## Chapter 2

## Literature Reviews

### 1. Area : attributes and usage

The genus *Mangifera* is one of the 73 genera (c. 850 species) belonging to the family Anacardiaceae in the order Sapindales (Bompard and Schnell, 1997). Mango trees are adapted to a wide range of subtropical and tropical climactic and edaphic conditions. Thus, the mango is now cultivated commercially throughout the tropics and in many subtropical areas. It is one of the most important fruits in the tropical Asia including Thailand (Mukherjee, 1997 ; Krisanapook *et al.*, 2000). In Thailand, the Department of Agricultural Extension (DOAE) reported that the mango planting areas in 2002 were 2.2 million rai, equivalent to 22.1 percent of total fruit tree areas. Agricultural Office of Chiang Mai Province (2002) reported there were 74,765 rai as mango growing areas and most were located in Amphur Chiang Dao (18,071 rai).

**General background of Chiang Dao**

**Geographical condition** Chiang Dao is a district situated in the north of Chiang Mai province, about 72 kilometers the city, altitude at MB 964413. The total area of Chiang Dao district is 2,052 $km^2$ (1,361,875 rai) equivalent to 10.8% of total area of Chiang Mai province. There are 7 sub-districts, 78 villages and 20,411 families in Chiang Dao district. The total cultivated area occupies about 70,855 rai, accounting for 5.2% of the total area. Most of agricultural uplands are under rainfed or non-irrigation system (Chiang Dao district, 2005).

**Boundary of Chiang Dao district** The north sides join with Chai Prakan district of Chiang Mai province and the border with Burma. The south joins with Mae Taeng district. While the eastern side borders joins with Phrao district and the western side joins with Wiang Haeng district of Chiang Mai province and Pai district of Mae Hong Son (Chiang Dao district, 2005).

**Topography** General aspect of Chiang Dao district has topography with several mountainous valleys such as Doi Luang Chiang Dao, nonsteep hilly upland and mixed orcharddisturbed deciduous dipterocarp forests (Tumbol in Chiang Mai Province, 2005). The average slope of areas did not exceed 6.5%. Elevations of more than 400 meters above sea level is a distinct characteristic of this region.

For the purposes of use, the land types share for farming in Chiang Dao is 84,587 rai, equivalent to 6.2% of total areas (Agricultural Office of Chiang Mai Province, 2002). The planting areas were between the hills around 20,625 rai or 24.4 percent of plantation areas. The major of occupation in this region is paddy rice, vegetable and fruit tree plantation (Chiang Dao district, 2005).

**Population** Total population in Chiang Dao recorded in September 2003 were 76,028 persons. These composed of 38,923 male and 37,105 female. In 2003, there were 11,968 households in Chiang Dao district, of which 91% of total family had the agricultural occupation. The people had their own farms 10,038 family or 85 % of the total agricultural people (Chiang Mai Province, 2005).

**Agricultural production** Chiang Dao is a province of traditional paddy rice, vegetable and fruit tree cultivation. There were three kinds of land use system observed in Chiang Dao district. The first is irrigated upland with high fertilizers and chemicals are used for vegetable production. The second is rainfed upland with high fertile soil and cool temperature for pomelo and longan cultivation. The first and second upland farming systems aim in order to gain more profit. The third is rainfed upland with low fertile soil and mainly occupied by pure mango orchard. In 2002/2003, (Chiang Dao district, 2005) expressed that among the mango cultivars, Kaew is dominant cultivated in Chiang Dao district. The total of Kaew mango cultivated areas in Chiang Dao was about 18,071 rai, accounted for 24.2 percent of Chiang Mai's mango growing areas. In term of average mango production was 1,475 kg per rai and a total production of 16,402 tons (Agricultural Office of Chiang Mai Province, 2002). Thus, rainfed upland of Chiang Dao is ranked as the dominant mango production region, particularly Tumbol Mae Na, Mae Ore Nai village (Figure 1). Owing to most of mango growing areas of Mae Ore Nai village is quite different from other sites because the planting areas are elevated above the mean sea level 400 m and surrounded with forest and hill. Thus, it is remarkable considered as a famous natural areas for producing late season Kaew mango because of its advantages of site and microclimate.

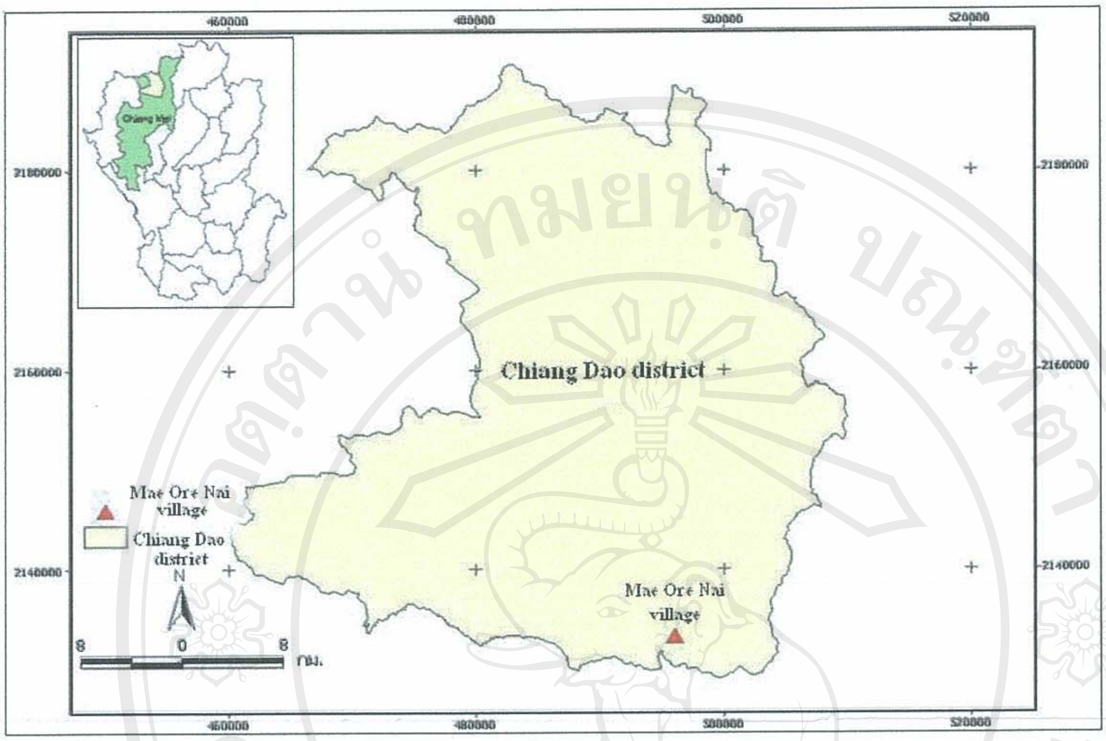


Figure 1. Position of Mae Ore Nai village, Chiang Dao district, Chiang Mai Province

**Climatic conditions** The weather pattern of this region is under influenced by both two tropical monsoons giving the typical wet and dry tropical climate throughout the year. The climate of Chiang Dao area consists of three different seasons (cool, hot and rainy season) (Chiang Dao district, 2005).

1. Cool season is covered several months between October to February. During this period, the average temperature in 2002, 2003 and 2004 is about 23.4, 22.9 and 22.5°C. The coolest months found in December and January are below 22°C. From Figure 2-4 showed the average monthly maximum temperature in cool season ranged from 28.6-37.2, 27.5-36.6 and 26.1-37.7°C in 2002, 2003 and 2004, respectively. While, the minimum temperature ranged from 13.3-20.3, 21.3-26.8 and 18.9-25.6°C in 2002, 2003 and 2004, respectively. Owing to low average temperature throughout the year and long lasting of cool season (five months) are being in these areas. These characteristics cause the favor to delay the natural reproductive stage of Kaew mango.

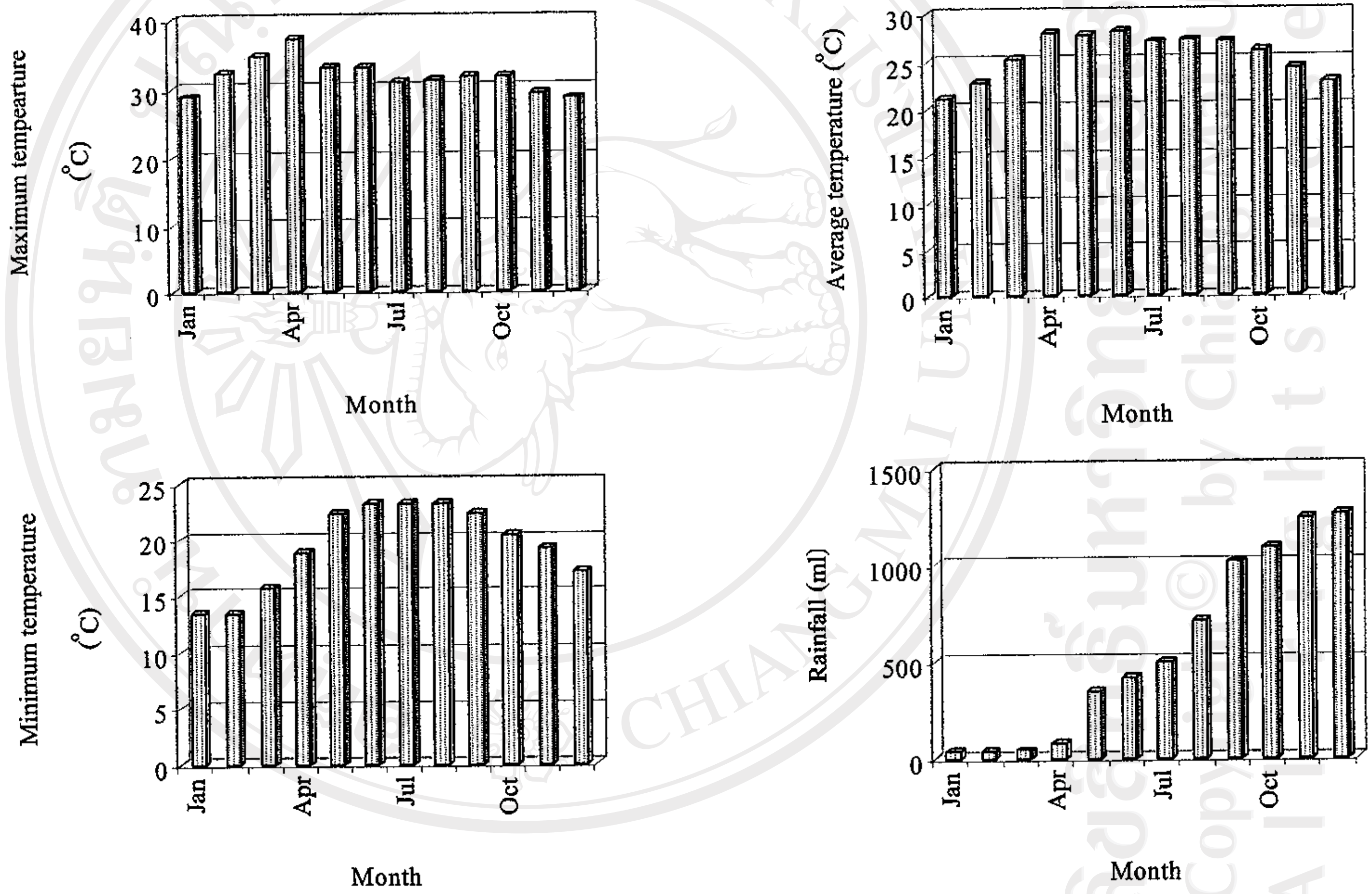


Figure 2. The average temperature and rainfall at Chiang Dao district in 2002

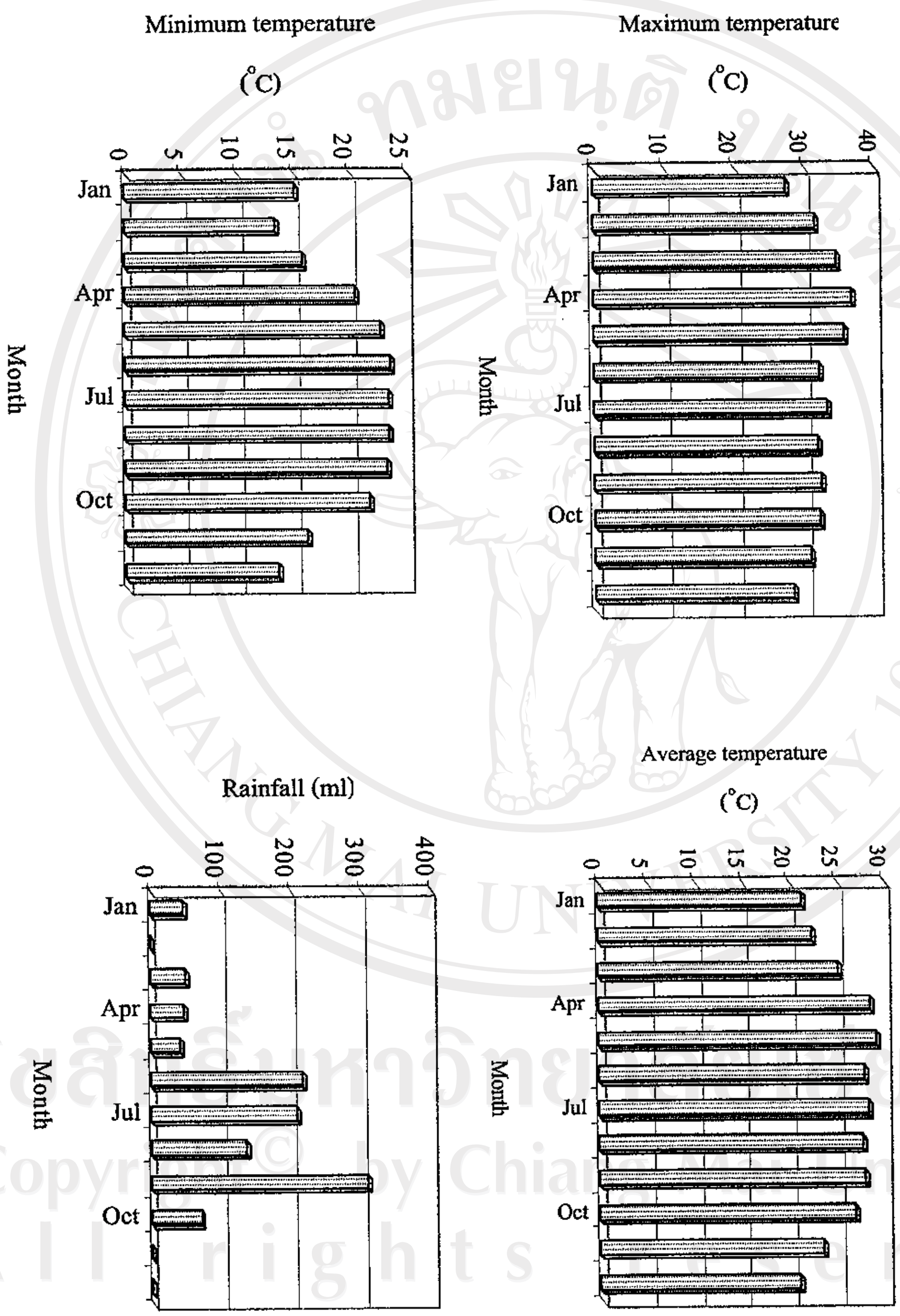


Figure 3. The average temperature and rainfall at Chiang Dao district in 2003

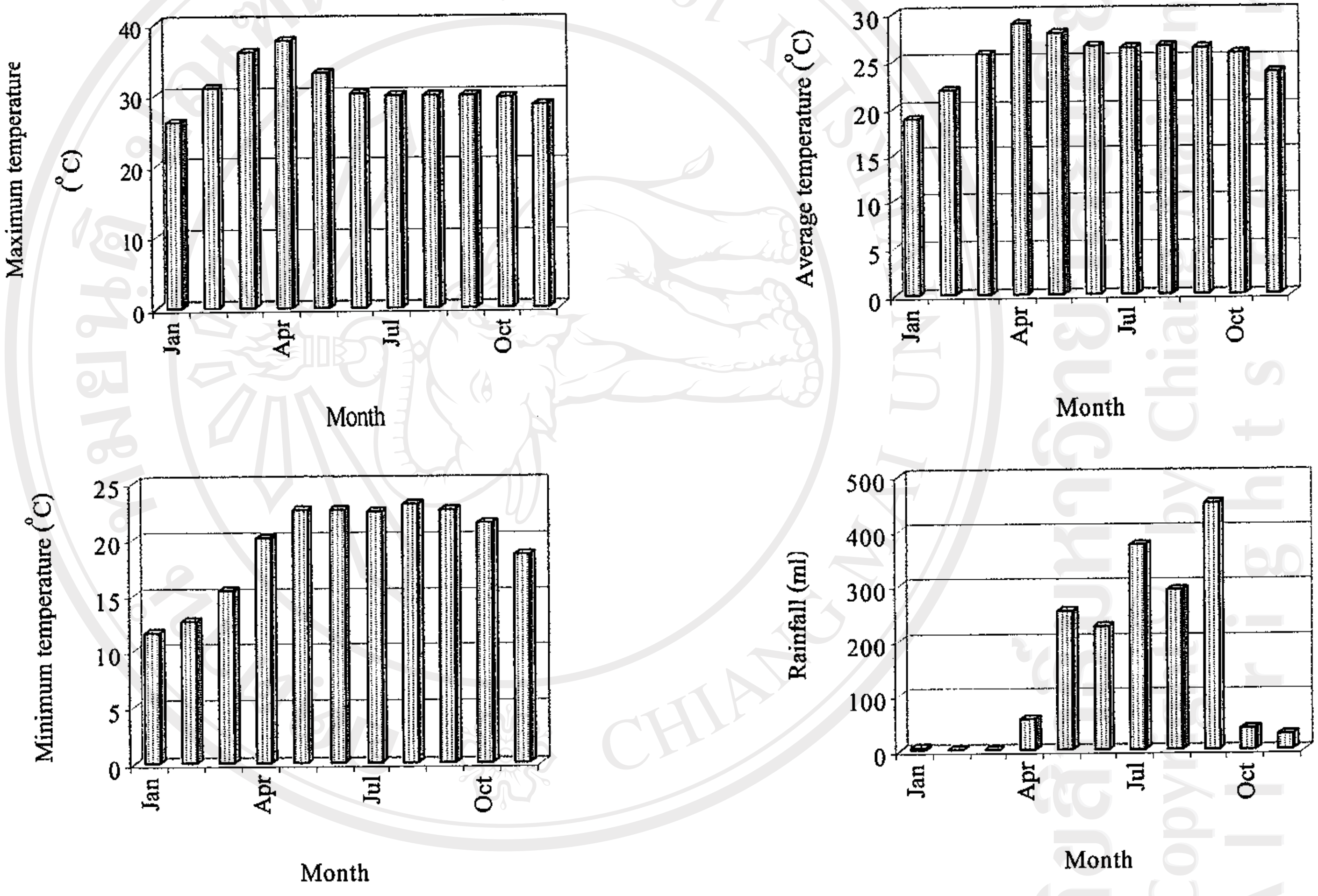


Figure 4. The average temperature and rainfall at Chiang Dao district in 2004

2. Hot season covers between March to May. During this period, the climate is rather hot and dry, particularly April to May. The average temperature was 27, 27.6 and 27.5°C in 2002, 2003 and 2004, respectively. The highest temperature was recorded at 37.2, 36.6 and 37.7°C for the year of 2002, 2003 and 2004, respectively (Figure 2-4).

3. Rainy season covers during June to October with the rainfall accounting for 55.1-79.9 percent of the total annual rainfall in the years of 2002-2004. Most rain falls in September and October. However, there is still some rain in the months of November and December. The Figure 2-4 indicated that the average rainfall was found to decrease in the year of 2004. Three-year average rainfall at Chaing Dao district was 562.8, 559.2 and 157.2 ml in 2002, 2003 and 2004, respectively.

Chiang Dao is considered as one of the areas of rainfed upland. As the Chiang Mai grew and prospered, farming areas extended to the rainfed upland. This agro-ecosystem covered 16.7% of the total area, most of them were non-steep hills alternating with plains. The total area of plain and hillside was 8,983,253 rai or 16.7% of total North region. The area cultivated was between 400 and 1600 meters above sea level, where the slope did not exceed 10% and was dry. Soil composition varied, much was loamy sand soil containing little organic matter as there was erosion. In addition, the climatic conditions were "Keppen" pattern or distinct differences between rain and drought called Tropical wet and dry climate. Thus majority of these areas were under rainfed condition, low rainfall (1215.6-1843.2 mm per year), and faced with drought conditions and climatic variation (Utumpan *et al.,* 2002). As a result, most of the farmers in these areas were poor and less privileged than the others because of the limitations of plant type that grew on these regions. Radanachaless (1998) recommended landuse alternatives for these areas by co-cultivation of annual crops and drought tolerant fruit trees in order to reduce risk and intensify land use. He also found that mango was appropriate for these Upper North because mango cv. Kaew was a native tree crop and thrived well in the semi-arid environment.

Pandey (1988) indicated that the climatic conditions depending upon latitude and altitude had profound effect on the time of mango flowering. These conditions affected the development period of the Kaew mango. Naturally, the harvesting of Kaew mango in Thailand would start in the central plain in March to mid April, the North Eastern region in mid April to May, and in the North region in mid May to June. In Amphur Chiang Dao, Chiang Mai was the most famous late production area because of their advantageous locations from the latitude and altitude (Radanachaless, 1998).

Owing to Chiang Dao's altitude of 300-500 metres above mean sea level and because climatic conditions were relative cool, (average mean temperatures between 26.2-27.7°C), the harvesting season of mango cv. Kaew is late, naturally between June to early July. Meanwhile there is no yield from the other regions. As a result, there is a potential for advancing the period of flowering, extending growth of the panicle and fruit, and delaying the fruit maturity on the tree to extend the late-season of Kaew mango in this area. Since the later harvesting period will give the farmers higher value. So a delayed harvesting period for consumption of fresh mango cv. Kaew in the Upper North will be very advantageous to the growers because it is the alternative to raise the farmers' income and reduce peak market overload. This strategy would help to reduce the poverty in the area (Radanachaless *et al.*, 2000).

Thus, the main objective of this study is to search for new strategies in order to delay the harvesting of Kaew mango naturally over the sharp drop in price during the peak season and increase the growers' income. If the growers can control the harvesting time to late production, mid July or beyond this, they will earn the higher price.

**2. The late production of Kaew mango strategies in the Upper North**

Mango is a perennial, evergreen plant having an annual growth, flowering and fruiting cycle (Cull, 1991). Growth of mango trees is not continuous, but exhibits periodic quiescence (Whiley, 1993). Both environmental conditions and cultural practices altered the flower development and fruit maturation behaviour of mango trees (Saure, 1992). Thus, late production of Kaew mango strategies in the semi-arid area of the Upper North will be divided the delayed flowering and fruiting period into three stages, delayed flowering, extension of panicle growth and delaying fruit maturation.

**2.1 Delayed flowering** There are two methods i.e. pruning and flower thinning.

**2.1.1 Pruning** Pruning is an important cultural practice after harvesting every one to two years (Campbell and Wasielewski, 2000). There are many reasons for pruning fruit trees, to remove dead or diseased wood, to reduce tree size keeping it within its allotted space in the orchard and to control the tree height for facilitating cultural management practices such as easier harvesting. Probably the most important reason for pruning is to increase the photosynthetic efficiency of the canopy with a potential improvement in yield and normal functioning, especially bloom and fruit set (Whiley and Schaffer, 1997 ; McCraw, 1999).

The cycle of vegetative growth pattern is usually called flushing, each flushing terminated when all new leaves were fully expanded. Vegetative growth occurs up to three or four times per year on individual shoots, depending upon cultivar and growth conditions (Davenport and Nunez-Elisea, 1997). Chacko (1984) reported that vegetative growth of mango trees was not continuous, but tended to be periodic. The early initiation and development of each new flush, was followed by a dormant period which helped the shoots to attain the proper physiology for flower initiation (Singh, 1978). Delayed vegetative growth could reduce the potential for new shoots to flower the following season (Davenport and Nunez-Elisea, 1997).

Flowering might be hastened or delayed by pruning. Pruning was considered to interfere primarily with endogenous growth control of trees because pruning initially resulted in tree rejuvenation (Saure, 1992). In addition, a balance between a growth promoter and a growth inhibitor might be required for flowering of mango. Chacko (1986) and Chen (1987) suggested that the high gibberellin levels after pruning, would enhance vegetative growth and inhibit the flowering of mango. Pandey (1988) agreed and also indicated that the synthesis of hormones to promote flowering depended upon the age and maturity of the shoot. Oosthuyse and Jacobs (1999) found that flowering of 'Sensation' mango trees was effectively delayed in accordance with pruning date due to the subsequent development of axillary inflorescences. The delayed flowering caused by the later the pruning, the later the harvest.

**2.1.2 Flower thinning** Panicle removal is a common practice for farmers to postpone flowering and the fruiting period of mango trees (Shu and Sheen, 1987 ; Shu, 1993). Mango trees typically show a pronounced apical dominance. Removal of the terminal bud or developing terminal panicle ("deblossoming") activates axillary bud growth, resulting in the formation of axillary panicles (Reece *et al.*, 1949). The subsequent development of axillary panicles cause a delay in the flowering period, which may in turn result in delayed fruit maturation and harvesting (Issarakraisila and Considine, 1991).

**2.2 Extension of panicle growth** Plant bioregulators (PBRs) are powerful and popular horticultural production tools (Mattheis and Fellman, 1999). Paclobutrazol (PBZ) ($C_{15}H_{20}ClN_3O$, (R*, R*)-(+)-$\beta$-[(4-Chlorophenyl) methyl ] -$\alpha$-(1,1-dimethyl)-1 H-1, 2, 4-

triazole-1-ethanol; 1-tert-butyl-2-(p-chlorobenzyl)-2-(1, 2, 4-triazol-1-yl)-ethanol ; (2 RS, 3RS)-1-(4- chlorophenyl)-4, 4-dimethyl-2-(1 H-1, 2, 4-triazol-1-yl) pentan-3-ol), has a molecular weight 293.80 and is classified as triazole plant growth regulator. It is a white crystalline substance, typically 95% purity with a melting point of $164\text{-}168^{\circ}C$. PBZ is involved in many aspects of plant development, such as inhibition of gibberellin biosynthesis (Rademacher, 1995), reduction of vegetative growth, induction of early and profuse flowering in many fruit crops (Erez, 1986) including mango (Burondkar *et al.*, 2000). It also increases yields and controls tree vigour in mango (Burondkar and Gunjate, 1993). In tropical regions, Cultar® (trade name of PBZ, typically 95% purity) was used annually to reduce vegetative growth and cause early flowering (Bally *et al.*, 2000). In Thailand, the popular use of PBZ is to produce off season mango (Nartvaranant *et al.*, 2000). In respect of panicle development, Schaffer *et al.* (1994) indicated the period between floral initiation and anthesis proceeded in a short time within four weeks under tropical conditions. While, Khader *et al.* (1988) reported that they could delay the panicle expansion and flowering of mango cv. Dashehari to avoid the poor fruit set under very low temperature by spraying Cultar onto panicles at two stages, 1-2 and 3-4 cm in length. From the treatment, they reported that Cultar could delay the panicle expansion significantly by 20-30 days with optimum concentrations of 2500 and 5000 ppm onto 1-2 cm length and 500 and 1000 ppm onto 3-4 cm of initial panicle length. Due to the delay in expansion of panicle by these chemicals, flowering was also delayed equally.

**2.3 Delaying fruit maturation** The experiments in this section composed of bagging and gibberellin (GA) application.

**2.3.1 Bagging** Ram (1992) reported the growth pattern of mango fruit showed sigmoid curve and that one of the factors which influenced the duration of fruit growth was cultural practice (de Leon *et al.*, 2000). Bagging is a commercial practice used for producing high quality, unblemished fruit in Japan (Kitagawa *et al.*, 1992). There are several objectives for fruit bagging, including pest control. This technique is found in several Asian countries, especially fruit wrapping with newspaper for fruit fly control. Another aim is to reduce postharvest diseases, especially in ripe mangoes. In addition, physiological disorders of the apple fruit are reduced and fruit appearance is improved because of the exclusion of direct sunlight (Mattheis and Fellman, 1999). Bagging is still used on a limited scale on late mango cultivars in southeast Queensland (Australia) (Tyas *et al.*, 1998). Hofman *et al.* (1997) reported the commercial potential for mango bagging would be significantly influenced by the late season market prices and the premium paid for better quality fruit.

**2.3.2 Gibberellin application** The gibberellins (GAs) : 2, 4 a, 7- Trihydroxy-1-methyl-8-methylenegibb-3-ene-1, 10-dicarboxylic acid 1, 4 a-lactone or $C_{19}H_{22}O_6$, molecular weight of $GA_3$ 346.37, constituted a large group of natural tetracyclic diterpenoid carboxylic acid derivatives possessing the ent-gibberellane ($C_{20}$) or ent-20-norgibberellane ($C_{19}$) skeletons, with more than 100 different structures extracted from higher plants, bacteria and fungi (Owen *et al.*, 1996). Gibberellins (GA) were biosynthesized from mevalonic acid via the hydrocarbon ent-kaurene (Kendrew and Lawrence, 1994). The occurrence is white crystalline substance, typically 90% purity with a melting point of 233-235°C. The typical biologically active GAs are involved in many aspects of plant development, such as seed germination, stem elongation, leaf expansion, flower development (Garcia-Martinez, 1997) and fruit growth (Santes *et al.*, 1995). Naturally, these chemicals are present in the actively growing plant tissues at 0.1 pmol-10 nmol $g^{-1}$ fresh weight (Garcia-Martinez, 1997). Ram (1983) reported that the growth of mango fruit is under hormonal control. During the rapid period of fruit growth, the level of inhibitors decreases and promoters increases. Then the levels of both growth promoters and inhibitors are low in the fruit during maturation and slows the rate of fruit growth. Kendrew and Lawrence (1994 ) indicated that the GA content in seeds increases rapidly during early seed growth, with the highest concentrations in developing seeds and a reduction as the seed matures. In mango fruit, the GA content increases with the rate of seed and fruit growth but sharply decreases after 42 days and remains low during the fruit maturation (Ram, 1992). From GA content drop during fruit maturation, there were several experiments on GAs applications to delay many fruit maturation. Majumdar *et al.* (1961) showed that GAs caused delayed chlorophyll degradation, degreening and the appearance of carotenoids in tomatoes, banana, pears and mangoes. Lavon *et al.* (1982) found that GAs controlled the ripening processes in other fruit crops. Ray and Sharma (1986) sprayed fruit panicles of litchi 'China' with $GA_3$ at 0.025 or 0.05 g/L three weeks before estimated harvest to delay harvesting. They found that the maturity of treated fruit was as much as 4-5 days later than the control. Looney and Lidster (1980) also reported that GAs extended the growing season of British Columbia's black sweet cherries, by delaying the onset of anthocyanin development for several days.

McDonald *et al.* (1997) found that peel senescence of ' Marsh' grapefruit (*Citrus paradisi* Macf.) was reduced by spraying gibberellic acid (GA) at 49 g/ha plus a wetting agent 0.05% Silwet L-77, prior to colorbreak stage. They reported that the GA-treated fruits showed more retention of green colour (chlorophyll concentrations) and fruit firmness than untreated fruits.

Schirra *et al.* (1999) sprayed cactus pear cv. Gialla with 10 ppm gibberellic acid ($GA_3$) 10 weeks after the second induced-bloom flush. He showed that fruit ripening was delayed as indicated by peel color change and epicuticular wax morphology.

**3. Opportunity of late production in fruit tree**

Nowadays, there are several techniques for late-production in fruit trees. These will increase the higher value of fresh fruit and avoid the overyield in the high season. Durian was an example which succeeded in extending the maturity of fruit. Normally, the durian season in the East is between May and June. Nowadays, farmers in these areas can produce late season durian by extending the harvesting to July to August. Hirunpradith *et al.* (2003) indicated that the late season durian production can be achieved by three stages.

1. Extending the fruit maturation. There are two methods, foliar application of fertilizer and bioregulator.

1.1 Foliar application of fertilizer Fruits at five weeks after full bloom were sprayed with chemical fertilizer formular 20-20-20 or 10-20-20 or 15-30-15 or a mixture of 10-20-30 plus humic acid 20 ml and glucose (or dextrose) 600 g/ 20 L. Spraying would continue every week until the thirteenth week after full bloom. Fruit maturation was delayed by 20 days.

1.2 Bioregulator Spraying 500 ppm paclobutrazol on inflorescence at stud size delayed the development of immature fruit. Fruit maturation was delayed by 7-10 days. If spraying 250-500 ppm paclobutrazol is done at four weeks after full bloom, fruit maturation is delayed by 14-20 days.

2. Inflorescence emasculation There are two methods, thinning the first inflorescence and destruction the first inflorescence by chemical application.

2.1 Thinning the first inflorescence extends the maturity of fruit for 14-40 days.

2.2 Destruction the first inflorescence by chemical application The first inflorescence is dried by spraying thiourea (3000 ppm) on inflorescence at caviar size. The secondary inflorescence appears 14-40 days later.

3. Postponement of the first inflorescence There are two methods, foliar application of fertilizer and bioregulator.

3.1 Interference in natural flowering by foliar application of fertilizer plus Proga-D at 50 ml per 20 l at the beginning of the dry season. This method prolongs development of the new flushes. The harvesting is delayed by more than 30 days.

3.2 Bioregulator By spraying gibberellin 10 mg/L with high nitrogen fertilizer, such as 15-0-0 or 16-16-16 at 2-3 kg/tree, and maintaining the level of water in soil at Kc=0.75. This method prolongs the development of new flushes by more than 30 days.

Nowadays, there are a limited number of fruit trees which produce by delayed harvesting technique. However for Kaew mango, there is no commercial or experimental procedures recommended for farmers to delay the harvesting period. Thus, if we take the advantages of the Upper North climatic conditions and the farmers' need to find the new potential technology for producing Kaew mango late season. These will offer an opportunity for mango growers in the rainfed upland to help them avoid the harvest season peak of Kaew mango and obtain better prices (Radanachaless *et al.*, 2000).

To search the alternative technology for producing the late season Kaew mango, three approaches were considered : (a) delaying the flowering period by tree pruning and panicle thinning (b) extending the growth of panicles by PBZ application and (c) delaying the preharvest fruit maturity by bagging and GA application. The most successful approach would be trial in rainfed upland.