

Regulation of flowering time for longan (*Dimorcarpus longan*) production in Thailand

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Abstract

Fresh longan fruits are now available in local markets in Thailand almost all year round. This is possible because the technique in producing off-season longan has been recently discovered and being adopted to practical use by growers in Thailand. The use of non-seasonal flowering cultivars and the application of chemicals to induce flowering in the seasonal flowering cultivars are practiced by growers in various provinces. The methodology for off-season production of longan in Thailand with the possible physiological responses of the trees is discussed.

Key words : *Dimorcarpus longan*, chemical application, flower induction, off-season crop, potassium chlorate.

Most tropical and subtropical fruit trees including longan are seasonal cropping with short harvesting season. This problem together with short storage life of these fruits are disadvantage to growers, as there are plentiful of tropical and subtropical fruits in the market with low price at the peak harvest.

Attempts to lengthen the supply of longan fruits have been searched by developing more cultivars with various flowering time, by selecting different growing areas with different microclimates to manipulate growth cycles as well as introducing various techniques in orchard management with the hope to force flowering of longan. However, these efforts were not so successful at present as the results are not consistent.

Producing longan in the off-season months in Thailand came to the turning point around the end of 1998, when a group of local Thai and Taiwanese businessmen made a contract with some longan growers in Pa-Sang District, Lamphun province as well as some orchards in the nearby Chiang Mai province. They rented these orchards for their secret management with the aim of producing early longan crop. Including in their practices, they applied greyish white chemical as soil drenching around the canopy or applied as a solution diluted in water, and continued watering the trees after application. About 20-25 days after this application, emergence of floral inflorescence was evident in most treated trees. However, there were some trees that showed declining symptoms such as yellow leaves, and some shoots were sprouted in some trees with no flowering occurred (Jungyoosuk, 1999). This chemical substance was later analysed and identified as potassium chlorate. The discovery of potassium chlorate is a break-through for producing off-season longan in Thailand. Since then many experiments have been conducted by scientists from various institutions. As potassium chlorate is a major compound in making fire-work, and it is quite harmful if not properly used. The license for importing this chemical has to be permitted from the Defense Ministry. Attempts to find alternative chemicals have been conducted and it was reported that sodium chlorate and possibly magnesium chlorate can also be used to induce flowering of longan (Department of Agriculture, 1999).

Hypothetical aspects on flowering of longan: Under natural conditions, flowering of longan depends on the climatic

conditions imposed on the trees. The period of cool and dry winter is ideal condition for flowering. Longan is quite sensitive to environmental changes for flowering which is seen in the irregular yields from year to year. It is believed that seasonal changes on environment will trigger the changes in endogenous hormonal levels which favor flowering. Huang (1996) studied the level of endogenous hormones that favour floral bud initiation in longan. He found high level of cytokinin (isopentenyl adenosine) and low level of gibberellin and abscisic acid during floral initiation. This finding is also supported by Chen *et al.* (1997) who found low level of cytokinin during the sprouting of vegetative shoot and the level increased during floral initiation. Boonplod (1996) found that the level of gibberellin started to decrease when the vegetative growth in the tree ceased and this level was not detectable at flowering time. However, attempt in using anti-gibberellin substances such as paclobutrazol fail to induce flowering in longan (Yupin, 1986). Thus, the hypothesis of hormonal balance in relation to flower induction of longan needs further investigations.

Methods of producing off-season longan in Thailand

Potassium chlorate applied as soil drench

1. Concentration: As mentioned earlier, since the introduction of potassium chlorate to induce flowering in longan about 3 years ago, now Thai growers apply this chemical as soil drench and the rate of application depends on tree size. Other factors that must be considered before the application include soil type, the availability of water supply as well as the management of orchard and the degree of healthiness of the trees. The studies from Mae Jo University in Chiang Mai (Manochai *et al.*, 1999) reported the induction of 100% flowering in longan var. E-Daw with the rate of potassium chlorate at 8 g/m² as soil drench. This was experimented in November which is not the normal flowering time of longan. Lower the rate to 4 g/m² induced the flowering to 86%. In See Chompoo variety, 100% flowering was seen at even lower rate of this chemical, *i.e.* all trees were flowered when they were treated with 1-4 g/m².

2. Stage of leaf development: The experiment was conducted on using potassium chlorate as soil drench to longan trees at different stages of leaf development, *i.e.* when the trees had new

young leaves of less than 10 days, at fully mature leaf (20-25 days) and at old leaf (about 45 days). The rate of chemical applied was 8 g/m² at all treatments. The results showed that trees with old leaf showed the most responsive to potassium chlorate in flowering while trees with young and immature leaf stage were the least response (Table 1). Thus, it was concluded that in order to obtain good induction of flowering, potassium chlorate should be applied when the trees stopped growing vegetatively, *i.e.* when all leaves were fully matured and no new flushes occurred.

3. Suitable time of application: It was found that the most suitable time to obtain good induction of flowering in Thailand was from October to February where the average night temperature was rather cool. The longan trees were in the dormant stage and were most responsive to the chemical. Whereas, during the rainy months from May to September, the trees were less responsive, those receiving potassium chlorate at the rate of 8 g/m² gave about 60% flowering and sometimes the figure of less than 50% flowering was found especially in the application September where most frequent rainfall was evident (Manochai, 2000).

3.1 Potassium chlorate applied as foliar spray: The experiment on using potassium chlorate solution sprayed to the tree canopy showed that flowering could be induced at the concentration of 1,000 ppm (Sritontip *et al.*, 1999). The advantage of foliar spray is less chemical usage and lower residual chemical in soil as compared to those of soil drenching. However, there are some limitations in using this chemical as foliar spray, the most evident one is due to leaf falling especially in some cultivars. It was found that using potassium chlorate at 1,000 ppm as foliar spray, can induce flowering up to 97%, but still some leaf falling was evident. The degree of leaf fall was found to depend on concentration of the chemical, the temperature and sunshine at the application time. More leaf fall was seen at high concentration and high temperature during the spraying time. It was recommended to spray in the early morning or evening when the temperature was not so high. The trees must not be under water stress and they must be in the dormant stage to obtain good result.

3.2 Potassium chlorate applied as trunk or stem injection: The experiment on the application of potassium chlorate as trunk injection (Viriyalongkorn *et al.*, 1999) showed that the rate of chemical at 0.25 g per 1 cm diameter of stem gave effective result and can induce 80% flowering in See Chompoo cultivar (Table 2). The size of stem used for injection to be effective should not be less than 10-15 cm in diameter. The method of injection is similar to trunk injection of potassium phosphonate fungicide to control phytophthora disease in avocado in Australia (Whiley, 1991). Well watering to the treated tree is required immediately after the treatment, as to increase the translocation in the tree.

3.3 Sodium chlorate as floral induction chemical: Since potassium chlorate had been discovered to have the property in stimulating flowering in longan, some researches have been directed to find alternative chemicals with similar property. This is due to the fact that potassium chlorate is normally used in fire cracker and as it is an explosive chemical, permit must be issued from the Defense Ministry authorities for import of the chemical which is inconvenient for farmers and agricultural business firms. Now it was found that sodium chlorate which is used as herbicide especially for deep-rooted perennial weeds as well as defoliant in cotton, can also be used to induce flowering in longan.

Sodium chlorate can be used to induce flowering in longan in the same way as potassium chlorate. Having a herbicidal property, this sodium chlorate is suggested to apply as soil drenching, not as

foliar spray. It has been reported in the comparison study on the effectiveness of potassium chlorate and sodium chlorate on flower induction of 4 years old longan cv. E-Daw, that the average time taken from the application of both chemical to the emergence of inflorescence was not significantly different (Khao-Sumeru, pers. com.). It took the average of 18 and 21 days for sodium chlorate and potassium chlorate treatments, respectively. The experiment on using sodium chlorate in longan cv. E-Daw by Changenraja *et al.* (1999) is shown in Table 3, which show a high percent of flowering within 21 days after the application of the chemical as soil drench.

Besides these two chemicals, other related chemicals such as hypochlorite, magnesium chlorate *etc.* which may have this flower inducing property, are under investigation, however no conclusive results are known at the present.

Table 1. Use of KClO₃ as soil drench to induce flowering in Longan cv. E-Daw at different stages of leaves (Manochai *et al.*, 1999)

Appl cation	Stage of leaves	% Flowering after application	
		45 days	60 days
KClO ₃ 8g/m ²	Control	0.00	0.00
	Young leaves (less than 10 days)	5.00	6.70
	Fully expanded leaf (20-25 days)	30.00	61.70
	Mature leaves (40-45 days)	85.00	100.00

Table 2. Use of KClO₃ injection to induce flowering in Longan cv. See Chompoo (Viriyalongkorn *et al.*, 1999)

Treatment	Flowering (%) after applied		
	5 (weeks)	6 (weeks)	7 (weeks)
0 g KClO ₃	0.0	3.3 b*	23.3 b
0.025 g KClO ₃	13.3 c	56.7 a	60.0 ab
0.05 g KClO ₃	53.3 b	63.3 a	83.3 a
0.25 g KClO ₃	80.0 a	83.3 a	90.0 a

* Means within the same parameter followed by a common letter are not significantly different at 5% level of probability by DMRT.

Table 3. Use of NaOCl as soil drench to induce flowering in Longan cv. E-Daw (Changenraja *et al.*, 1999)

Treatment	Time to flowering (days)	Flowering (%) after treatment
Control	-	0
NaOCl 6% 5 ml	21	75
NaOCl 6% 10 ml	21	75

Table 4. Effect of potassium chlorate applied as soil drench on flowering of longan cv. See Chompoo (Manochai *et al.*, 1999)

Rate of chemical (g/m ²)	Flowering (%)
0	28
1	100
2	100
4	100

4. Cultivars: As expected there was some differences in the degree of response to potassium chlorate among longan cultivars. See Chompoo was the most responsive cultivar to the chemical (Manochai, 2000). Other cultivar that showed good response were E-Daw, Haew, E-Dam (or Bai Dam), as they can be induced to 100% flowering by using potassium chlorate at 2-4 g/m².

5. Practical methods of using potassium chlorate: Potassium chlorate is, at present, the most effective chemical for inducing flowering in longan when it is applied as soil drench (Manochai *et al.*, 1999). Sodium chlorate is not so popularly used as the

chemicals can cause environmental problems, such as building up of sodium salt in the soil which affect crop production. Also higher rate of sodium chlorate can cause deleterious effect to longan trees as well as residual effect in the soil.

High concentration of potassium chlorate may cause undesirable effects such as leaf falling, restricted growth, sometimes panicle malformation and shoot deformity. Anyway, soil drenching is a convenient method for off-season production of longan. Khao-Sumeru *et al.* (1999) summarized the procedure to control flowering of longan based on the research findings as diagrammatically outlined in Fig. 1 for soil drenching application and in Figure 2 for foliar spray application.

The techniques described have been recommended to growers in Thailand. By applying potassium chlorate (or sodium chlorate) as shown in the diagram, flowering of longan tree is almost completely being controlled. The following tips concerning the success of flowering control of longan are :

1. The tree must be healthy and stopped vegetative growth at the time of chemical treatment.
2. Rate of potassium chlorate depends on leaf canopy size. Generally, the application rate of potassium chlorate is based on 1-4 gram per square meter of leaf canopy (Table 4). Higher application rates produce leaf falling, flower malformation and even death of the tree.
3. Watering is essential in the area that has long dry spell. Therefore, available water sources are needed for irrigation after the treatment.
4. Soil type must come into consideration. It has been observed that longan trees grown in sandy soil response better to potassium chlorate as compared to the heavy soil type.
5. Suitable fertilizer application is needed to maintain the healthy trees.

6. Possible physiological role of potassium chlorate: It is well believed that the chlorate ion (ClO_3^-) dissociated from either potassium chlorate or sodium chlorate is responsible for floral induction in longan. The potassium ion (K^+) or sodium ion (Na^+) are only by product left in the soil. It is also interesting to see whether other chlorine compounds such as chlorite (ClO_2^-), perchlorate (ClO_4^-) and hypochlorite (ClO^-) have any induction effect on flowering of longan.

In plant, the chlorate ion has the competitive property to the nitrate ion (NO_3^-) in the reduction reaction with nitrate reductase enzyme. The chlorate ion better competes in locking with nitrate reductase structure in comparison to nitrate ion (LaBrie *et al.*, 1991). Nitrate reductase is an important enzyme for the reduction of nitrate ion to nitrite ion and further to ammonium ion by nitrite reductase. However, the relation of this biochemical change to flower induction is awaiting the support from experimental data.

Chlorate ion can enter the plant from both leaves and roots via absorption (Audus, 1976). Thus, the methods of applying chlorate include soil drenching through root and foliar spray through leaves. It is believed that the chlorate ion moved in the xylem cells, and worked by fixing with nitrate reductase enzyme to release one atom of oxygen to form chlorite ion (ClO_2^-). This chlorite ion will inhibit nitrate reductase enzyme. As the nitrate reductase enzyme is formed by stimulating of the substrate inducible enzyme, therefore the chlorate ion would help in inducing the forming of nitrate reductase mRNA as the activity of this enzyme increased whereas the activity of nitrate reductase



Fig. 1. Diagrammatic scheme for control flowering in longan using potassium chlorate as soil drench.

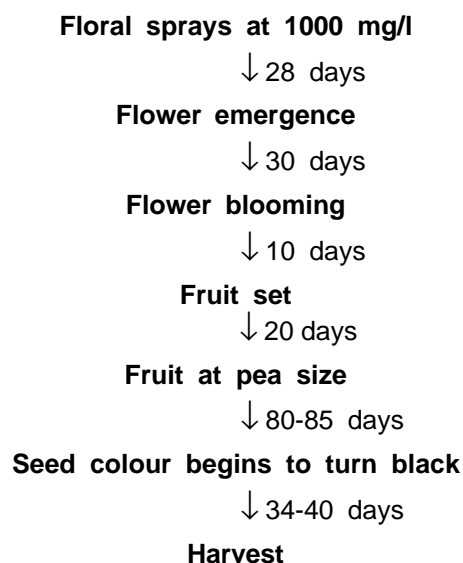


Fig. 2. Diagrammatic scheme for control flowering in longan using potassium chlorate as foliar spray

was decreased under the presence of chlorate ion (LaBrie *et al.*, 1991).

When longan tree received high concentration of potassium chlorate, a patch of brown symptom appeared in leaf blade, leaf will later turn yellow with a symptom like burning. This injury was first seen in young leaf. In severe case leaf fallen is evident. The longan trees that lost the leaves would not flower. Thus high concentration of potassium chlorate would not be beneficial in inducing flowering in longan. It was found that chlorate compound caused injury to the roots which rendered the trees sensitive to flooding and drought. This is supported by the previous reason that ample of water source must be available for producing off-season longan with potassium chlorate or sodium chlorate compounds.

7. Regular flowering cultivar and "Tawai" clones: At present, growers can select and develop the easy-to-flower cultivars. The local name "Tawai" is used to indicate this habit in Thailand. These cultivars are naturally selected. The easy-to-flower longan cultivars in Thailand include 'Petchsakon Tawai', and some introduced longan from Vietnam. These longans are easily

flowering and easily set fruits. The leaves of these cultivars are generally small. Under natural condition, the trees flower twice a year. The first flower flush appears in December - January and harvesting in May - June. The second flower flush is seen around July - August and harvesting in December. These longan cultivars are commonly grown in the central region of Thailand where the climate is a real warm tropic. It has the advantage in easy to flower and does not need any chemical regulation. However, the quality of flesh and fruit size are inferior to those cultivars grown in the northern region.

This easy-to-flower cultivar can be induced to flower by girdling or cincturing of the branches or stems. The explanation of cincturing on flowering of the tree had been known (Menzel and Paxton, 1987). It has been reported that cincturing can induce earliness and uniform flowering in Petchsakon cultivar as compared to the control treatment (Chaiprasob, 1998; Saengpan, 1998).

8. Orchard management

8.1 Choosing suitable location: Longan trees need dry period for flower bud formation. A period of dryness is widely accepted as the effective criteria for flowering of longan grown under tropical conditions. Low temperature and/or water stress which restrict vegetative growth can enhance flower bud formation of longan. Thus, the normal flowering time of longan in Thailand is in January which the trees experienced dryness and cool temperature. The rainy area with insufficient dry period for floral bud formation must be avoided, as the flower forcing of longan in such area is quite difficult. The area having low rainfall or receiving steady rain period, sandy soil or good drainage soil, would be suitable for producing off season longan as enough dry period is commonly evident.

8.2 Proper management: The orchard management is very important in producing off-season longan. The practice of controlling water level is commonly seen in longan and lychee growing under ridge cultivation in the central region of Thailand. Here the water level in the small ditch around the ridge bed can be controlled. However, the control of water level is difficult in the rainy season and flower forcing can not be easily practised. Thus, the combination with other methods such as chemical treatment is necessary.

9. Future prospect: It is now evident that the chlorate salts of potassium and sodium can induce flowering in longan. The longan fruits produced have been analysed and shown not to contain any chemical residues in the aril nor the skin, and it is permitted by The Food and Health authority to be sold to consumers. However, more researches should be emphasized on finding alternative chemicals especially those that are less oxidizing power than potassium chlorate. Also the mode of action of the chemicals in inducing flowering as well as the physiological responses of longan trees should be understood in more details.

The easy flowering cultivars such as 'Petchsakon' which does not require the chemical treatment should be further studied especially in identifying gene(s) that control flowering. Gene manipulation of the easy flowering character incorporate to the difficult to flower cultivars which have high quality fruits may be possible in obtaining better longan cultivars with easy to control flowering in the future.

References

- Audus, L.J. 1976. *Herbicide : Physiology, Biochemistry, Ecology* 2nded. Vol. 1. Academic Press Inc., New York.
- Boonplod, N. 1996. Changes in endogenous gibberellin-like substances in shoot apex of longan var. E-Daw before flowering. Unpublished M.Sc. Thesis, Chiang Mai University, Thailand. (in Thai with English abstract)
- Chaiprasob, C. 1998. Effect of cincturing lateral and main branches on flowering of longan cv. Petchsakon. Unpublished B.Sc. Special Problem, Department of Horticulture, Mae Jo University, Chiang Mai. (in Thai)
- Changenraja, S., C. Sritontip and Y. Khao-Sumeru, 1999 Preliminary study on sodium hypochlorite to induce off-season flowering in longan. *Fruit Newsletter*, 4(4): 5.
- Chen, W.S., Q.W. Huang, and W.C. Ku, 1997. Cytokinin from terminal bud of *Euphoria longana* during different growth stages. *Physiol. Plant.*, 99: 185-189.
- Department of Agriculture. 1999. An introduction to the safety use of chlorate substances for floral induction in longan. Cooperative Agriculture of Thailand Publ., Bangkok. (in Thai)
- Huang, Q.W. 1999. Effect of plant growth regulators and endogenous hormones in bud differentiation of longan. *Hort. Abstract*, 68(1): 738.
- Jungyoosuk, P. 1999. Off-season longan-good or bad news for growers. *Kehakarn-Kaset*. 23(2): 73-74. (in Thai)
- Khao-Sumeru, Y., C. Sritontip and S. Changenraja, 1999. Summary on the use of potassium chlorate and sodium chlorate for inducing off-season flowers in longan. Institute of Agriculture Research and Training, Lampang. (Mimeograph) (in Thai)
- LaBrie, S.T., J.Q. Wilkinson and N.M. Crawford, 1991. Effect of chlorate treatment on nitrate reductase and gene expression in *Arabidopsis thaliana*. *Plant Physiol*. 97: 873-879.
- Manochai, P. 2000. Longan : Department of Horticulture, Faculty of Agriculture Production, Mae Jo University. 114 pp. (in Thai)
- Manochai, P., V. Suton, W. Viriya-alongkorn, N. Charasamrit and S. Ussahatanon, 1999. Effect of potassium chlorate on flowering of longan cvs. E-Daw and See Chompoo. p. 1-8. In Seminar on Using Plant Hormone for Off-season Production in Fruit Trees. National Research Council, Thailand. (in Thai)
- Menzel, C.M. and B.F. Paxton, 1987. Effect of cincturing on growth and flowering of lychee several seasons in subtropical Queensland. *Aust. J. Exp. Agric.*, 27: 733-738.
- Saengpan, P. 1998. The effect of cincturing at different stages of leaf development on flowering of longan cv. Petchsakon. Unpublished B.Sc. Special Problem, Department of Horticulture, Mae Jo University, Chiang Mai. (in Thai)
- Sritontip, C., Y. Khao-Sumeru and S. Changenraja, 1999. Effect of potassium chlorate to flowering in longan cv.E-Daw. Paper presented at Plant Hormone for Off-Season Fruits Crop Symposium. Chantabury, Thailand.
- Viriya-alongkorn, W.V. Suton, P. Manochai, N. Charasamrit and S. Ussahatanon, 1999. Preliminary study on branch injection of potassium chlorate on flowering of longan cv. See Chompoo p. 9-14. In Seminar on Using Plant Hormone for Off-season Production in Fruit Trees. National Research Council, Thailand. (in Thai)
- Wiley, A.W. 1991. *Persea americana* Miller. In. *Plant Resources of South-East Asia 2. Edible fruits and nuts*. PROSEA, Pudoc, Wageningen, p. 249-254.
- Yupin, P. 1986. Effect of paclobutrazol on growth, flowering and fruit setting of longan var. Haew. Unpublished Special Problem submitted to the Department of Plant Production Technology, Mae Jo Institute of Agricultural Technology, Chiang Mai, Thailand. (in Thai)