transcription accumulation (Jacob et al., 1999). GA_3 at 20-40 p.p.m was able to delay colour development in Valencia oranges (Coggins and Hennings, 1985). However, the intensity of colour delay with GA_3 depends upon its concentration and stage of colour development at application. Ralex® use may not be an issue for early cultivars of navel where fruit is normally harvested in May but mid or late maturing cultivars need attention. Colour effects can vary in a particular growing season due to climatic conditions. Other quality factors and marketing strategies can also have an influence on fruit colour at harvest.

Five cultivars with different times of maturity were selected to assess the fruit colour responses to Ralex® application. These cultivars were Early Ryan, Washington navel, Bellamy (Washington) navel, Lane Late navel and Barnfield navel.

The objective of the study reported in this chapter was to quantify the colour delay effect after Ralex® application at different stages of colour development in a range of navel cultivars.

Materials and Methods:

A range of experiments were conducted in 2005 season in different navel cultivars. These experiments were conducted on 10-year-old Early Ryan/Carrizo citrange, 15-year-old Bellamy (Washington) navel/*Poncirus trifoliata*, 6-year-old Lane Late/*Poncirus trifoliata* at the Agricultural Research and Advisory Station, Dareton and on 39-year-old Washington navel/Sweet orange, and 14-year-old Barnfield navel/*Poncirus trifoliata* at a commercial grower's property at Dareton.

Fruit in pairs were randomly selected at mid point around the tree canopy and tagged. Ten pairs of fruit per tree were tagged on 4 single-tree replicates. Each pair of tagged fruit experienced the same climatic conditions due to their proximity to each other. This technique eliminated the difference in amount of chill received by each fruit with in a pair. In each pair one fruit was treated with Ralex® treatments @ 200 ml/100 L and the other fruit was left untreated (control). The control fruit were temporarily covered against the spray drift and to avoid contact with the treated fruit. Ralex® treatment was sprayed onto a fruit with a hand-held sprayer to a point of run-off (Figure 4.1). Ralex® treatment was applied at different stages of colour development (Figure 4.2) for different cultivars. These stages of colour development mainly coincided with the first and second sensitivity peaks. Ralex® was applied around mid-day on a sunny and calm day. Maximum temperature at time of spray application was 13-15 ^{0}C.

Figure 4.1: Fruit was sprayed with hand-held sprayer up to the point of run-off

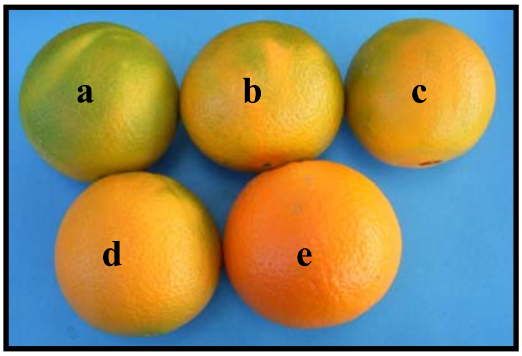

Figure 4.2: Colour scoring is based on the colour covering the fruit surface with yellow colour as opposed to green (a) 5-10% colour, (b) 25% colour, (c) 50% colour, (d) 75% colour, and (e) 100% colour

Data Collection and statistical analysis:

Colour assessment data was recorded for all experimental fruit at the commercial harvest dates. Fruit was subjectively assessed and the proportions of different colour components per fruit surface were recorded. Each fruit was visually assessed for percent soft green, hard green, yellow and orange colour and the data was recorded. Soft green colour is defined as the light green colour appears around the fruit or on shoulders (Figure 4.3a). Hard green colour is defined as dark green colour usually found on shoulders of the fruit (Figure 4.3b). Yellow and orange coloured fruits are shown in (Figure 4.3 c & d). Percentage of colour data sets for treatments were analysed by analysis of variance using the statistical software package Genstat 8. Difference between the treatment means was tested with least significant differences (LSD) at 5% level of significance.

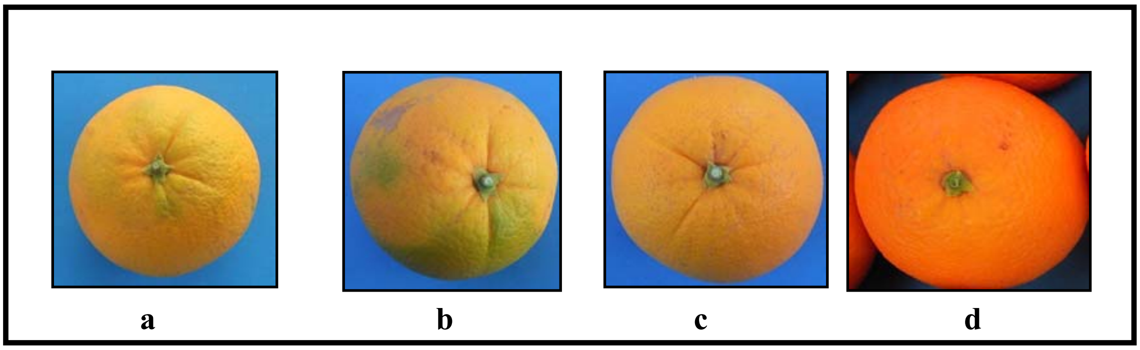

Figure 4.3: (a) Soft green, (b) hard green, (c) yellow, and (d) orange coloured fruit

Results:

A range of cultivars were sprayed with Ralex® at different stages of colour development are summarised in Table 4.1.

Table 4.1: Summary of the Ralex® application for different stages of colour development, application dates and dates of fruit harvest in 2005 season

	Stage of colour development	Date of Ralex® application	Date of fruit harvest/assessment
Experiment 1	5-10%	8 March	28 May
(Early Ryan)	25%	28 April	28 May
	100%	3 June	28 May
Experiment 2	5-10%	28 April	8 June
(Washington navel)	25%	28 April	8 June
	50%	10 May	8 June
	100%	23 May	8 June
Experiment 3	5-10%	8 March	30 June
(Bellamy navel)	100%	31 May	30 June
Experiment 4	5-10%	3 May	26 July
(Lane Late)	50%	3 June	26 July
	100%	16 June	26 July
Experiment 5	50%	16 June	25 August
(Barnfield)	100%	16 June	25 August

Experiment 1: Early Ryan

Ryan navel is an early maturing cultivar and popular for its easy peeling properties. Ralex® was applied at three different stages of colour development in this cultivar (Table 4.1). Fruit harvest was carried out on 28 May, 05. The first Ralex® application was made when fruit were 5-10% colour. The data indicated no significant differences in treated and untreated fruit for soft green colour.

Table 4.2: The effect of Ralex® application (200 ml/100 L) at different stages of colour development and its subsequent effects on final fruit colour at harvest in Early Ryan navel oranges

Stage at application	Treatment	Soft green	Yellow	Orange	Hard green
5-10% colour					
	Control	4.5	79.9	16.7	0.0
	Ralex®	6.7	92.7	0.80	0.3
	Lsd (5%)	**ns(4.8)**	***(10)**	****(16.7)**	****(0.3)**
25% colour					
	Control	3.4	71.2	19.8	1
	Ralex®	6.5	79.5	0.80	0.5
	Lsd (5%)	**ns(4.7)**	**ns(16.6)**	****(12.5)**	**ns(10)**
100% colour					
	Control	-	52.5	47.5	-
	Ralex®	-	90.0	10.0	-
	Lsd (5%)	-	*****(20.8)**	*****(20.8)**	-

*P<0.05; **P<0.01; ***P<0.001; ns, not significant

Lsd (Least significant difference) is used to compare the treatment means within the columns

The main significant difference was found for orange colour in treated and untreated fruit where less than 1% orange colour was found in treated fruit (Table 4.2). The second application was made when fruit were in 25% colour stage. Ralex® treated fruit had less than 1% orange colour than the untreated fruit at harvest (Table 4.1). When Ralex® was applied at 100% colour stage, it had more fruit in yellow colour and only 10% orange colour (Table 4.2). At this stage there was absolutely no soft or hard green colour found on any fruit. These results suggest that Ralex® application can not delay fruit colour.

Experiment 2: Washington navel

In this experiment Ralex® was applied at four different colour development stages. Fruit harvest for all fruit was carried out on 8 June, 2005. For Ralex® applied on 28 April fruit were 10% coloured (refer to Figure 4.1), data indicated that there were significant differences in soft green colour at harvest in Ralex® treated fruit as compared to control (Table 4.3). Yellow colour remained the same among treated and untreated fruit. However, untreated fruit carried more orange colour, a sign of maturity (ageing) fruit (Table 4.3).

Table 4.3: The effect of Ralex® application (200 ml/100 L) at different stages of colour development and its subsequent effects on final fruit colour at harvest in Washington navel oranges

Stage at application	Treatment	Soft green	Yellow	Orange	Hard green
5-10% colour					
	Control	13.5	44.0	42.5	-
	Ralex®	27.0	59.6	13.5	-
	Lsd (5%)	***(11.3)**	**ns(18.6)**	****(20.3)**	-
25% colour					
	Control	8.0	71.2	19.8	1.0
	Ralex®	19.5	79.5	0.80	0.5
	Lsd (5%)	***(11.9)**	**ns(16.6)**	****(12.5)**	**ns(0.4)**
50% colour					
	Control	3.3	67.2	29.4	-
	Ralex®	7.5	77.8	15.6	-
	Lsd (5%)	**ns(7.0)**	**ns(23.9)**	**ns(23.7)**	-
100% colour					
	Control	1.5	92.2	4.0	-
	Ralex®	1.0	92.3	6.5	-
	Lsd (5%)	**ns(0.7)**	**ns(13)**	**ns(12.8)**	-

*P<0.05; **P<0.01; ns, not significant
Lsd (Least significant difference) is used to compare the treatment means within the columns

When Ralex® was applied at 25% colour stage on 28 April, at harvest Ralex® treated fruit had more soft green colour than untreated fruits. Treated fruits also had less orange colour than the untreated fruit (Table 4.3). When Ralex® was applied at 50% colour stage, there were no significant differences between treated and untreated fruit for soft green, yellow or orange colour. Fruit treated with Ralex® at 100% colour stage followed that same pattern as the fruit treated at 50% colour stage (Table 4.3). This data suggested that when Ralex® was applied very earlier it may slightly delay maturity with somewhat green colour, but at the later dates Ralex® did not cause any colour delay problems.

Experiment 3: Bellamy navel

Bellamy is a nucellar selection of Washington navel and matures in July. In this cultivar Ralex® was applied at two different stages of colour development in this cultivar. Fruit harvest was carried out on 30 June 05. The first Ralex® application was made on 8 March 05 when fruit were at 5-10% colour stage. Some fruit were almost green at this stage. The data indicated that there were significant differences between treated and untreated fruit for soft green colour. Ralex® treated fruit had slightly more soft green colour than untreated fruit (Table 4.4). There were significant differences among treated and untreated fruit for yellow and orange coloured fruit. Ralex® treated fruit had more than 80% yellow and less than 10% orange colour compared to control (Table 4.4) and there was no hard green colour found on any fruit.

Ralex® application at 100% fruit colour stage (31 May) indicated no significant differences in treated and untreated fruit for any type of green colour (Table 4.4). However, Ralex® treated trees had more yellow and less orange colour than untreated fruits (Table 4.4).

Table 4.4: The effect of Ralex® application (200 ml/100 L) at different stages of colour development and its subsequent effects on final fruit colour at harvest in Bellamy navel oranges

Stage at application	Treatment	Soft green	Yellow	Orange	Hard green
5-10% colour					
	Control	0.5	23.5	76.0	-
	Ralex®	3.6	86.4	9.9	-
	Lsd (5%)	***(3.0)**	*****(18.7)**	*****(19.0)**	-
100% colour					
	Control	0.2	30.0	71.9	-
	Ralex®	1.3	84.3	18.0	-
	Lsd (5%)	**ns(2.0)**	*****(19.3)**	*****(20.7)**	-

*P<0.05; ***P<0.001; ns, not significant
Lsd (Least significant difference) is used to compare the treatment means within the columns

Experiment 4: Lane Late

Lane Late navel is a late maturing cultivar. Ralex® was applied at three different stages of colour development in this cultivar. Fruit harvest was carried out on 26 July. The first Ralex® application was made on 3 May 05 when fruit were at 5-10% colour stage. Fruit were almost green. The data indicated that there were significant differences between treated and untreated fruit for soft green colour. Ralex® treated fruit had more soft green colour than the untreated fruit (Table 4.5). There were significant differences among treated and untreated fruit for yellow and orange colour. Ralex® treatment had more yellow and less orange coloured fruit (Table 4.5). When Ralex® was applied at 50% colour stage, it followed the same trend as the earlier stage. Ralex® application at 100% colour stage resulted in no soft green or hard green colour on any fruit. However, Ralex®

treated fruit were more yellow and less orange coloured than untreated fruit (Table 4.5). The extent of the difference was smaller than the previous (50% colour stage) treatment.

Table 4.5: The effect of Ralex® application (200 ml/100 L) at different stages of colour development and its subsequent effects on final fruit colour at harvest in Lane Late navel oranges

Stage at application	Treatment	Soft green	Yellow	Orange	Hard green
0-5% colour					
	Control	3.7	25.5	70.8	-
	Ralex®	14.0	64.0	22.0	-
	Lsd (5%)	*****(4.5)**	*****(11.4)**	*****(11.2)**	-
50-60% colour					
	Control	2.0	43.0	55.0	-
	Ralex®	9.5	77.5	13.0	-
	Lsd (5%)	***(7.5)**	*****(15.1)**	*****(12.5)**	-
100% colour					
	Control	0.3	20.8	78.9	-
	Ralex®	0.0	37.1	62.8	-
	Lsd (5%)	**ns(0.5)**	****(12.9)**	****(12.9)**	-

*P<0.05; **P<0.01; ***P<0.001; ns, not significant
Lsd (Least significant difference) is used to compare the treatment means within the columns

Experiment 5: Barnfield navel

Barnfield navel is another late maturing cultivar and harvest is usually carried out in August/September depending on the market situation. Ralex® was applied at two different stages of colour development in this cultivar. Fruit harvest was carried out on 25 August 05. Ralex® application was made on 16 June 05 when fruit were 50% or 100% colour stage (Table 4.6).

Table 4.6: The effect of Ralex® application (200 ml/100 L) at different stages of colour development and its subsequent effects on final fruit colour at harvest in Barnfield navel oranges

Stage at application	Treatment	Soft green	Yellow	Orange	Hard green
50% colour					
	Control	1.0	57.0	42.0	0.0
	Ralex®	3.7	83.1	11.9	1.80
	Lsd (5%)	*****(2.0)**	*****(13.4)**	*****(13.9)**	**ns(2.4)**
100% colour					
	Control	-	23.8	76.2	-
	Ralex®	-	72.4	27.6	-
	Lsd (5%)	-	*****(13.4)**	****(13.4)**	-

***P<0.001; ns, not significant
Lsd (Least significant difference) is used to compare the treatment means within the columns

This period was in the middle of first and second sensitivity peak. The data indicated that there were significant differences between among treated and untreated fruit for proportion in the soft green colour (Table 4.6). These differences ranged from 1% to 4% not a very an important difference from a commercial point of view. Ralex® treated fruit did have significant increase in yellow colour of fruit than untreated fruit (Table 4.6). Ralex® treated at 100% colour stage had no soft green colour at all, and had a higher percent of yellow colour (Table 4.6)

Discussion:

A range of navel experiments were designed to evaluate the Ralex® effects on fruit colour. In experiments reported in this chapter the higher rate of Ralex® (200 ml/100 L) was used to quantify its effect on fruit colour. Plant growth regulator GA_3 is known to delay rind colour (Greenberg and Goldschmidt, 1989). In the two years duration of this project trees were treated with Ralex® for flower suppression in 2003 or 2004 did not exhibit any colour delay at harvest.

In 2003, Ralex® was applied as early as the first week of May while in 2004 Ralex® was applied as early as on 20 May and onwards (see Chapters 2 & 3). However, stage of colour development on the existing crop was not considered at the time of Ralex® application in 2003 or 2004 but the attention was focussed to study the effects on flower suppression, flower quality and fruit size optimisation.

The studies described in previous chapters had clearly indicated that Ralex® was more effective to suppress flowers when applied earlier during first sensitivity peak which generally occurs in May-June period. One of the apprehensions for the growers would be the colour delay issue with Ralex® use as early as May if fruit are needed to be picked for fresh market without delaying the harvests.

To study the effect on colour delay in more detail, Ralex® was applied at different stages of colour development. In Early Ryan there was not any significant colour differences from fruit treated with Ralex® as early as May or April. There were negligible amount of soft green (6%) was present in treated fruit (Figure 4.4). Although, Ralex® seemed to be having a positive effect, as most of the fruit had higher percentage of yellow colour rather than orange colour (Figures 4.4 & 4.5). Orange colour is a sign of fruit maturity and ageing. Previously, GA_3 was shown to contribute to delayed maturation, a phenomenon observed in oranges (Coggins and Lewis, 1962).

These findings are encouraging for Ralex® use in early cultivars. Growers would probably not want to see their early crop delayed if they need to pick for the early market. Once Ralex® was applied on partially coloured fruit there was certainly no colour delay indicated from our results.

In Washington navel oranges (mid maturing cultivar) a very early application in April did have slight delay in terms of soft green colour (Figure 4.7 & 4.8), however, no hard green colour was detected. This result would not have any implications on Ralex® use. Our previous results have not suggested the use of Ralex® earlier than May/June for flower suppression and at this instance Ralex® use was perfectly safe when used during first and 3rd week of May at 50% colour stage (Figure 4.9). In another navel cultivar Bellamy navel, 4% of soft green colour was evidenced on fruit treated in March. This is expected because fruit were almost green at the time of Ralex® application and March is not a practical date for its application for flower suppression.

Ralex® applied at the end of May at 100% colour stage caused rather positive effects in the treated fruit as compared to untreated fruit. There was no green colour found in any cultivar and higher proportion of fruit had yellow colour. Visually it was obvious that Ralex® may have improved the rind conditions. However, rind quality and post harvest storage data was not recorded as it was not the part of this project. The chemical formulation of Ralex® probably suppress the flowers within the unbroken bud and improve the rind quality at the same time as the chemical active constituent of Ralex® is 40 g/L Gibberellic acid. Gibberellic acid is known for it positive effects on rind firmness and improved the rind quality.

In late cultivars such as Lane Late or Barnfield colour delay was obvious at harvest when Ralex® was applied under 50% colour stage, although the percent of fruit which exhibited green colour was 14% and 4% in Lane Late and Barnfield respectively. Fruit of late cultivars usually grow at the slower rate after April and they are late maturing with regards to Brix^0 and acid in the fruit. It may be possible that the rind of late maturing cultivar is not at the same stage of maturity as the rind of early or mid maturing cultivars. Therefore, fruit in late cultivars may show some colour delay effects. However, there was not any problem of green colour at harvest with Lane Late cultivar even when application was made on 3 June (50% colour stage).

The only cultivar which did show some colour delay (green colour) at harvest was Barnfield navel that received Ralex® at 50% colour stage. However, this was found in small proportion of treated fruit. This suggests that for Barnfield growers must be cautioned about the colour delay effects. Otherwise, Ralex® application must be made at 100% colour stage as in our case 100% colour stage occurred during mid June. Mid June is an ideal time for flower suppression treatments. The data from different cultivars reported in our study suggest that there is no real danger of colour delay with Ralex® when applied in the month of June. However, very warm winters can delay rind colour regardless Ralex® application. Fruit colour responses to Ralex® and its interaction with climate warrants further research.

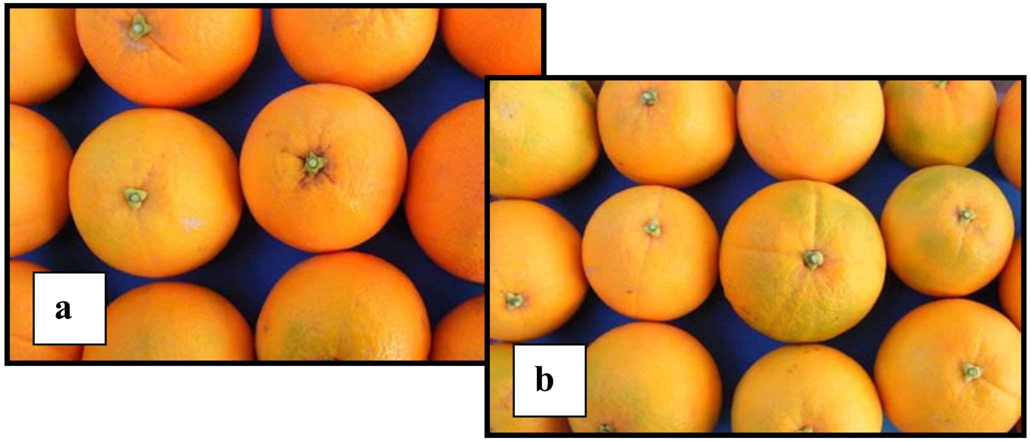

Figure 4.4: Fruit colour at harvest for (a) control and (b) Ralex® (200 ml/100 L) treated at 5-10% colour stage in Early Ryan navel for 2005

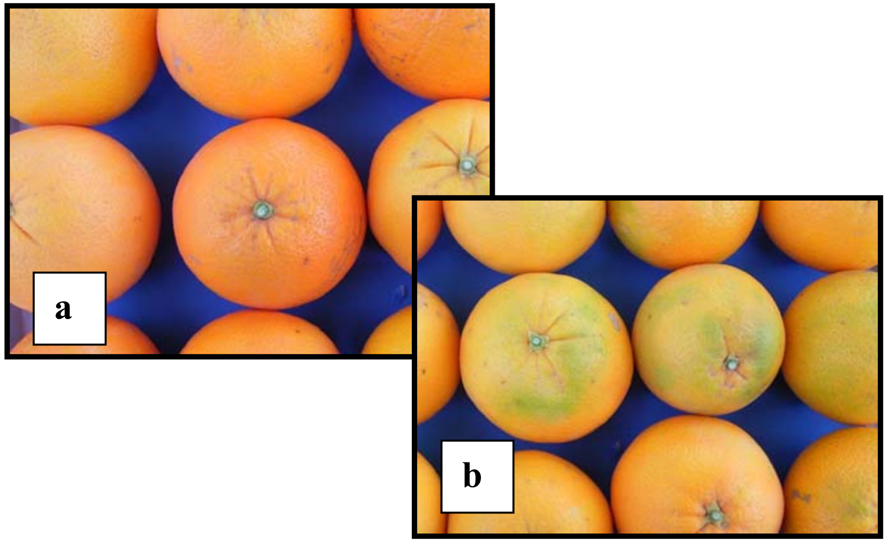

Figure 4.5: Fruit colour at harvest for (a) control and (b) Ralex® (200 ml/100 L) treated at 25% colour stage in Early Ryan navel for 2005

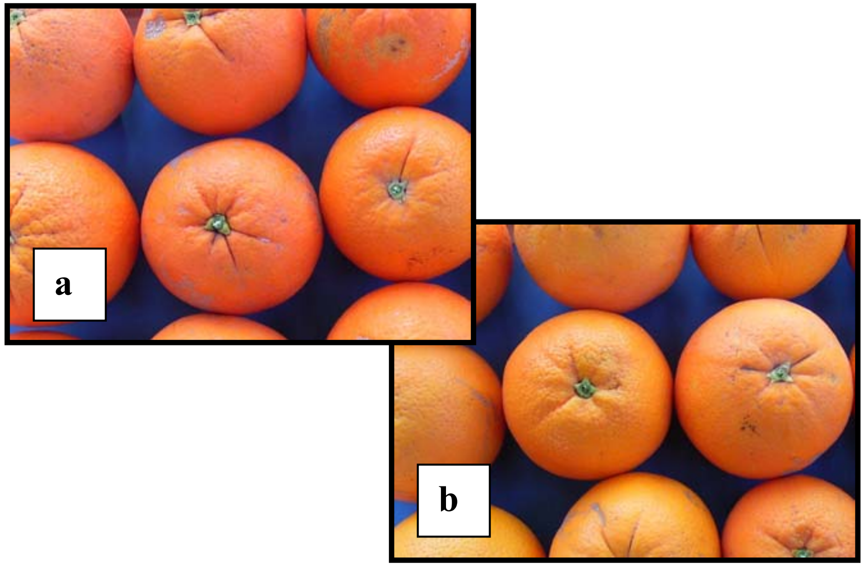

Figure 4.6: Fruit colour at harvest for (a) control and (b) Ralex® (200 ml/100 L) treated at 100% colour stage in Early Ryan navel for 2005

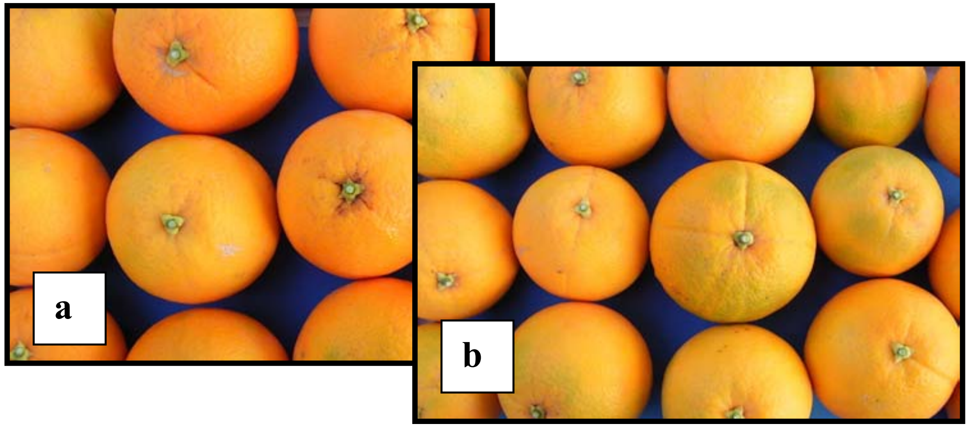

Figure 4.7: Fruit colour at harvest for (a) control and (b) Ralex® (200 ml/100 L) treated at 5-10% colour stage in Washington navel for 2005

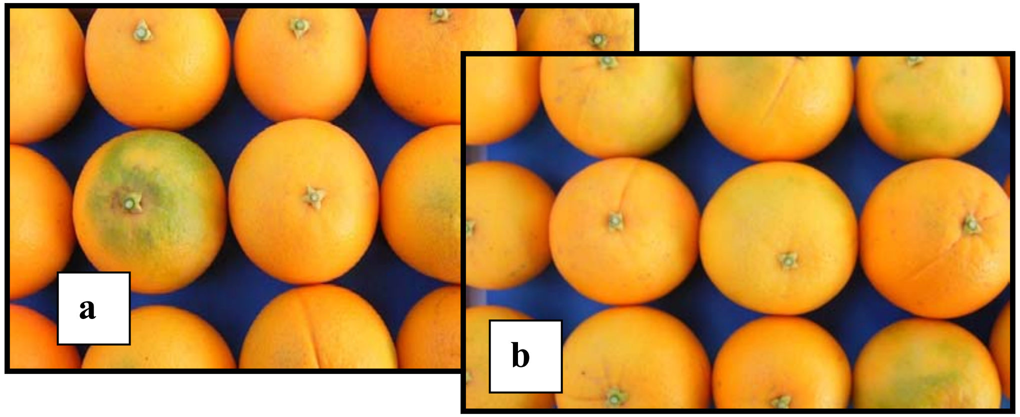

Figure 4.8: Fruit colour at harvest for (a) control and (b) Ralex® (200 ml/100 L) treated at 25% colour stage in Washington navel for 2005

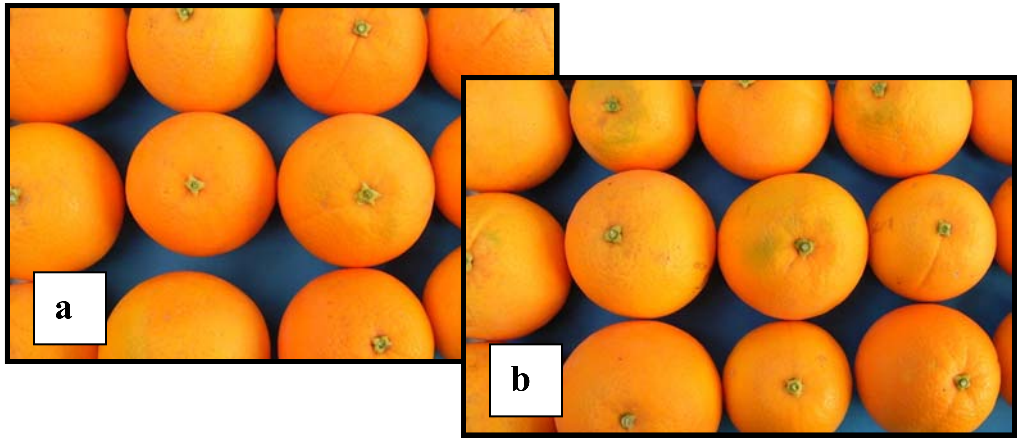

Figure 4.9: Fruit colour at harvest for (a) control and (b) Ralex® (200 ml/100 L) treated at 50% colour stage in Washington navel for 2005

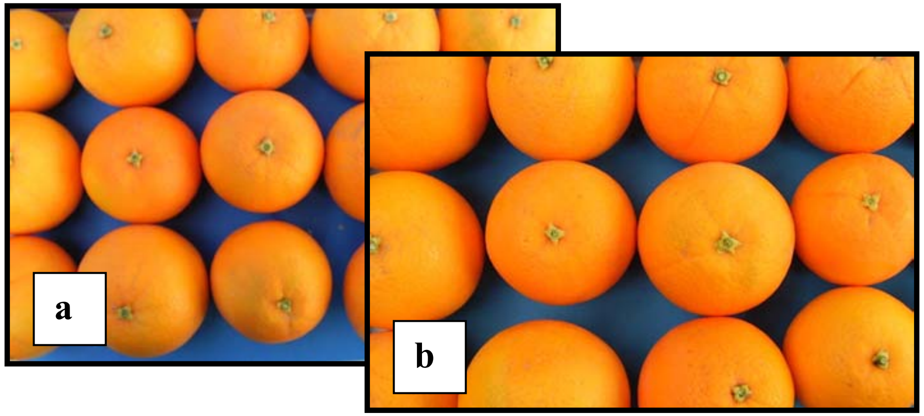

Figure 4.10: Fruit colour at harvest for (a) control and (b) Ralex® (200 ml/100 L) treated at 100% colour stage in Washington navel for 2005

5. Recommendation for Ralex® use in navel oranges

Recommendations are based on the outcome of two years Ralex® study conducted at ARAS, Dareton. The study was carried out in an "on-flowering" and "off-flowering" year. Experimental trees were selected from the same blocks for 2003 and 2004 Ralex® applications for Washington navel and Navelina cultivars to avoid rootstock, soil and site variations across both seasons.

1. Ralex® application @150-200 ml/100 L in mid June in an anticipated "on-flowering" year is an effective treatment for reducing leafless inflorescences and increasing the percent of fruit size in the highest class (77-87 mm) at harvest.

2. Due to difference in bud break timings across different cultivars, growers must keep a good record of the bud break for their navel blocks. Ralex® should be applied at 150 ml/100 L around mid June (approx. 4-6 weeks) before bud break. Therefore, the use of Ralex® in the first sensitivity peak is recommended.

3. In experiments reported in this study there was no yield reduction with the fruit size increases. Perhaps yield losses will become apparent when the reduction of leafless inflorescences occurs beyond 50% which will only be possible with higher Ralex® rates applied very early in the season.

4. Investigations on fruit colour trials revealed no colour delay affects at harvest with Ralex® use if applied during late May-June or at 50% colour stage. Ralex® indicated positive effects on skin colour with higher percentage of yellow and lower percentage of orange coloured fruit. Ralex® effects for rind quality needs urgent attention for further research.

5. Ralex® may substitute for May/June GA_3 application without delaying the colour or harvest date. Further research is needed to explore this possibility.

6. Ralex® application can eliminate alternate bearing across two growing seasons. Return fruit size data indicated the potential benefits of Ralex®. In both 2003 & 2004 seasons Ralex® decreased leafless inflorescences; however, mixed inflorescences remained unaffected. Final yields were very similar across two years.

7. Ralex® application is not recommended in an anticipated "off-flowering" year. Results in this project did not suggest any benefits of fruit size increases at harvest after "off-flowering" year application of Ralex®.

8. Ralex® effects may vary among different cultivars. Tree age and health, bud break differences and climatic variations may affect bud responses to Ralex® in terms of flower suppression.

9. Ralex® effects may also vary if not used carefully according to the label, with regards to timing and rates.

10. A permit is now in place (22 June 2005-30 September 2007) for a limited use of Ralex®. Sumitomo Chemical Australia can be contacted to obtain further information.

6. Technology Transfer and Extension

Ralex® flowering field day

Project results were presented at a major industry field day held at Dareton in October, 2003. The field day covered the aspect of flowering intensity and flowering type data based on the preliminary results from 2003 Ralex® application. Data was presented for Navelina and Washington navel oranges and growers had the opportunity to observe the treated and untreated trees visually during flowering period.

Grower's Presentations/Farm Walks

A range of citttgroup presentations were held in different parts of Australia. These presentations and farm walks were arranged by the industry development officers for their representative areas.

1.	Ralex® Results (Cittgroup) Presentation, Nangiloc, NSW	5 May 05
2.	Ralex® Results (Cittgroup) Presentation, Dareton, NSW	4 May 05
3.	Ralex® Results (Cittgroup) Presentation, Harvey, WA	6 Apr 05
4.	Ralex® Results (Cittgroup) Presentation, Gingin, WA	7 Apr 05
5.	Ralex® Results (Cittgroup) Presentation, (HO) Perth, WA	8 Apr 05
6.	Ralex® Results (Cittgroup) Presentation, Yanco, NSW	22 Mar 05
7.	Ralex® Results (Cittgroup) Presentation, Griffith, NSW	23 Mar 05
8.	Ralex® Results (Cittgroup) Presentation, Dareton, NSW	1-2 Apr 04
9.	Ralex® Results (Cittgroup) Presentation, Collignan, VIC	19 May 04
10.	Ralex® Results (Cittgroup) Presentation, Loxton, SA	9 Jun 04
11.	Ralex® Results (Cittgroup) Presentation, Waikerri, SA	10 Jun 04
12.	Ralex® Results (Cittgroup) Presentation, Yandilla Park, SA	11 Jun 04
13.	Ralex® Results (Cittgroup) Presentation, Alstonville, NSW	29 Jul 04
14.	Ralex® Results (Cittgroup) Presentation, Gosford, NSW	28 Jul 04
15.	Ralex® Results (Cittgroup) Presentation, Yanco, NSW	19 Aug 04
16.	Ralex® Results Field Day, Dareton, NSW	10 Oct 03
17.	Ralex® Results (Cittgroup) Presentation, Collignan, VIC	1 Dec 03
18.	Ralex® Results (Cittgroup) Presentation, Barham, VIC	1 Dec 03

Publications

- **Khurshid, T.** 2004. Ralex – a new growth regulator used for flower suppression in Navel oranges. (in Print).

- **Khurshid, T.** 2004. Ralex use for flower manipulation in Navel oranges. (in Print)

- **Khurshid, T. and Bevington, K. B.** 2004. Crop load manipulation with Ralex for fruit size increase (in Print).

- **Khurshid, T.** 2004. Ralex use for navel size increase. *Good Fruit and Vegetables*. Vol. 15(1):16

- **Khurshid, T.** 2004. Ralex use for navel size increase. *Herald Weekly Times*. 7TH May

- **Khurshid, T.** 2003. Ralex use for bigger sized oranges. *Cittgroup* NSW DPI Farm Walk, Dareton NSW, Australia.

- **Khurshid, T.** 2003. Ralex Trials 2003/04 – Preliminary results. NSW DPI Farm Walk, Dareton NSW, Australia.

National and International Conferences

Data was presented in national and international conferences to scientific audience, academics and industry people.

- **Khurshid, T.** 2005. Flower suppression with Ralex use to enhance fruit size in ‘Navel’ oranges. *Proceedings of New Zealand Institute of Agricultural and Horticultural Science*, Lincoln University, New Zealand.

- **Khurshid, T.** 2004. Ralex – a new growth regulator used for flower suppression in Navel oranges. *Proceedings of the International Society of Citriculture*, 10th ISC Congress, Agadir, Morocco.

- **Khurshid, T.** 2004. Ralex use for flower manipulation in Navel oranges. *Proceedings of the Australian Society of Horticultural Science,* Hayat Coolum, Sunshine Coast, Queensland, Australia.

- **Khurshid, T.** 2004. Ralex presentations. 56th Australian Citrus growers Conference (19-21 April), Mildura, Victoria, Australia.

- **Khurshid, T.** 2003. Ralex presentations. 55th Australian Citrus growers Conference (6-10 April), Leeton, NSW, Australia.

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Garcia-Luis, A.; Fornes, F.; Sanz, A. and Guardiola, J. L. 1988. The regulation of flowering and fruit set in Citrus: Relationship with carbohydrate levels. Israel *Journal of Botany* 37:189-201.

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Appendix

A research permit is now in place (22 June 2005-30 September 2007) for a limited use of Ralex®. Sumitomo Chemical Australia can be contacted to obtain further information.

Copy of the Permit number: (PER8269) from Australian Pesticides and Veterinary Medicines Authority is attached on the next pages.

→ MARGO DAVIS ←

Hi Margo,
Here is advance copy of the permit. Formal copy should arrive next week. Rgds, [signature] (Ron Marks)
1640
W 22/6/05

Australian Pesticides & Veterinary Medicines Authority

PERMIT TO ALLOW RESEARCH USE OF AN AGVET CHEMICAL PRODUCT

PERMIT NUMBER - PER8269

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows any person to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 22 June 2005 TO 30 September 2007.

Permit Holder:
SUMITOMO CHEMICAL AUSTRALIA PTY LTD
501 Victoria Avenue
CHATSWOOD NSW 2067

Persons who can use the product under this permit:
Employees of Sumitomo Chemical Australia Ltd., or contractors or growers under their supervision.

CONDITIONS OF USE

Product to be used:
RALEX PLANT GROWTH REGULATOR
containing: 40 g/L GIBBERELLIC ACID as its only active constituent.

Directions for Use:

Crop	Purpos	Rate
CITRUS (ORANGES)	FOR REDUCTION OF FLOWERING AND FRUITING (THINNING) OF ORANGES, IN THE SEASON FOLLOWING APPLICATION.	150-200mL/100L

Critical Use Comments:
NOTE: APPLICATION OF RALEX MAY DELAY HARVEST.
Apply once per season, using an air-blast sprayer or similar, in a spray volume of at least 3000 L-spray-mix/ha.

Refer to the **RESTRAINTS** on the product label.
DO NOT apply to trees that are in an "off" flowering year.
Apply as a single spray at flower bud initiation stage. This is generally from May to June. Timing of application is dependant on variety and location.
Consult with your Sumitomo Chemical Australia Ltd. representative for the latest information on the best application timing for your varieties.

Note the **Mixing** and **Application** instructions on the product label (particularly re pH adjustment of spray-mix), with the following amendments below:

- for optimum results in oranges, uniform coverage of **BUD-WOOD** is critical, as well as leaves, shoots and buds.
- to optimise response, make applications during periods that are conducive to longer drying: e.g. late afternoon in some areas. In areas prone to dew, this may restrict application to the hours between 10 am and 4 pm, as dew may dilute the spray mix significantly (by 10 am, dew has usually dried and after 4 pm, dew starts to build up).

Withholding Period:
NOT REQUIRED WHEN USED AS DIRECTED.

Jurisdiction:
ALL States.

ADDITIONAL CONDITIONS:

THIS PERMIT provides for the use of a product in a manner other than specified on the approved label of the product. Unless otherwise stated in this permit, the use of the product must be in accordance with instructions on its label.

PERSONS who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit.

TRIAL RECORDS
The permit holder must maintain records of the trials performed under this permit. Specifically details must include the date and location where the trials were conducted, commodities treated, rates and frequency of application, total amount of product used and the names and addresses of the persons conducting the trial. These details must be maintained for a minimum period of two years from the date of expiry of this permit and must be made available to the APVMA upon request.

Maximum Area to be Treated:
A maximum total of 1000 hectares/season, across all states.

Issued by

Jay KOTTEGE
Delegated Officer