Chapter 5

Discussion

Lychee cv. Kom is classified as a low chilling requirement cultivar. In the first study, potassium chlorate ($KClO_3$) with paclobutrazol (PP333) was applied to lychee cv. Kom. It was found that potassium chlorate with paclobutrazol at the concentrations of $KClO_3$: PP333 = 1 : 5, 1 : 7 and 1 :9 g/pot could reduce flowering time (time between treatment and flowering). The treated trees were flowering about two weeks earlier than the untreated trees. Therefore, the fruits could be harvested before the normal season which could be sold in higher price. In addition, the flowering percentages of the treated trees were also higher than the untreated trees. However, the high concentrations of potassium chlorate with paclobutrazol ($KClO_3$: PP333 = 5 : 5 and 5 : 7 g/pot) could toxic to the lychee. The toxic symptoms were chlorosis and defoliation. These toxic symptoms were as same as the chlorate toxic symptom in longan.

Lychee is susceptible to chlorate. Therefore, potassium chlorate cannot be use as a flowering induction substance for lychee as in longan. It should be caused by lychee leaves contain small amount of antioxidant substances while longan leaves contain high amount of antioxidant substances. The application of potassium chlorate with paclobutrazol in lychee could be one of the key to control flowering of lychee. The application of potassium chlorate with paclobutrazol could reduce the toxicity of chlorate to lychee as seen in the treatment of $KClO_3$: PP333 = 5 : 9 g/pot which did not show the toxic symptom of chlorate while the treatments which contained lower amount of paclobutrazol, $KClO_3$: PP333 = 5 : 5 and 5 : 7 g/pot showed toxic symptom. Paclobutrazol is a GA inhibitor which could use for enhancing flowering percentage in lychee but only paclobutrazol still cannot use for inducing lychee flowering. Therefore, potassium chlorate application in lychee at smaller amount than using in longan and added with paclobutrazol should be a potential method to induce lychee flowering. From the results of this study, Potassium chlorate with paclobutyrazol could reduce flowering time of the treated trees. The application of $KClO_3$: PP333 also tended to reduced the panicle length and width of the treated trees. This should be the effect of $KClO_3$ and PP333. It agreed with many reports, $KClO_3$ and PP333 reduce GA contents, which studied in longan and mango respectively. Therefore, the application of GA after flowering to the $KClO_3$: PP333 treated trees should increase the panicle length and width.

However, all of the treated and untreated lychee cv. Kom trees were flowering. From this point the three appropriate $KClO_3$: PP333 concentrations were selected to apply for lychee cv. Chakrapad, a high chilling requirement cultivar, which were grown at the fruit tree nursery of Department of Horticulture, Faculty of Agriculture, Chiang Mai University. It is generally known that lychee cv. Chakrapad cannot grow in this area because it does not flowering due to its high chilling requirement. But all of the potassium chlorate with paclobutrazol treated trees were flowered while the untreated trees did not flowering. This result inferred that the used of potassium chlorate with paclobutrazol could induce flowering of lychee by lower its chilling requirement.

Three appropriate concentrations of potassium chlorate with paclobutrazol were selected from the first study to use for induce off-season flowering in lychee cv. Hong Huay and Chakrapad which grew in the production field of Chiang Rai Horticulture Research Center during July, 2004 (rainy season). It was found that potassium chlorate with paclobutrazol could not induce off-season flowering of both cultivars, It could be caused by the amount of potassium chlorate with paclobutrazol which applied to the trees were too small. Because in the rainy season, potassium chlorate with paclobutrazol was leaching by the rain and the soil type is clay which could absorb potassium chlorate and paclobutrazol higher than the sandy soil. Therefore, the application by soil drenching which were absorbed by the plant in these studies might be interrupted. In addition, soil which high moisture content before potassium chlorate with paclobutrazol application could affect the absorption of ClO_3^- and paclobutrazol. Pankasemsuk (2001) reported that plants with drought stress before potassium chlorate application could absorb potassium chlorate more than those without drought stress. Due to there are many clouds in rainy season. Sunlight also will be shaded by the clouds. This affects the effectiveness of potassium chlorate in inducing flowering. Because nitrate reductase which is necessary for potassium chlorate flower inducing process do not effective without sunlight. In rainy season, lychee trees have highly vegetative growth. In order to induce off-season flowering, the vegetative growth must be overcome before flower bud induction. In the high vegetative growth period, lychee trees have high internal auxins and gibberellins contents. This should be another problem for inducing the off-season flowering. So, increasing in the amount of potassium chlorate with paclobutrazol for inducing off-season flowering of lychee is interesting to study in the future. For increasing the amount of potassium chlorate with paclobutrazol which applied to the lychee trees, direct inject of potassium chlorate with paclobutrazol to the trunk or big branches is another choices. The application timing especially in the sunny day should be considered and increasing only paclobutrazol concentration is also interesting in reducing the gibberellins content in the lychee off-season flowering induction. In the following flowering season (December – January), Hong Huay treated trees flowering percentage did not differ from the untreated trees. But the flowering percentages of Chakrapad treated trees were higher than the untreated trees. This should be the effect of paclobutrazol as reported by Menzel and Simpson (1990). It can be inferred that amount of potassium chlorate with paclobutrazol which use in this study could not induce off-season flowering. However, it is still interesting to use potassium chlorate with paclobutrazol in higher amount in further studies.

The study of the application potassium chlorate with paclobutrazol for 2 years old lychee cv. Hong Huay at immature (10 days old) and mature (30 days old) leaves stages on July 4, 2004, it was found that potassium chlorate with paclobutrazol could not induce off-season flowering in both leaf maturity stages as it was found when applied potassium chlorate with paclobutrazol in 14 years old Chakrapad lychees. In the following natural flowering season (January, 2005), the treated 2 years old Hong Huay lychee could have flowering normally as in the untreated trees. It could be inferred that leaf maturity and plant age did not influence the off-season flowering inducing by potassium chlorate with paclobutrazol. It is known that the effective potassium chlorate application for inducing flowering in longan is the application of potassium chlorate at fully leaf mature stage. But the most effective paclobutrazol application for inducing flowering in mango is the application of paclobutrazol at immature leaf stage (fully expand and still have bronze colour). Manochai *et al.*, (2005) reported that most subtropical fruit trees need the presence of mature leaves for flowering induction, whereas young immature leaves may inhibit this process. Without $KClO_3$ treatment there was no flowering induction at this out of season time. With $KClO_3$ application an increasing efficacy of the treatment with increasing leaf age was found. Full flower induction was achieved only with 40-50 days old "hardened" leaves. Very young leaves (10 days old) almost prevented $KClO_3$ induced flowering. The presence of leaves has long been considered as an absolute necessity for flowering induction of most fruit trees whether they are deciduous or subtropical (Davenport and Nunez-Elisea, 1997). With subtropical trees this necessity is restricted to mature leaves. Nothing is presently known about the "mode of action" by which mature leaves positively affect flowering induction. Mature leaves are unable to induce flowering in longan, as well as in other subtropical trees, in the absence of low temperature or sufficient light, therefore, it cannot be considered as a flowering inducing factor by itself. They can only be seen as some kind of a "co-factor" or as a "storage organ" for flowering induction signals from other organs of the tree (Bangerth, 1997). It is, therefore, a surprise that $KClO_3$ treatment is able to replace the effect of the main and absolutely essential flowering signal, cool temperature, but not the one of mature leaves. More refined experiments are needed to elucidate whether $KClO_3$ is under all circumstances unable to overcome the "young leaf effect". Most trees show opposing flushes of root and shoot growth, which presumably could affect $KClO_3$ efficacy on flowering induction. A good opportunity to rule out this possibility would be the injection technique that could become of considerable scientific importance in this respect. Therefore, it is difficult to find out the best leaf stage for off-season flowering inducing by potassium chlorate with paclobutrazol. From the result of these studies, the application of potassium chlorate with paclobutrazol for lychee in fully leaf mature stage was used in the further studies.

The application of potassium chlorate with paclobutrazol for induce early season flowering in 14 years old lychee cv. Hong Huay on November 16, 2004, it was found that the potassium chlorate with paclobutrazol treated trees were flowering 7-9 days earlier than the untreated trees. It could be due to potassium chlorate with paclobutrazol affected the hormonal balances of the treated trees. However, the flowering percentage, panicle length and panicle width did not show any difference between the treated and untreated trees. It could be inferred that potassium chlorate with paclobutrazol treatments affected only the flowering process but it did not affect the growth and development of the panicle. It agree with Sritontip *et al.,* (1999) which reported that soil drench at 5.0 and 5.25 g/m^2 of potassium chlorate, The treated trees flowered better and earlier than untreated trees. They reported that $KClO_3$ could induce high percentage flowering of terminal buds in longan trees even out of season. The $KClO_3$ were applied at 0, 4, 8 and 12 g/m^2 to E-Daw but only, 0, 1, 2 and 4 g/m^2 to Si-Chornpoo, without $KClO_3$ application there was no flowering in out of season experiments. Aleady 4 g/m^2 of $KClO_3$ induced more than 80% of the buds to flower and 8 g/m^2 had already a saturating effect. Flowering occurred already 21 days after $KClO_3$ treatment (Manochai *et al.,* 2005). Soil drenched with potassium chlorate at 5 g/m^2 of canopy, foliar spray 1,000 ppm potassium chlorate had highest percentage of leaf flushing and the least time of terminal bud break comparing to the untreated treatments. The longan trees treated with $KClO_3$ at 5 g/m^2 had flower emergence better than untreated trees and decreased leaf flushing (Sritontip *et al.,* 1999). Trees treated with distilled water had no flower bud development. Trees sprayed with $KClO_3$ at 2,000 mg/l, applied with $KClO_3$ on soil surface at 2.5g/m^2 canopy appeared to have developed their flower buds at three weeks after the application. Trees with foliar application of $KClO_3$ at 2,000 mg/l flowered 82%, with $KClO_3$ on soil surface at 2.5 g/m^2 flowered 76% (Poruksa *et al.,* 1999). However, the factors which need to be taken into consideration are soil type,_availability of water supply, general health of the plant and management of the_orchard. Trees grew on a sandy soil respond better to $KCLO_3$ than those on a heavy clay soil. Watering is essential in an area with a long dry spell, and the plant must be healthy and dormant in vegetative growth at the time of chemical application. Different cultivars are found to require different rates of chemical to induce flowering of the longan (Subhadrabandhu and Yapwattanaphun, 2001 b).

Paclobutrazol applications, foliar spray (1.00-4.00 g/l) or soil drenching (0.25-1.00 g/m^2 tree ground cover), reduced the percentage of terminal branches flushing vegetatively before panicle emergence and increased the level of flowering. The maximum level of flowering in paclobutrazol treated trees occurred when the control trees bloomed moderately (40—60% of terminal branches). The responses were sometimes weak when the trees were very vigorous (<30% bloom). Paclobutrazol had no significant effect or reduced flowering of heavily blooming (70 - 100% bloom) trees (Menzel and Simpson,1990). Paclobutrazol applied as soil drench at 2, 4, 8 g ai/tree were compared to the single spray at the concentrations of 125, 250, 500 ppm and the untreated control in the 12 years old lychee cv. Hong Huay. Soil drench treatment did not affect vegetative growth but spray increased the diameter of internode greater than soil drench and untreated control. The treatment did not affect flowering, while soil drench reduced panicle length to be shorter than spraying and control (Chaitrakulsub *et al.*, 1992). Single spray of paclobutrazol follow by ethephon at the concentrations of 1,000 : 500 ppm reduced the percentage of leaf flushing about 10 percents compared to the untreated control, but did not affect the percentage of flowering (Chaitrakulsub *et al.*, 1989).

For the application of potassium chlorate with paclobutrazol for induce early season flowering in 14 years old lychee cv. Hong Huay on November 16, 2004, it was found that IAA and ethylene contents did not differ between treated and untreated trees. While the GAs contents reduced but the cytokinins contents increased in the treated trees. This could be inferred that potassium chlorate with paclobutrazol did not affect the IAA and ethylene contents of the lychee trees. The reducing of GAs contents should be affect by paclobutrazol and potassium chlorate. However, the increasing of cytokinins should be only affected by potassium chlorate. The changed of GAs and cytokinin contents should be one of the causes of the early flowering in the treated trees. But this change did not affect flowering percentage, panicle length and panicle width. It agree with Chen (1990) which reported that the changes in cytokinins and gibberellins in xylem sap of lychee *(Litchi chinensis* Sonn. cv. Heh yeh) trees were investigated at the stages of leaf expansion, dormant bud (when apical leaves are dropped), 30 days before flower bud formation, flower bud formation, and full bloom of grafted field-grown lychee trees. Also, the diffusible IAA and ABA in difusate from shoot tips were examined at the successive stages of development. High gibberellins were found in the xylem sap at the stage of leaf expansion. A Constant level of IAA was maintained through the five growth stages. At 30 days before flower bud formation, ABA increased dramatically. Concurrently, total cytokinins content increased in the xylem sap, reaching a maximum during flower bud formation and full bloom. Gibberellins content in the xylem sap was at a low level 30 days before flower bud formation and through the stage of flower bud formation. The cytokinins content in the stem apex tissue varied with the stage of growth. The cytokinins were low at eight weeks prior to flowering and constant until six weeks prior to flowering when flower bud initiation took place. The increment was found at four weeks and rose to maximum at two weeks prior to flowering then the level was constant again until flower emergence. The level of gibberellin-like substances was high at four and three weeks. Then it decreased at two weeks prior to flowering when flower initiation was found. At the flower emergence, gibberellin-like substances were not deteced (Naphrom *et al.,* 2001). The level of cytokinin-like substances in stem apex of lychee increased at the time prior to flowering and the degree of flower bud initiation increased in relation to the rise of cytokinins content. This result was similar to those found in mango shoot where cytokinins content was low before flower bud initiation but rose to high level at initiating stage and reached the highest level after flower bud initiation (Chen 1991). Whereas the level of gibberellin-like substances showed an opposite trend. The level of gibberellins decreased at the time prior to flower bud initiation. Chen (1990) also reported low level of the gibberellins content in xylem sap of mango and lychee shoots at flower bud initiation and full bloom. High amounts of endogenous growth substances in the reproductive structure and the changes in their levels during development suggested that these chemicals to play some role in the control of flower bud initiation, inflorescence differentiation and growth. There are few studies on the metabolism of these growth substances during flowering although available evidence indicated that altered metabolism of growth regulators, such as GAs and cytokinins, may play an essential role in the control of flowering (Bernier,1985).

Therefore, the effects of potassium chlorate with paclobutrazol treatments should be caused by the increasing of cytokinins and the reduction of GAs which promote a better flowering in the treated trees. The influence of the environmental factors which affected the stage of development of lychee trees was also the important factors in the flowering process. The treatments of potassium chlorate with paclobutrazol in this study could not overcome the effect of the environmental factors. Therefore, potassium chlorate with paclobutrazol could only induce early season flowering but they could not induce off-season flowering.

The total non-structural carbohydrate (TNC) in untreated trees reduced at 2nd week after treatment but it slightly increased at the 4th week after treatment. This period of time, November, should be the natural floral induction period of lychee. The cool weather could promote the dormancy of the trees before changing from vegetative growth to reproductive growth. The cool weather also reduced the photosynthesis rate of the leaves which could resulted in the reduction of TNC in leaves. In addition, the TNC of leaves should be transported to the shoots where the flower buds developed. In potassium chlorate with paclobutrazol treated trees, the TNC contents reduced at 2nd week after treatment and slightly reduced at the 4th week after treatment. But the TNC contents of treated trees were less than the control. This should be caused by the photosynthesis inhibited effect of potassium chlorate and/or potassium chlorate with paclobutrazol accelerated the TNC transportation out of the leaves.

For TNC contents in shoot, the TNC contents in the untreated trees rapidly increased during 2nd week after treatment and slightly increased until the 4th week after treatment. This should be caused by the TNC was transported from leaves to shoot which facilitated the flower induction process. However, the received TNC was not used due to the apical buds were still in the dormancy stage before flower induction began. Therefore, the accumulation of TNC in the shoot increased. For the treated trees, the changes of TNC were the same as the untreated trees. But the TNC contents in the treated trees shoots were less than those of the untreated trees. This should be caused by potassium chlorate with paclobutrazol shorten the dormancy stage of the apical bud in the treated trees and/or it did not take place. Therefore, the TNC contents in shoots reduced and the flowering time was decreased in the treated trees.

The leaves RS tended to reduced during this study in all treatments. At 4th week after treatment, the leaves RS contents of the treated trees were lower than the untreated trees. It should be caused by the translocation of RS from the leaves to the shoots which the RS used in the flower bud induction. The cool weather also reduced the photosynthesis rate and respiration rate of the trees. Therefore, the need in using RS in the leaves cell also reduced. It could be another reason for the reduction of RS leaves. For the potassium chlorate with paclobutrazol treated trees, the reduction of

RS was greater than the untreated trees. It should caused by potassium chlorate which inhibited photosynthesis and increased the respiration rate (Pankasemsuk, 1999). Therefore, the RS contents in the leaves were using the respiration. In additional, the RS should be transported from the leaves to the shoots more than the untreated trees.

The shoots RS contents in all treatments rapidly increased during the 2nd and 4th week after treatment. However, the shoots RS contents of the untreated trees were lower than the treated trees. This should be caused by the natural flowering process which lychee trees would come into the dormancy stage before flowering. In this stage the TNC and RS will be transported from the leaves to the shoots as found reduced in the untreated trees. Potassium chlorate with paclobutrazol should reduce this stage. Therefore, the flowering of the treated trees were earlier than the untreated trees. For the sink and source theory, flower bud is the strong sink. The leaves which are known as the source will transported their storage food (TNC and RS) to the shoots where the flower bud occurred. It agreed with Wangsin and Pankasemsuk (2005) which reported that the treated of $KClO_3$ at 0,200, 500 and 800 g/tree by soil application in longan. TNC all $KClO_3$-treated trees tended to decrease before flowering (1st - 3rd week) then increase after flowering, while the untreated trees tended to decrease gradually. The treated of $KClO_3$ at 2 g/l by foliar sprayed at young and mature leaves stage in longan. In all treatments, TNC tended to decrease from the beginning until the 4th week after treatment and increased during the 4th to 6th (Charoensri *et al.,* 2005). Pichakum and Kunyamee (2005) reported that TNC and RS concentrations increased significantly during the panicle development of longan. Reproductive structures are very strong sinks, as shown by rapid transport of large amounts of reserve carbohydrates and current photosynthate into growing such as the flowers and fruits. Available carbohydrates contents increased along with its growth. The ratio of TNC: TN (total nitrogen) in shoots and leaves of longan cv. Daw related with flowering and setting. TNC content in shoots was higher than in the leaves. Kiatsakul (2004) reported that It was not significant difference in leaves TNC, but shoots TNC of treated longan trees has significantly higher on the 2nd and 3rd weeks after potassium chlorate treatment. RS content of treated leaves were significantly lower than controlled plants in the 4th week after the treatment. Nevertheless, RS contents of the shoot at the 2nd, 3rd and 4th week in treated plants were higher than controlled plants.

However, Thonglem (2000) reported that TNC fluctuated without a pattern during the flowering process in the longan. The TNC content in leaves and shoots every week was not stable (Sritontip *et al.*, 2005). Menzel *et al.* (1995) also reported that high carbohydrate content was not necessary for flower initiation in the lychee. Jitareerat (2002) reported that dormancy breaking which was a part of the mechanism in stimulating flowering and flowering of longan tree was not affected by total nonstructural carbohydrate (TNC) and reducing sugar (RS) levels in the corresponding shoot or leaf tissues.

In the further studies, amount of potassium chlorate with paclobutrazol should be increased approximately two times in the application for off-season flowering induction for lychee which grew in the orchard due to the size of the trees and the physical property of soil.