Chapter 5

Discussion

1. Comparison of vegetative growth and development and flowering of mango during El Niño and La Niña conditions.

During El Niño condition (May to September, 1998), all scion-rootstock combinations (Table 4.3, 4.6, 4.9 and 4.11) had the rate of growth and development including cumulative rate of height, canopy width, stem diameter and percentage and total number of shooting higher than during La Niña condition (May to September, 1999). They had small numbers of flowering, fruit setting or even no flowering in the normal season of 1997 through 1998 (December 1997 to February 1998). There were only small amount of accumulated photoassimilate (carbohydrate), used in the inflorescences and fruit setting. Therefore, much of it's remaining in the tree could provide the following cultivars of mangoes to have the scattering off-season flowering from May to November 1998 as followed ; Nam Dok Mai on Choke Anan, Nam Dok Mai on Kaew, Pim Sen Mun on Choke Anan, Pim Sen Mun on Kaew and Khiew Sawoey on Choke Anan (Table 4.15 and 4.16). Accumulated photoassimilates of the tree still remained enough to produce new shoots, which had the high rate of growth and development during El Niño condition. Furthermore, there were enough accumulated photoassimilate left to produce the flowering in the following normal season (December 1998 to March 1999) and high numbers of fruits per tree. The mango trees had to use accumulated photoassimilates for inflorescence and fruit development for long time until May 1999 (normal season), while Pim Sen Mun had late flowering, and fruit development until July 1999. Therefore the lesser accumulated photoassimilates of the trees, requiring a period of time to accumulate more photoassimilates for growth and development of the trees during La Niña (June to September 1999) were much lesser than during El Niño condition. During La Niña, there were 80 rainy days with cloudy sky more than El Niño which had only 63 rainy days (Map and metereological data section, 1999). In La Niña year, there were much more clouds over Thailand and average sunshine duration per day for 4 months during

El Niño condition was 5.04 hours, whereas average sunshine duration during La Niña was 32.98% lesser than El Niño (Map and metereological data section, 1999). Therefore time for the photosynthesis of trees during El Niño were longer. The experimental plants grown in pots with evenly watering (unirrigated trees dried under field condition), continue to photosynthesis and accumulated more photoassimilates, so that growth and development of the trees were better than during La Niña. These showed definitely that from June to September 1999, rate of growth and development of all scion-rootstock combinations were decreased, especially the rate of stem diameters. The means of maximum and minimum temperatures during the 4 months of La Niña condition,was 32.1 °C and 27.6 °C. They were lower than El Niño condition which had the means of 33.1 °C and 28.6 °C, respectively (Map and metereological data section, 1999). The mean maximum and minimun temperatures during El Niño were 1°C higher than La Niña. High temperature could promote the growth of leaves and stems than roots. Therefore the growth expressed as height, canopy width, stem diameters and percentage of shooting were higher during El Niño. These results were similar to those in Whiley's experiment (1989) which studied the growth of roots, stems and leaves of the vigorous Kensington, and semi-dwarf-Irwin mango under day/nigth temperature of 30/20, 25/20 and 20/15 °C. He found that Kensington mango grown at 30/25 °C had the growth of leaves, stems and roots 62, 20 and 18%; 54, 10 and 36% at 25/20 °C and only root growth at 20/15 °C. Irwin had the growth of leaves, stems and roots at of 50, 10 and 40% at 30/25°C; 34, 5 and 61% at 25/20°C; and 25, 5 and 70% at 20/15 °C. It indicated that high temperature promoted the growth of leaves and stems, but at low temperature promoted roots growth. Willis and Marler (1993) also observed that there was a complete cessation of shoot growth on 'Keitt' and only one brief shoot flush on 'Julie' during the four months when mean maximum temperatures were below 30°C and mean minimum temperatures were below 20 °C. This suggested that canopy growth was more influenced by low temperature than the root. When the weather was cool enough to cease shoot elongation for several months, root growth continued. Tobacco plants grown at 40-45 °C for a short time, produced zeatin riboside monophosphate, zeatin riboside and zeatin up to 23, 46 and 80 times than normal plant (Arteca, 1996).

Therefore, higher temperature during El Niño could cause mango trees to produce more cytokinin which responsible for better growth and development of the trees.

The interesting observation were that the total rates of growth and development and new shooting increased definitely in all scion-rootstock combinations in December 1998, as that period of time were the end of rainy season with a great climatic changes. There were bright sunshine in November and December 1998; in October and November 1998, the average sunshine duration was 7.2 hours (increased from September 1998 which was 5.8 hours), and December 1998 was 7.5 hours. These were suitable condition for photosynthesis of the leaves to increased more accumulated photoassimilate, in additions to lowering of temperatures during days and nights that was decreased rate of respiration and metabolisms, so increased accumulated photoassimilate too. When the temperatures, humidity and amount of sunshine duration were suitable environment factors caused more new shoots, increased growth of leaves and stems of mango definitely, especially growth of stem diameter.

During El Niño condition from May 1997 to the end of 1998. Table 5.1 showed the sea surface temperature; SST anomaly (^{o}C) at the same latitude of different parts in the Pacific ocean during June 1997 to December 1998 found that the sea surface temperature in China, Japan and Taiwan were higher +1 to +1.5 than average sea surface temperature while Thailand were average or higher than average not exceed +1 (most of them higher than average = +0.5), so the sea surface temperature in China, Taiwan and Japan were higher than in Thailand, the air above sea surface were raised up, the more thunderstorm were moved to China, Japan, Taiwan, caused increasing rainfall and many times of flooding. While Thailand's sea surface temperature were lower, atmospheric pressure decreased; these made Thailand arid, from less rainfall and thunder storm did not move to Thailand. In 1998, there were only 16-17 tropical thunderstorms occurred in the western Pacific ocean. Most of them moved to the north, only 5 of them moved to the South China sea, but no tropical thunderstorm across the northern region of Thailand, only 1 came closely in August 1998 (Climate Prediction section, 1999). Thus, Thailand had very low rainfall especially in 1998 as showed in Table 5.2 and Figure 5.1

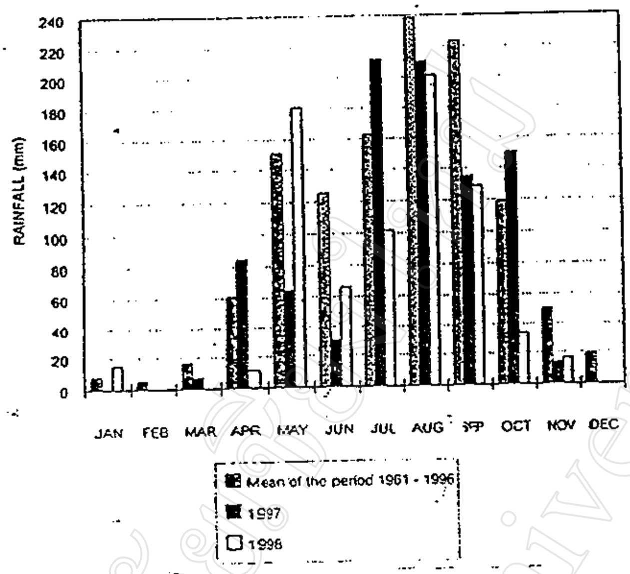

Figure 5.1 Monthly rainfall during 1961-1996 ,1997 and 1998

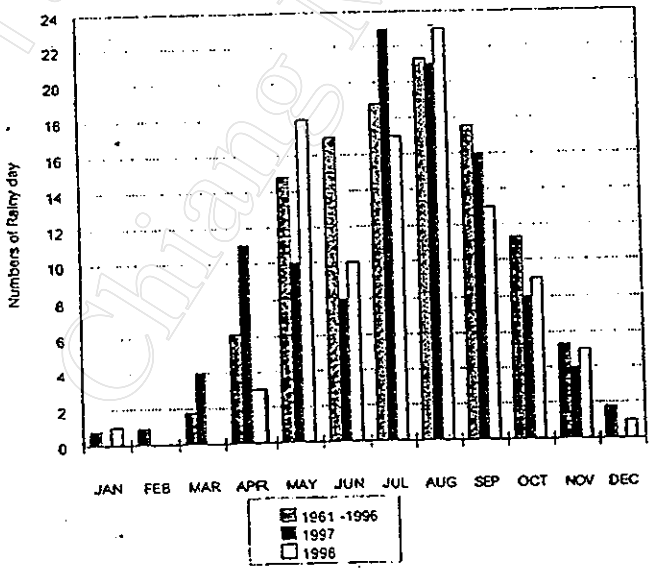

Figure 5.2 Numbers of Rainy day during 1961-1996 and 1997

Table 5.1 Sea surface temperature anomaly (°C) in the Pacific Ocean (NOAA, 1999)

Region of the Pacific Ocean	1997		1998											
	Jun	Dec.	Jan	Feb.	Mar.	Apr	May.	Jun	Jul.	Aug	Sep	Oct	Nov.	Dec
Thailand	0	+0.5	+1.0	+1.0	+1.0	+0.5	+0.5	+1.0	+1.0	+0.5 to +1.5	+0.5	+0.5	+0.5	+0.5
Indonesia	0 to +0.5	+0.5	+0.5 to +1.0	+1.0	+1.0	+0.5 to +1.0	+0.5 to +1.0	+1.0	+1.0	+1.0 to 1.5	+1.5	+1.0 to +1.5	+0.5 +1.0	0 to +0.5
Australia	0	+0.5 to +1.0	+0 to +0.5	+0.5	+0.5 to +1.0	+0.5 to +1.0	+0.5 to +1.0	+1.0	+1.0	+0.5 to +1.0	+0 to +1.0	+1.0 to +1.5	+0.5 to +1.0	0 to +0.5
Taiwan and Japan	0	+0.5 to +1.0	+1.5	+1.5	+0.5 to +1.0	+1.5	+1.0 to +1.5	+0.5 to +1.0	+1.0 to +1.5	+1.5	+1.0 to +1.5	+1.5	+1.5	+1.0 to +1.5
Western Pacific	+1.5 to+2.0	+2.0 to +4.5	+1.5 to +2.5	+0.5 to +2.0	+0.5 to +2.0	+0.5 to +1.5	+0.5 to +1.5	-1.5 to -0.5	-1.5 to -1.0	-1.5 to -1.0	-2.0 to -0.5	-1.5 to 0	-1.5 to 0	-2.0 to -0.5
Peru and Ecuador	+3.0	+4.5	+4.0	+3.0	+2.5	+2.5	+2.0 to +2.5	+2.0 to +2.5	+2.0 to +2.5	+1.5 to +2.0	+0 to +1.0	0 to +0.5	0	0

Table 5.2 Climatological data for 1961-1996, 1997 and 1998.

Statation : Chiang Mai — Elevation of station above MSL 312 Meter

Index station : 48327 — Height of the thermometer above ground 1.20 Meter

Latitude : 18° 47′N — Height of rain gauge 0.80 Meter

Longitude : 89° 59′ E

Year	CLIMATOLOGICAL DATA	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
							Temperature (degree celsius)							
1961-1996	Mean max	28.2	32.1	35.0	36.1	34.2	32.4	31.7	31.1	31.3	31.1	29.8	26.3	31.8
	Mean min	13.7	14.9	18.4	21.9	23.5	23.8	23.6	23.4	23.0	21.8	18.9	15.0	20.1
	Mean	20.6	22.9	26.5	28.8	28.2	27.4	27.0	26.6	26.5	25.8	23.7	21.0	25.4
1997	Mean max	28.8	31.8	35.1	33.8	35.4	33.9	31.9	31.3	30.6	31.7	30.3	30.4	32.1
	Mean min	12.9	13.3	18.7	20.5	24.1	24.4	24.4	23.9	23.1	22.1	19.5	16.6	20.3
	Mean	19.8	22.1	26.4	26.6	29.2	28.7	27.3	26.5	26.2	26.1	24.1	22.6	25.5
1998	Mean max	31.7	33.7	37.1	37.9	35.8	35.0	32.2	32.8	32.6	33.0	31.0	30.1	33.6
	Mean min	14.0	14.1	18.8	29.9	24.5	24.9	24.1	24.0	23.2	22.3	19.7	18.4	20.9
	Mean	22.9	23.9	28.0	30.4	30.2	30.0	28.2	28.4	27.9	27.6	25.3	24.3	27.3
							Relative Humidity (%)							
1961-1996	Mean	70.5	61.2	54.5	58.6	70.6	77.8	78.1	81.3	78.9	79.0	76.9	72.2	71.8
1997	Mean	69	52	53	61	65	69	79	84	83	82	76	75	71
1998	Mean	46	54	46	52	70	71	81	84	84	71	70	64	66
							Rain fall (mm)							
1961-1996	Monthly total mean	7.9	5.4	16.5	61.3	151.1	125.7	162.7	236.3	222.8	119.2	49.9	19.4	1,171.7
	Mean rainy days	0.8	0.9	1.8	6.2	14.8	17.0	18.8	21.3	17.5	11.2	5.3	1.6	117.4
1997	Monthly total mean	0.0	0.0	6.7	85.1	64.5	31.1	211.6	210.4	135.3	15.01	13.6	0.0	906.6
	Number of rainy day	0	0	4	11	10	8	23	21	16	8	4	0	106
1998	Monthly totals mean	14.6	0.0	0.0	11.5	181.3	66.4	101.3	201.6	128.8	33.3	16.9	0.2	755.9
	Number of Rainy day	1	0	0	3	18	10	17	23	13	9	5	1	100

Table 5.2 showed very little amount of rainfall in Chiang Mai 1997 were 908.6 mm, very low in 1998 = 755.9 mm, and significantly lesser than the average of the 36 years (1961 to 1996)= 1171.68. The total numbers of rainy day in 1997 and 1998 were 105 and 100 days respectively, and significantly lesser than the average of 36 years (1961 to 1996) = 117.38 day (Figure 5.2) . The rain water might be helped to clean the dirty off the leaves, so increased the rate of photosynthesis, increasing rain water also increasing soil humidity and water reserved of the trees, but in these experiment the plants were grown in pots with well-watered so the rain fall were less effective. Furthermore lower rain water during of El Niño condition (Figure 5.1), effect directly on the relative humidity of the air, as the relative humidity during El Niño definitely decreased from January to June 1998, especially in January 1998 (figure 5.3), which were the period of flowering in normal season. The relative humidity were only 46% which were 24% lower than average level of 36 years which were 70.5%. In February, March, April 1998, the relative humidity were lower than average level 6, 9 and 7% respectively. The transpiration increased with low relative humidity, increased water loss from trees that caused closure of the stomata, shortened the time of photosynthesis, decreased accumulative photoassimilate for flowering, so there was not enough food for flowering or abnormal flowering in normal season. The low relative humidity, caused drying of the stigma on the style. The pollen died sooner than normal, so reduce fertilization or fruit-drop after fruit-setting, because when the relative humidity decreased, plant lost much water that caused water deprivation. The mango fruits dropped , decreased the amount of mature fruits. The highest, the lowest and the average monthly temperatures during El Niño were shown in Figure 5.4, 5.5 and 5.6 respectively; the highest temperature during December 1997 to December 1998 were higher than the average temperature of 36 years about 1.5 to 3 °C especially in January 1998 higher than the average 3 °C. The lowest temperature in some months were higher than the average of 36 year about 1.5 °C, such as in December 1997 and the average temperature from December 1997 to December 1998 were higher than the average of 36 year about 1 to 3.3 °C. There were reports showing the effect of days and nights temperatures on the flowering of mangoes. Shu and Sheen (1987) found that Haden mangoes with 5-10 cm length of inflorescence, were cut off the terminal shoots about 5 cm from the tip. The experiment took places at day/night temperatures 3 levels, 19/13, 25/19 and 30/25 °C for 3 weeks, the percentage of new shoots were 87, 60 and 0% respectively (at 30/25 °C, the percentage of new shoot were 100%). Whiley (1993) concluded that mango produced flowers at day/night temperatures of 20/15 °C. Nunez-Elisea and Davenport (1995) found that 30/25 °C day/night temperature stimulated producing growth and development of stems and leaves, while at 18/10 °C for the at least 3 weeks and the leaves aged must be at least 7 weeks, then the mangoes had flowered. Pongsomboon (1991) found that Nam Dok Mai had perfect sunshine duration in controlled condition with day/night temperatures 30/20 °C for 16 weeks,water potential of leaves (ψ_l) = -1.5 Mpa (pre-dawn). After watering, no flowering occurred but emergence new shoots 100%. The temperature higher than mean temperature for the whole year, would affect directly on transpiration. The temperature causing much different of vapor pressure deficit between leaves and the atmosphere which increased the transpiration. If the transpiration occurred more than absorption, the trees were wilted or stopped growing. The high temperature during day time had the higher respiration rate of leaves, roots and the other tissues of the trees, increased the metabolisms of accumulative assimilate, whereas lesser in photosynthetic rate, rapid closure of stomata, affecting lesser accumulative assimilates for flowering in the season. Furthermore the higher temperature at night caused higher respiration, so the lesser the accumulative photoassimilates for flowering. These affected the experimental mangoes had no flowering or decreased the flowering as usual in normal season similar to the normal season fruits production of fruit grower in Chiang Mai as followed, the average fruit yield were increased from April to June 1997 which was 658 kg/rai to only 439 kg/rai in 1998 which were 66.7% less than in 1997. In 1999, effecting during La Niña found that average fruit yield in season were increased up to 612 kg/rai nearly closed at 1997. These impacts were not occurred only in mango; but occurred in longan and litchee too. The average fruit yield of longan were decreased from 1,175 kg/rai in 1997 to only 659 kg/rai in 1998, and of lichee were decrease from 789 kg/rai to only 145 kg/rai (Agricultural extension data section, 1999). Therefore, low relative humidity or aridness for long time, caused increasing of accumulative photoassimilates high enough for flowering off-season.

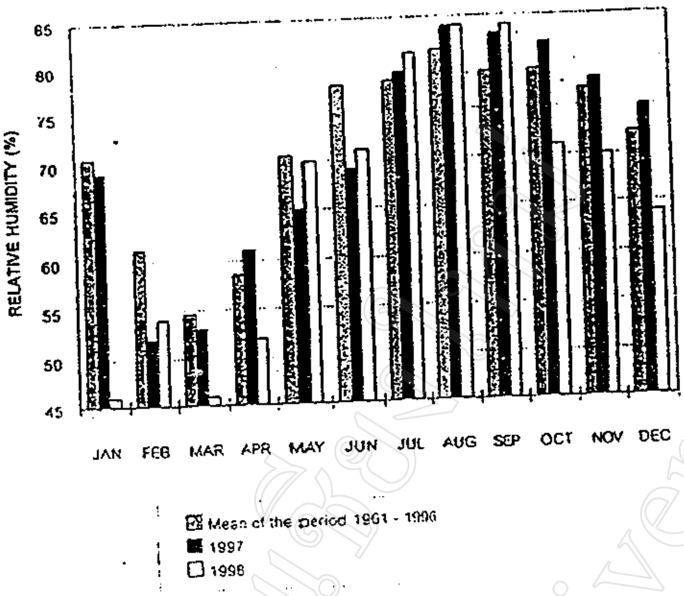

Figure 5.3 Relatively Humidity during 1961-1996 and 1998

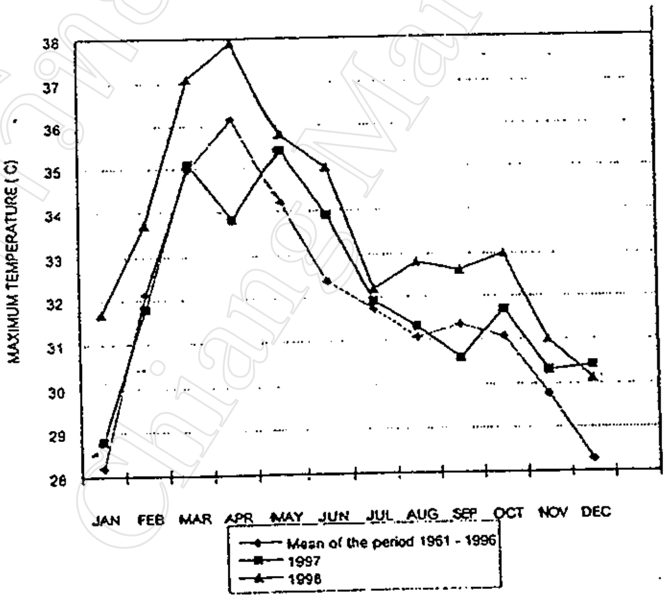

Figure 5.4 Maximum temperatures during 1961 to 1966, 1997 and 1998

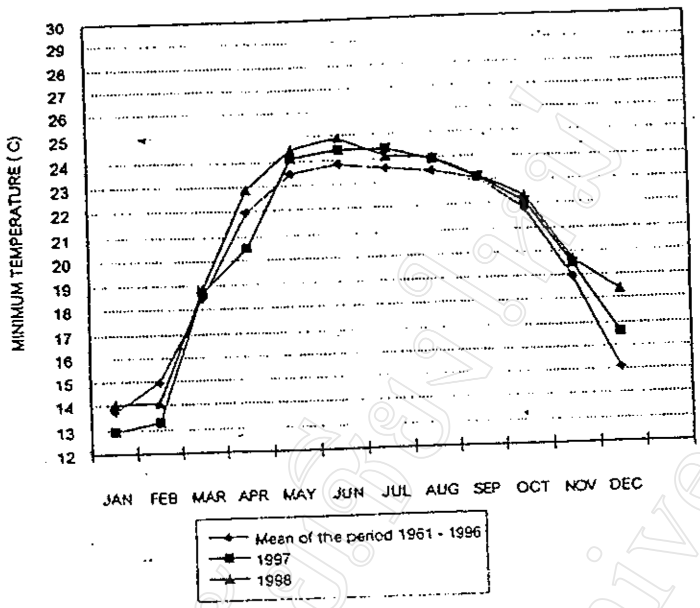

Figure 5.5 Minimum temperatures during 1961 to 1996, 1997 and 1998

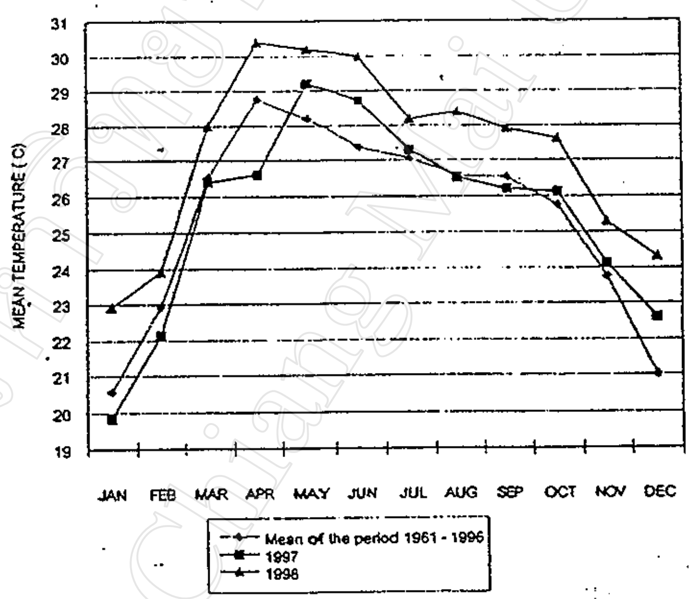

Figure 5.6 Mean temperatures during 1961 to 1996, 1997 and 1998

Furthermore, Chen *et al.* (1997) found that during dormancy of longan (*Euphoria Longana* Lam.) had amount of zeation riboside-o-glucoside (OGZR), zeatin-o-glucoside (ZOG), zeatin riboside (ZR) and zeatin (Z) were 1.44, 1.20, 0.12 and 0.08 mg/100 gof fresh terminal shoots, respectively. While flower bud initiation had zeatin (Z) zeatin riboside (ZR) isopentenyladenosine (iPA) and isopentenyladenine (iP) were increased up to 3.6, 2.6, 0.38 and 0.27 mg/100 g of fresh terminal shoots respectively, which were higher than in leaf flush of 0.30, 0.45, 0.19 and 0.12

mg/100 g of fresh terminal shoots, respectively. It migth be explained that high temperature, low relative humidity, increased transpiration provided more water from roots carrying through xylem to the tip of shoots. It was believed that roots synthesized gibberellins and may be a site for interconversion of gibberellins produced in the shoot rather than a primary source, for example GA_{19} produce in shoot then moves to the roots where it is converted to GA_1 and exported back to the shoot in *Phaseolus coccineus* (Waisel *et al.*, 1996). Low root temperature reduced gibberellins content and reduced temperature caused a reduction in GA production in the leaves which allowed for greater flower numbers (Nilsen and Orcutt, 1995). In normal condition there was low temperature in the winter. In contrast, during the strong 'El Nino' year (December 1997 to January 1998), high temperature in winter occurred increasing amount of gibberellins cumulated in the terminal shoots, so higher level of gibberellins; and because gibberellin was associated with the enhancement of vegetative growth and inhibited flowering of mango (Pongsomboon, 1997), Thus stopped flowering in the season. After winter, warm and arid atmosphere (low relative humidity), it may be explained that gibberellins were used to produce new shoots, so lower the level of gibberellins in terminal shoots. While the cytokinins level in shoots were high enough for induced flower bud initiation, so off-season flowering occurred. These may be caused of the experimental mango trees which decreased flowering in normal season but had abnormal off-season flowering in place; flowering occurred almost from May to November 1998 (Figures 5.7, 5.8, 5.9 and 5.10). Another hypothesis believed that because of mature mango leaves produced the floral stimulus (Nunez-Elisea and Davenport, 1992), whereas immature mango leaves were rich sources of floral inhibitors (Chen, 1987), the promotion of flowering by increasing the total amount of floral stimulus produced by canopy (the lower concentration of floral stimulus in each leaf is probably only partially compensated by the increased proportion of mature leaves in canopy), and the dehydrated apical meristems may become more sensitive to low levels of floral induction (Schaffer *et al.*, 1994). These may be caused of off-season flowering in 'El Niño' condition during May to November 1998. But the off-season flowering of mango trees were not occurred in the same time, because of the completely sensitivity of apical meristem tissue for the induction of floral stimulus in the trees were vary in each terminal shoot of the stems. The impact of the El Niño condition on Nam Dok Mai grafted on Choke Anan and on Kaew were highest responded; followed by Pim Sen Mun on Choke Anan had almost flowering only some months rather more than on Kaew rootstock. While Khiew Sawoey grafted on Choke Anan responded the least, but no response on Kaew. (Table 4.15, 4.17 and Figure 4.13)

Figure 5.7 Off-season inflorescence of the mango cv. 'Nam Dok Mai' grafted on 'Choke Anan' rootstock occurred during 'El Niño' condition (Photographed. at 1998, July 27 at the experimental plot, Department of Horticulture, Chiang Mai University)

Figure 5.8 Off-season flowering which fruit-setting have fruit's size of match's head of the mango cv. 'Nam Dok Mai' grafted on 'Kaew' rootstock occurred during 'El Niño' conditions (Photographed at 1998, July 27 at the experimental plot, Department of Horticulture, Chiang Mai University)

Figure 5.9 Off-season flowering which fruit-setting have fruit's size larger than 1.5 cm long of the mango cv. 'Nam Dok Mai' grafted on 'Choke Anan' rootstock occurred during 'El Niño' conditions (Photographed at 1998, July 27 at the experimental plot, Department of Horticulture, Chiang Mai University)

Figure 5.10 Off-season inflorescence of the mango cv. 'Pim Sen Mun' grafted on 'Choke Anan' rootstock occurred during 'El Niño' condition (Photographed at 1998, July 27 at the experimental plot, Department of, Horticulture Chiang Mai University)

The flowering of mango in normal season of the year 1999 occurred during January to March 1999, the climatological data (Map and climatological data section, 1999) found that the lowest temperature in December 1998 lower than 20 °C for 20 days. The temperature lower than 20 °C were continued for long time. The lowest temperatures were between 14 to 16 °C in December 1998 for 11 days, and in January 1999 for 14 days, which were suitable for mango flowering. Their flowering, similar to the report of Pongsomboon (1991) which found that field grown Nam Dok Mai, near Bangkok, at the highest/lowest temperature = 28/17 °C, had leaf water potential (ψ_1) = -0.74 MPa (pre-dawn) for 6 weeks had flowering 90%. Furthermore Pongsoomboon *et al.* (1997) grew 4 year old Nam Dok Mai at the Department of Horticulture, Kasetsart University Kamphaengsan Campus, beginning of water deficit from mid November 1991, ψ_1 = -0.82 MPa and the lowest temperature in the whole month of December 1991 between 14-19 °C, had flowering in January 4, 1992. Shu and Sheen (1987) reported that mango cv. 'Haden' had flowering at the highest/lowest temperature = 25/19 °C.

In February, 1999, the lowest temperature began to increase, the temperature lower than 20 °C were only 14 days, the lowest temperature were between 18-19.5 °C, mangoes had only small amount of flowering (almost none)

In March 1999, the lowest temperature were decreased lower than 20 °C almost whole month (24 days), the lowest temperature was 16 °C and there were 9 days of the lowest temperature between 16-18 °C, Pim Sen Mun on Kaew and on Choke Anan had more flowering, while Khiew Sawoey on Choke Anan and on Kaew had only few flowering. According to Nunez-Elisea and Davenport (1995) who examined in the container-grown 'Tommy Atkins' mango trees and found that the minimum leaf age and time of exposure to a low temperature regime (18 °C day/10 °C night) required by stems to initiate inflorescences, Leaves became competent to respond to cool temperature when they reached 7 weeks of age. The competence of leaves for floral induction increased with age, and that floral initiation occurred after at least 3 weeks of cool temperature treatment. On the other hand, the youngest leaf age at which floral initiation was observed for 68 days. Subtracting the 21-day period required for floral induction from 68 days (the youngest leaf age at which floral primordia were observed), gave 47 days or about 7 weeks, which represents the minimum age at which leaves began to respond to cool temperatures to become floral inductive. In these experiment, Pim Sen Mun on Kaew and Choke Anan rootstocks had new shoots at the beginning of December 1998, so the mango's leaves were old enough (more than 7 weeks of age) for their response to cool temperatures in February and March 1999 to become on-season floral inductive of Pim Sen Mun on both rootstocks.

The flowering of mango in normal season of the year 2000 occurred during December 1999 to February 2000, the climatological data (Map and climatological data section, 2000) showed that the lowest temperature were lower than 20 °C during November 18, 1999 to February 16, 2000 continued for 3 months, and below 10 °C during December 24-29, 1999 with the lowest of 3.8 °C in December 25, 1999. This suitable cool temperature lasting for long time induced more floral bud initiation and flowering in normal season of the mango trees than the other years. Thus, according to the results showed that all scion-rootstock combinations had the percentage of flowering on February, 2000 of 100%.

The impacts of climatic variability during El Niño and La Niña conditions on vegetative growth and development and flowering of all scion-rootstock combinations were showed differently between each pair of scion-rootstock combinations. However, although there were ending of El Niño but still being influenced by La Niña which were estimated to end in December 2000. Both El Niño and La Niña would recur again for every 3 to 4 years (U.S. Department of Commerce /NOAA, 1999). The more increasing amount of CO_2 in the atmosphere, the stronger impacts of El Niño and La Niña which caused the greater damage two times as usual, (Henson and Trenberth, 1998) so that serously studied about the El Niño and La Niña conditions, would be much helpful in preparing the national plans to prevent losser or damage.

2. Effect of scion-rootstock combinations on growth and development of scions

Khiew Sawoey on Kaew had the longest length of new shoots, followed by Khiew Sawoey on Choke Anan, Pim Sen Mun on Kaew, Pim Sen Mun on Choke Anan, Nam Dok Mai on Kaew and Nam Dok Mai on Choke Anan, respectively (Table 4.19). Although there were non significant difference in the average level of nitrogen of leaves among all scion-rootstock combinations and between both rootstocks; but among three scions, Khiew Sawoey had significantly higher than Pim Sen Mun and Nam Dok Mai, respectively (Table 4.60a). Because of nitrogen was involved in the structure of all amino acids, protein and many enzymes, also prevent in the tetrapyrrole ring of cholrophyll, NADH, NADPH and indoleacetic acid, and also found as free nitrate in the vacuole sap which will accumulate at substantial concentrations in the conductive tissue (petiole and stem) during the vegetative growth period (Mills and Jones, 1996); therefore Khiew Sawoey on both rootstocks had significant longer the length of new shoots than

Pim Sen Mun and Nam Dok Mai, respectively. According to Willis and Marler (1993), studied that Mango 'Keitt' trees had a greater rate of shoot elongation than 'Julie' trees. The overall mean daily shoot elongation rate was 8.7 mm for 'Keitt' trees and 6.9 mm for 'Julie' trees, with a maximum of 27.3 and 20.0 mm, respectively; and concluded that the variation in vegetative growth among cultivars may be more dependent on the scion genotype than on rootstock genotype for these two varieties.

The most interesting observation were that, the total growth rate and the shooting were increased definity for all scion-rootstock combinations in December 1998 (Figure 4.1, 4.4, 4.7, 4.10). As that month were the end of the rainy season, with great variation of climatic environments from impacts of El Niño. The growth and development of all mangoes were decreased slowly, but increased the accumulative photoassimilates in stems, leaves and roots. In November and December 1998, there were bright sunshine, suitable for photosynthesis of leaves, produced more photoassimilates, addition with lower temperature during day and night, these made decreasing of respiration rate and metabolism, so increasing of accumulative photoassimilates. When the temperature, humidity and sunshine were suitable may be induced more shoot and vegetative growth of all parts of the tree definitely, especially the stem diameter growth rate.

3. Effects of scions-rootstock combination on flowering and fruit-setting

Nam Dok Mai and Khiew Sawoey on Choke Anan had significantly higher the percentage of flowering and the total numbers of flowering than on Kaew (Table 4.15 and 4.17). Because of Choke Anan rootstock had significantly higher zeatin/zeatin riboside (Z/ZR) content than Kaew rootstock (Table 4.58). The high level of cytokinin showed the important role for initiation of bud-break in many fruits crops such as longan (Chen *et al*, 1997), litchee (Chen, 1991) and also in mango (Chen, 1987). Whereas gibberellin-like substances of terminal shoots in the mature stage of ready to bud-break of Khiew Sawoey on Kaew rootstock had significantly more than on Choke Anan. Believing that gibberellin was associated with enhanced vegetative growth and inhibits flowering of mango (Pongsomboon *et al.*, 1997) by prevent initiation of reproductive shoots of mango rather than inhibiting floral induction (Nunez-Elisea and Davenport, 1998). Thus Nam Dok Mai and Khiew Sawoey on Choke Anan, which had higher cytokinins level and lower gibberellins level should have higher the percentage of flowering and the total numbers of flowering than on Kaew. While the percentage of fruit-setting and the average numbers of fruits per tree were non-significant difference between both rootstocks (Table 4.25, 4.26, 4.27, 4.28, 4.29 and 4.30).

4. Effects of scion-rootstock combinations on fruit qualities

Nam Dok Mai and Khiew Sawoey on Choke Anan had significantly higher the fruit weight than on Kaew (Table 4.31). In the same way, Kohli and Reddy. (1988) found that 'Alphonso' on 'Chandrakaran' rootstock had the highest fruit weight comparing with other rootstocks. Smith *et al.* (1996) found that 'Kensington' on 'Sg Siput' had fruit weight 10% higher than 'Kensington' on 'Kensington' and 20% higher than 'Kensington' on 'Sabre' (most favourite in Australia). Furthermore according with Avilan *et al.* (1996) studied the influence of the polyembryonic mango rootstocks 'Rosa', 'Camphor', 'Ceniap', 'Peru' and the fruit size and shape of 'Haden', 'Tommy Atkins', 'Edward' and 'Springfels' cultivars; the results indicated that the rootstock modified the fruit dimension, weight and shape, and these changes varied according to the scion/rootstock combination used, the cultivars Edward and Springfels increased their fruit weight and size significantly. 'Haden' and 'Tommy Atkins' increased their fruit weight and size also. Thus, the rootstock influenced the fruit size and shape of grafted cultivars scions.

Nam Dok Mai on Choke Anan had significantly higher the total soluble solids (TSS) of fruit than on Kaew (Table 4.35). Choke Anan rootstock had significantly higher levels of potassium (Table 4.60) and because of potassium was required for the accumulation and translocation of newly synthesized carbohydrates. This role was particularly important during fruit formation period, if potassium-deficiency occurred, growth showed that sugar and starch tend to accumulate where they were formed; so that Choke Anan had higher sugar content in mature fruits (measured in form of TSS). In the same way, Kohli and Reddy (1988) studied the various rootstock tried were 'Open Pollinated (Alphonso)', 'Vellaikolamban', 'Bappakai', 'Chandrakaran', 'Kurukan', 'Muvandan', 'Mylepelian' and 'Olour'. Except the first one, the rest seven rootstocks are polyembryonic; 'Muvandan' rootstock grafted with 'Alphonso' had the highest TSS in fruits, whereas 'Kurukan' and 'Olour' rootstock recorded the lowest TSS. Whereas, there were non significant difference in the amount of titratable acid (TA) of fruits between both rootstocks and among all scion-rootstock combinations (Table 4.36)

5. Effect of scion-rootstock combinations on the amount of chlorophyll a and b of the leaves.

There were non significant difference in the amount of chlorophyll a and b of leaves in all scions, rootstocks and their combinations. According to Kurian *et al.*(1996) studied that 'Alphonso' as scion grafted on nucellar seedlings of seven polyembryonic varieties, grafted on seedlings obtained from open-pollinated cv. 'Alphonso' as a control. The polyembryonic cultivars used as rootstocks were 'Vellaikolamban', 'Bappakai', 'Chandrakaran', 'Kurukan', 'Muvandan', 'Mylepelian' and 'Olour'; found that the chlorophyll content (chlorophyll a, chlorophyll b, total chlorophyll and ratio of chlorophyll a to chlorophyll b) of 'Alphonso' leaves were not significantly influenced by different rootstocks.

6. Effects of scion-rootstock combinations on the net photosynthetic rate.

Khiew Sawoey on Choke Anan had the highest net photosynthetic rate = 13.38 µmol CO_2 $m^{-2}s^{-1}$ and Choke Anan on Kaew had the lowest = 8.37 µmol CO_2 $m^{-2}s^{-1}$. Between both rootstocks, Choke Anan had significantly higher than Kaew. Among the three scions, Khiew Sawoey had significantly higher than Pim Sen Mun and Nam Dok Mai, respectively. According to the list of Flore and Lakso (1989) showed that the maximum photosynthetic rates for several fruit trees, which ranged from 4.4 µmol CO_2 $m^{-2}s^{-1}$ for lemon (*Citrus limon*), 10.4 µmol CO_2 $m^{-2}s^{-1}$ for peach (*Prunus persica* [L.] Batsch)(Escoba-Gutierrez and Gaudillere, 1997), 26.2 µmol CO_2 $m^{-2}s^{-1}$ for plum (*Prunus domestica*), to 37.8 µmol CO_2 $m^{-2}s^{-1}$ for kiwifruit vines (*Actinidia deliciosa* cv. Hayward)(Buwalda and Greaves, 1997). The maximum photosynthetic rates of approximately 7.0 µmol CO_2 $m^{-2}s^{-1}$ (Schaffer and Gaye, 1989; Larson *et al.*, 1992). Chabot and Hicks (1982) reported that the container-grown 'Turpentine' and 'Peach' mango trees in full sunlight were in the lower range for fruit trees, and comply with the long-accepted doctrine tree. In Australia, Pongsomboon *et al.* 1992 observed that net photosynthetic rate of containerized 'Nam Dok Mai' mango trees which received a photosynthetic photon-flux of 1300 µmol quanta $m^{-2}s^{-1}$, was 7.8 µmol CO_2 $m^{-2}s^{-1}$, as same as that observed for container-grown 'Turpentine' trees (Schaffer and Gaye, 1989), and Phattaralerphong (1997) measured in pot-grown 'Nam Dok Mai' and 'Khiew Sawoey' mango trees at the leaf age of 45 days were 9.4 and 8.8 µmol CO_2 $m^{-2}s^{-1}$, respectively and declining slowly to 5.3 and 5.2 µmol CO_2 $m^{-2}s^{-1}$, respectively of 240 day-leaves, which nearly the same as the range of net photosynthetic rate in this experiment; but considerably lower than rates observed for field-grown trees in Australia (12-19 µmol CO_2 $m^{-2}s^{-1}$)(Schaffer *et al.* 1994), and India (12-13 µmol CO_2 $m^{-2}s^{-1}$)(Chacko and Ananthanarayanan (1985). The difference in photosynthetic rates between container-grown and field-grown trees was attributed to feedback inhibition of photosynthesis for plant in container due to root restriction (Shaffer *et al.*,1994); Arp (1991) established a strong correlation between container volume and photosynthetic capacity of a number of species which had been exposed to elevated CO_2 concentrations, and found that smaller containers inhibited the photosynthetic capacity of plant which significantly increased with larger container volume. Which suggested mechanisms involved in the reduction of net photosynthetic rate in containerized plants were a decrease in the Rubisco activity (Caemmerer and Farquhar. 1984), a reduction in chlorophyll content (Arp, 1991), and source accumulation of sucrose resulting in "end product inhibition" of photosynthesis (Sharkey, 1985). These mechanisms are precipitated by the reduction of sink capacity for carbohydrates which could occurred when root growth was restricted.

The results of mango leaves analysis found that Choke Anan rootstock had influenced all scions to have higher level of phosphorous and potassium than Kaew rootstock. Phosphorous was an essential part of many sugar phasphates involed in photosynthesis; while potassium was an activator of many enzymes that were essential for photosynthesis and also a major contributor to the osmotic potential of cell, therefore to their turgor pressure(Salisbury and Ross, 1992) , the level of K also may affect photosynthesis through regulation of stomatal aperture. Stomatal opening, associated with high K availability, resulted in increased gas exchange, so increased photosynthetic rate (Kozlowski and Pollardy, 1997). Thus, Choke Anan rootstock, which had significantly higher phosphorous and potassium content of leaves, would be higher photosynthetic rate than on Kaew rootstock.

7. Effect of scion-rootstock combinations on the stomatal behavior

7.1 Effect of scion-rootstock combinations on the stomatal width

The results found that Pim Sen Mun, Khiew Sawoey and Nam Dok Mai on Choke Anan rootstock had significantly wider the average stomatal width (from 6.30 a.m. to 18.30 p.m.) than on Kaew (Table 4.41) and the same scion on Choke Anan rootstock had wider the widest of stomatal width than on Kaew (Figure 4.19). The opening and closing of the stomata were correlated with to the amount of K^+ in the guard cells of leaves. Analysis of the average concentration of K of leaves of different scions on Kaew and Choke Anan rootstocks (Table 4.60 c) found that Choke Anan rootstock had significantly higher the amount of K content of leaves as followed; Pim Sen Mun on Choke Anan had K content = 0.800% dry weight of leaves more than Pim Sen Mun on Kaew = 0.668%, Khiew Sawoey on Choke Anan had 0.779% higher than Khiew Sawoey on Kaew = 0.699%; Nam Dok Mai on Choke Anan had 0.803% higher than Nam Dok Mai on Kaew = 0.683%. According to Fischer and Hsioa (1968) experiment, epidermal strips of *Vicia faba* leaves were floated on the different concentration of K^+ solution from 1 to 100 mM in light under normal condition. The higher the K^+ concentration, the wider the stomatal width. Thus, the amount of K of leaves of scions on Choke Anan rootstock were higher than on Kaew for all scions, therefore stomata of scions on Choke Anan rootstocks opening wider than on Kaew for all scions.

Choke Anan rootstock had xylem exudate contained significantly more cytokinins than Kaew rootstock. Choke Anan rootstock contained significantly higher zeatin/zeatin riboside (Z/ZR) level which was 8.67 ng/ml than Kaew contained 2.47 ng/ml. Xylem exudate from Choke Anan contained concentration of Z/ZR much higher than Kaew rootstock. If the Z/ZR of Choke Anan rootstock were converted to 100%, Kaew rootstock had only 28.26%. Xylem exudate of rootstocks with high content of cytokinins, resulted wider stomatal width, similarly to Pallas and Box (1970), sprayed 0.5 μg/ml of Kinetin solutions to Avena leaves, there were increased stomatal width, increased rate of transpiration higher than control (sprayed with distilled water) to 61.8% and decreased stomatal resistance to 32% comparing with control. Tal *et al* (1970) found that 5 weeks old mutant *flacca* (f) had root exudate containing cytokinins concentration = 0.41 μ g/l kinetin, while normal tomato (*Rheinlands Ruhm* =R) contained 0.36 μg/l kinetin, and the mutant had the stomatal width wider than the normal. Leaves of *flacca* were floated on water in the dark for 3 hours, the stomata aperture were 6 μm, compared to the normal tomato floating on distilled water, the stomata definitely closed. When 1 mg/l kinetin solution was given through the roots of normal tomato (R), the stomata aperture was 6.4 μm. Compared with normal (R) scions grafted on flacca (f) had 16.8% transpiration rate higher than normal (R) on normal (R) and *flacca* (f) scion on normal (R) had 22% transpiration rate less than mutant (f) on mutant (f). Opening of stomata of *flacca* (f) on normal (R), were 2 μm lesser than stomata of mutant (f) on mutant (f); so that rootstocks which contained higher cytokinins content had wider stomatal width of scions than rootstocks which contained lower cytokinins.

Table 5.3 The average stomatal width (μm) from 06.30 a.m. to 11.30 a.m. (the temperatures :21.1 to 28.7 °C) and from 13.30 p.m. to 17.30 p.m.(the high temperature : 31.6 to 32.5°C)

Scions/Rootstocks	The average stomatal width (μm)	
	Time 06..30-11.30	Time 13.30-17.30
Pim Sen Mun/Kaew	1.47	1.60
Pim Sen Mun/Choke Anan	1.87	1.63
Khiew Sawoey/Kaew	1.28	1.59
Khiew Sawoey/Choke Anan	1.95	1.71
Nam Dok Mai/Kaew	1.31	1.66
Nam Dok Mai/Choke Anan	1.72	1.55
Choke Anan/Kaew	1.78	1.75

From table 5.3 found that before midday during 6.30 a.m. to 11.30 a.m., the low temperature period (21.1 to 28.7 °C) compared to afternoon during 13.30 p.m. to 17.30 p.m., the high temperature period (31.6 to 32.5°C); Pim Sen Mun on Kaew rootstock had the average stomatal width 1.47 μm in low temperature narrower than 1.60 μm in high temperature. Khiew Sawoey on Kaew had the average stomatal width of 1.28 μm in low temperature narrower than 1.59 μm in high temperature. Nam Dok Mai on Kaew had 1.31 μm in low temperature narrower than 1.66 μm in high temperature. Stomata of all scions on Kaew rootstock (grafted with all scions) in low temperature were narrower than in high temperature. During 6.30 a.m. to 9.30 a.m. the temperature between 21.1 °C to 25.3 °C , the stomatal width were wider when the temperatures were increased such as Khiew Sawoey on Kaew at 6.30 a.m. the stomatal width was 0.73 μm, at 7.30 a.m. was 0.98 μm, at 8.30 a.m. was 1.50 μm, at 9.30 a.m. was 1.73 μm (which were widest in the morning) and then were decreased continuously. As much more water loss from the plant, the stomatal width were narrower to prevent water loss from transpiration. At 10.30 a.m. the stomatal width was 1.31 μm, 11.30 a.m. was 1.36 μm and mid-day closure at 12.30 p.m. was only 1 μm. In the afternoon, the high temperature period (31.6 to 32.5 °C), the stomata of scions on Kaew opened wider such as Khiew Sawoey on Kaew at 13.30 p.m. the temperature of 31.6°C stomatal width was 1.61 μm while the relative humidity = 43%, so the plants lost a lot of water Therefore the stomatal width was narrower to 1.36 μm at 14.30 p.m. and the relative humidity = 37%, at 15.30 p.m. was only 1.25 μm and the relative humidity = 35%. The narrowing of stomatal width decreased the water loss from plant for a long time, so there were enough amount of water stored of the leaves and stems. The stomata opened widest 1.98 μm at 16.30 p.m. with 32.2 °C. At 17.30 p.m. decreased to 1.73 μm with 30.7 °C. Similarly with Roger *et al.* (1986), using epidermal strip of *Vicia faba's* leaves floated on 10 mM KCl solution in the light at 25, 35, 40, 45, 47 and 50 °C, and in CO_2-free air with saturated water vapour; found that the average stomatal apertures were increasing during 25°C to 40 °C, then decreasing while rising of temperature up to 50 °C. The average stomatal width were 1.75 μm at 25 °C, 3.5 μm at 35 °C, 5.1 μm at 40 °C but decreased to 4.3 μm at 45 °C, 3.9 μm at 47 °C and only 2.6 μm at 50 °C . Ilan *et al.*(1995) suggested that the conductance of depolarization-activated K channels,K_D channels (Channels where the K^+efflux of guard cells in order to close stomata) were depressed at high temperature affected stomatal closure were out of order or decreased, these showed down the rate of closure. But hyperpolarization-activated K channels: K_H channels (Channels entered guard cell to open the stomata) the conductance of K_H channels slightly decreased in high temperature, that made the stomata of well-watered plant open wider when rising of temperature. Stomata during the high temperature lead to increased transpiration from leaves in order to reduce the temperature on leaf surface.

The average stomatal width of leaves of Pim Sen Mun on Choke Anan in low temperature period were 1.87 μm wider than in the high temperature period which were 1.63 μm; Khiew Sawoey on Choke Anan in low temperature = 1.95 μm wider than in high temperature = 1.71 μm; and Nam Dok Mai on Choke Anan in low temperature = 1.72 μm wider than in high temperature = 1.55 μm. These can be concluded that the stomata of all scions grafted on Choke Anan rootstock during low temperature period opened wider than during high temperature period (this behavior contrasted to Kaew rootstock). Before midday period, at 6.30 a.m. stomata of Khiew Sawoey on Choke Anan was 1.46 μm (which was wider 2 times of stomatal width than on Kaew rootstock, might be the effect of higher cytokinins) at 7.30 a.m. = 1.36 μm, at 8.30 a.m. = 2.13 μm. at 9.30 a.m. = 2.19 μm and the widest stomatal width were 2.88 μm at 27.8 ^{o}C at 10.30 a.m., from then on the stomata were narrower. Choke Anan rootstock had the amount of cytokinins more than on Kaew. The effect of cytokinins caused stomata open wider during the plant had more water of the leaves and stems. Because the tree lost a lot of water in the morning, so there were low water of leaves and stems. In the afternoon, the temperatures were high, water of the trees of Choke Anan rootstock were decreased, therefore their stomata opened narrower . Similarly to Tal *et al.* (1970) worked on tomato *flacca* which contained cytokinins higher than tomato *Rheinlands Rhum* found that *flacca* had much higher rate of transpiration than *Rheinlands Ruhms* (rate of transpiration of *flacca* in 24 hours were 324 mg/cm^2, while 116.8 mg/cm^2 in *Rheinlands Rhum*). Furthermore, *flacca* had lower relative humidity than *Rheinlands Ruhm* as followed, in the morning *flacca* had relative turgidity of 93.8% lower than 96.7% in *Rhienlands Ruhm* at midday (noon) *flacca* had 77.8% lower than 90% in *Rheinlands Rhum* while in afternoon *flacca* had 82.1% lower than 92.0% in normal *Rhienlands Ruhm.* Similarly to Pallas and Box (1970) explained that the response of tomato to the effect of cytokinins by reducing stomatal resistance, rate of respiration and the decreased internal CO_2 , so the stomata open wider.

In conclusion, Choke Anan rootstock had amount of K^+ and cytokinins of the leaves more than Kaew. Effect on the leaves of scions grafted on Choke Anan rootstock had the stomatal width wider than on Kaew rootstock for all scions. To study the time of infiltration passed through the stomata of the leaves of scions grafted on Kaew rootstock required more period of time than on Choke Anan almost all the times. Finally, it can be said that the stomatal width of the leaves on Kaew rootstock were narrower than on Choke Anan rootstock.

7.2 Effect of scion-rootstock combinations on the stomatal density.

Stomatal density were correlated to the size of tree (in this point, considered on the average of canopy width growth rate from the beginning to the end of this experiments). The more increasing of stomatal density, the higher the canopy width growth rate. The experiments, should be arranged in order as followed: Pim Sen Mun on Choke Anan had higher canopy width growth rate than Nam Dok Mai on Choke Anan, Pim Sen Mun on Kaew, Nam Dok Mai on Kaew, respectively. Most of them except Khiew Sawoey on Kaew and on Choke Anan were similar to the experiments of Pathak *et al.*(1977) studied by using the stomatal density to predict the vigor of 9 Plum rootstocks. The vigorous rootstocks were Myrobalan A had stomatal number of 18.98, while Damas C which were dwarfing rootstock had only 6.62.

The average stomatal width for whole day were correlated to the size of the tree (In this experiment, using the average canopy width growth rate instead of the whole tree) the wider the stomatal width, the higher the canopy width growth rate, the data should be arranged (Table 4.6) in order as followed : Khiew Sawoey on Choke Anan had the stomatal width = 1.74 μm, so that the canopy width growth rate were higher than Pim Sen Mun on Choke Anan which had 1.65 μm, wider than Nam Dok Mai on Choke Anan (1.54 μm), wider than Pim Sen Mun on Kaew (1.46 μ m), wider than Nam Dok Mai on Kaew (1.39 μm) and should be more than Khiew Sawoey on Kaew = 1.39 μm. Most of them (except Khiew Sawoey on Kaew) were similar to the experiment of Banger and Prasad (1992) using density and size of stomata in categories ber with 4 kinds of rootstocks found that the more increasing in size of stomata and stomatal density, the more vigorous size of rootstocks. While using the average canopy width growth rate of the whole experiment, found that Khiew Sawoey on Kaew had the highest canopy width growth rate = 84.50% , followed by Khiew Sawoey on Choke Anan = 70.70% , Pim Sen Mun on Choke Anan 64.47%, Nam Dok Mai on Choke Anan = 63.94%, Pim Sen Mun on Kaew = 63.65% and Nam Dok Mai on Kaew = 52.02% respectively. Both stomatal width and stomatal density were similar to the canopy width growth rate, those were Khiew Sawoey on Choke Anan had the canopy width growth rate higher than Pim Sen Mun on Choke Anan, Nam Dok Mai on Choke Anan, Pim Sen

Mun on Kaew and Nam Dok Mai on Kaew, respectively and should be higher than Khiew Sawoey on Kaew, but in fact Khiew Sawoey on Kaew used more the accumulate foods for canopy growth than flowering. Khiew Sawoey on Kaew had the lowest the total numbers of flowering for both rootstocks and all scions as followed, Khiew Sawoey on Kaew = 1.39, Pim Sen Mun on Kaew = 1.94, Nam Dok Mai on Kaew = 2.01, Pim Sen Mun on Choke Anan = 2.11, Khiew Sawoey on Choke Anan = 2.45 and Nam Dok Mai on Choke Anan = 2.67 (Table 4.17). If converted the number of flowering of Nam Dok Mai on Choke Anan during the whole time of experiments into 100% Khiew Sawoey on Kaew had the number of inflorescence only 52.06% which were much lower. There were possible that Khiew Sawoey on Kaew used the least amount of the accumulative foods for flowering and fruit-setting. These were the reasons for the highest canopy width growth rate. It was possible that if their canopy growth were continued; Khiew Sawoey on Kaew may have the lower canopy width than Nam Dok Mai on Kaew. These hinder idea were similar to Beakbane and Majumder (1975) studied the stomatal density of different kinds of apple rootstocks found that the dwarfing clone M9 had the lowest stomatal density while the vigorating clone MM111 and M25 had the highest stomatal density. The stomatal density or number of stomata per 0.02 mm^2 should be arranged in order as followed : M9 and M27 (dwarfing clone) had number of stomata = 7.0 and 8.6 per 0.02 mm^2 respectively. Intermediate clone MM106 = 10.1 per 0.02 mm^2 and Invigorating MM111 and M25 = 11.8 and 25.0 per 0.02 mm^2, respectively. While M27 grafted with scions had the canopy width growth rate as dwarfing clone, but study by stomatal density = 8.6 per 0.02 mm^2 nearly the range of 8.8 to 8.9 per 0.02 mm^2 as semi-dwarfing clone M26, M27 respectively. When M27 rootstock was naturally grown the size of tree was a semi-dwarfing clone. Pallus and Box (1970) explained the effect of cytokinins on stomatal aperture that cytokinins increased the stomata opening by decreased the resistance of stomata and the rate of respiration to decrease internal CO_2, so that Choke Anan rootstock contained significantly higher level of cytokinins content than Kaew, from this experiment, which found in that xylem exudate of Choke Anan rootstock contained higher zeatin/zeatin riboside (Z/ZR) level (8.67 ng/ml) than Kaew (2.45 ng/ml) . Choke Anan provide the amount of cytokinins higher than on Kaew, these affected the scions which grafted on Choke Anan to had the stomatal width wider than the same scion on Kaew rootstock. These high level of cytokinins in rootstocks affected the scions by decreasing rate of respiration, decreasing metabolism and in using accumulative foods for respiration. Therefore, they remained the important accumulative foods for good growth and development and increased flowering. According to Kamboj *et al.* (1999), using apple rootstock M27, M9 and MM106 grafted with 'Fiesta' scions found that concentration of zeatin/zeatin riboside in shoot-xylem sap of rootstocks were increased while increased rootstocks vigor. The dwarfing clone M27 and M 29 rootstocks contained zeatin/zeatin riboside 1.13 and 1.41 ng/ml respectively. Intermediate MM 106 rootstocks contained 1.9 ng/ml. Fiesta scion grafted on those rootstocks found that the shoot xylem sap containing concentration of zeatin/zeatin riboside in M27, M9 and MM 106 were 1.08, 1.51 and 1.65 ng/ml respectively. These showed that cytokinins content in shoot xylem sap were increased when increasing rootstocks vigor and also found that average shoot length of 'Fiesta' on M27 , M9 and MM106 were 99.60, 105.80 and 134.90 cm. respectively. Indicated that increasing of concentration of cytokinins correlating to increasing of shoot length which were the growth of young plant in juvenile stage, (no flowering), therefore cytokinins are definitely affected on the growth and development of plants.

8. Effect of scion-rootstock combinations on dry weight of the scions

There were non significant difference between both rootstocks, but among three scions, Khiew Sawoey had significantly higher the dry weight of whole plant than Pim Sen Mun and Nam Dok Mai, respectively. Observation on these, Khiew Sawoey on both rootstocks were the most vigorous, followed by Pim Sen Mun and Nam Dok Mai, respectively. According to, Garcia-Perez and Mosqueda-Vazuez (1993) were tested several interstock/rootstock combination with some cultivars like 'Irwin'(I), 'Esmeralda'(E) and 'Manila'(M) as treatments: M/I/I, M/E/M, M/M/M, M/M, M/I and M (seedlings). The analysis was done during the main vegetative growth. The dry weight in all treatments measured even though a difference can be observed between treatments M/I and M seedling which showed more dry weight than M/I/I and M/E/M.

9. Effect of scion-rootstock combinations on carbohydrate of leaves and terminal shoots

9.1 Effect of scion-rootstock combinations on the amount of total non-structural carbohydrate (TNC) and reducing sugar (RS) content of leaves during flowering.

Choke Anan rootstock had significantly higher the TNC content of leaves of all scions than on Kaew rootstock. Among the three scions, Nam Dok Mai had significantly higher than Khiew Sawoey and Pim Sen Mun, respectively in all 4 stages of inflorescence development (Table 4.45 and Figure 4.28) and were decreased from 1st stage to the 4th stage, similarly for all scion-rootstock combinations. As there were flowering and development of inflorescence in the 2nd and the 3rd stages, more amount of carbohydrates from leaves were needed to be a strong sink. Carbohydrates from leaves were remobilized by digested into sugars, and translocated to the organ of rapid growth. While in the 4th stage, the inflorescence began to grow by cell elongation, also used more amount of nutrient too. There results were similar with Nartvaranant *et al.* (1998) which studied the decreasing of TNC of leaves in the different stages during inflorescence development 5, 10 and 18 days after bud-break of Nam Dok Mai which declined by 7.2% and reaching 105.4 mg/g DW. at full bloom. Furthermore, according to Subhadrabandhu *et al.*(1997), reported in Khiew Sawoey that the TNC content of leaves accumulated to the highest level at 96, 62 and 46 days after the paclobutrazol treatment at the rate of 2, 4 and 8 g.ai./tree respectively, or at the time before first flowering in these treated trees. This indicated that terminal shoots and leaves are important organs in accumulating food reserves as a preparation stage for flowering. When flower buds development for flowering and fruit setting, they became a strong sink and needed more amounts of food reserves first from leaves and later from terminal shoots. This was shown by the rapid decrease of TNC of leaves and later of the terminal shoots at flowering time.

The reducing sugar (RS) of leaves (Table 4.46), there were non significant difference in all scion-rootstock combinations during the 4 stages of inflorescence development. The amount of the RS of leaves were slightly decreased from the 1st stage to the 4th stage similar to all scion-rootstock combinations (Table 4.29). The RS were translocated from leaves for growth and development of inflorescence, similar to the study of Nartvaranant *et al.* (1999) in Nam Dok Mai that no significant change of leaf RS content over the 20 days after bud-break.

9.2 Effects of rootstocks on the amount of total non-structural carbohydrate (TNC) and reducing sugar (RS) of the terminal shoot during flowering.

Nam Dok Mai had significantly higher the TNC content of terminal shoot than Khiew Sawoey and Pim Sen Mun on Kaew,respectively in the 2nd , the 3rd and the 4th stages but Khiew Sawoey had lower than Pim Sen Mun in the 1st stage; whereas there were non significant difference between both rootstocks in all 4 stages (Table 4.47). In all scion-rootstock combinations, there were low in the 1st stage (one week before flowering), and increased in the 2nd stage, beginning of flowering (tip of the terminal shoot turned white) in order to accumulate more carbohydrate in the last week before flowering, preparing the nutrients for growth and development of inflorescence, and were constant in the 3rd and the 4th stages (Figure 4.30). There were similar to Juthamanee (1989), found that TNC the terminal shoots were low at one week before flowering and increased to the highest prior to bud-break. Nartvaranant *et al.* (1998) found that there were no significant change in the TNC content of terminal shoots of Nam Dok Mai from beginning of inflorescence to the 100% full bloom.

The reducing sugar of the terminal shoot, found that Nam Dok Mai had significantly higher the cumulative RS than Khiew Sawoey and Pim Sen Mun, respectively; but there were non significant difference between both rootstocks (Table 4.48). The amount of RS of all scion-rootstock combinations were slightly increased from the 1^{st} stage to the 4^{th} stage (Figure 4.31). The RS were translocated from the leaves through the terminal shoots toward the inflorescences. The more growth of inflorescence, the increasing the RS translocated through the terminal shoots. Similar to the study of Nartvaranant *et al.*(1998) in Nam Dok Mai that did not significantly change in RS during inflorescence development from bud-break to full bloom during 20 days after bud break.

The decline of TNC and RS content in the inflorescence during development may be due to the high growth rate of this organ which requires an external supply of assimilate for growth (Chauhan and Pandey, 1984). During floral development the inflorescences of mango (non-photosynthetic tissue) are strong sink for assimilates and mineral nutrients compared to other organs such as leaves and stems. According to Nartvaranant *et al.,* (1998) five days after bud-break, the TNC of the inflorescence was high (236.1 mg/g DW.) compared to the TNC content of leaves and bark (113.5 and 125.7 mg/g DW.) respectively, suggesting that remobilization of assimilates from adjacent tissue to support cell division during early inflorescence development had occurred. The decline it utilization of TNC and RS content during floral development is likely due to an increase in cell size. Patrick (1981) reported that in developing inflorescences and fruits, cell division is limited by carbohydrate supply from leaves and other tissue whereas cell expansion in the later stage of fruit ontogeny is limited by carbohydrate stored in the inflorescence and young fruit. Nartvaranant *et al.*(1998) additional suggested that cell division in the inflorescences at 5 days after bud-break that was nearly completion resulting in the translocation of carbohydrate from leaves to other plant organs. Searle *et al.* (1997) found a significant decline in root and leaf starch concentration during the weeks prior to inflorescence emergence in cv. 'Kensington Pride' mangoes. The rapid growth of the inflorescence over the duration of the study, which was most likely due to cell expansion and the cause of the depletion of TNC and RS within the inflorescence. Also the demand for assimilate increases during anthesis to support development of fruit sink (Vemmos, 1995).

Chacko, *et al.* (1982) suggested that during flowering and fruit setting, carbohydrate from storage sites within the tree were depleted to support the developing inflorescences and fruit. Mango roots have been identified as a major source of carbohydrates during flowering with a significant decline in starch levels during this period (Searle, *et al.*,1997). Street and Opick (1984) reports that providing a 'pool' of assimilate for remobilization during the period of high demand. The storage of carbohydrate excess to tree requirements for remobilization during the flowering and fruiting phases of growth is an established patterns for many fruit tree crops. Thus the most significant changes in carbohydrate concentration during the sink phase of inflorescence growth occurred in the leaf tissue as an important energy source supporting floral development.

9.3 Effect of scion-rootstock combinations on the total nitrogen (TN) of the leaves.

Khiew Sawoey on Kaew had the significantly higher the amount of total nitrogen of the leaves more than on Choke Anan in the 2nd to the 4th stage, while Pim Sen Mun on Kaew had significantly higher than on Kaew, and Nam Dok Mai on Choke Anan had significantly higher than on Kaew in the 1st , the 2nd and the 4th stages but lower in the 3rd stage (Table 4.49). All scion-rootstock combinations had the variable amount of TN almost the similar pattern as the following: in the 1st stage (about 1 week before flowering) the amount of TN of leaves were high, then decreased rapidly during flowering in the 2nd stage (the tip of shoot turned white color) and increased in the 3rd and 4th stages (Figure 4.32). The findings of Juthamanee (1989) that Khiew Sawoey had the lowest amount of TN in the week of flowering(bud emergence).

The amount of TN of leaves were corresponded with the growth and development of the mango trees. Khiew Sawoey had significantly higher the TN of leaves than Pim Sen Mun and Nam Dok Mai, respectively (Table 4.3, 4.6, 4.9 and 4.14), so that the growth rate of stem height, canopy width and stem diameter and the total number of shooting on Khiew Sawoey were significantly better than Pim Sen Mun and Nam Dok Mai, respectively too. These results were similar to Kohli and Reddy (1988) found that 'Alphonso' mango were grafted on vigorous rootstocks such as open pollinated and 'Olour' had the highest amount of TN of leaves. Whereas Samaddar *et al.* (1988) found that 'Olour' rootstock grafted with 'Himsagar' had lesser canopy width of 67%, while comparing with 'Himsagar' grafted an 'Himsagar' and 'Olour' rootstocks grafted with 'Langra' had lesser canopy width of 44% comparing with 'Langra' grafted on 'Langra'. Therefore 'Olour' rootstock was vigor also when grafted with 'Alphonso' but they were dwarf when grafted with 'Himsagar' and 'Langra', showed that the translocated of TN to the leaves were corresponded to each pair of rootstocks and scions.

9.4 Effect of scion-rootstock combinations on total nitrogen (TN) of terminal shoots.

All scion-rootstock combination, had high amount of TN in the 1st stage (1 week before flowering) and decreased to the lowest in the 2nd stage and increased again in the 3rd and 4th stages for growth and development of inflorescences at flowering time (Figure 4.33). The results similar to Juthamance (1989), found that Khiew Sawoey in the week of in florescences (bud-emergence) had the lowest amount of TN of terminal shoot, and according to Subhadrabandhu *et al.* (1997) found that after receiving Paclobutrazol 112 to 113 days, Khiew Sawoey had the lowest amount of TN of the terminal shoots at flowering time, stimulated the flowering by urea sprayed, then it could be induced to flowering for 100%.

9.5 Effect of rootstocks on the carbohydrate/nitrogen (C/N ratio) of leaves.

Nam Dok Mai on Choke Anan had significanty higher the C/N ratio of leaves than on Kaew in the 3rd stage. Pim Sen Mun on Kaew had significantly higher than Choke Anan in the 3rd stage, but Khiew Sawoey on Choke Anan had significantly higher than on Kaew in the 2nd and the 3rd stages (Table 4.51) that all scion-rootstock combinations had the lowest amount of the C/N ratio of leaves in the 1st stage (about 1 week before inflorescences emergence) there were rapidly increased in the 2nd stage (Inflorescence emergence whitish tip) and decrease in the 3rd and the 4th stages (Figure 4.34).

9.6 Effects of rootstocks on the C/N ratio of the terminal shoots.

Nam Dok Mai on Kaew had significantly higher the C/N ratio of terminal shoots than on Choke Anan in the 1st to the 3rd stage but lower in the 4th stage. Pim Sen Mun on Kaew had significantly higher than on Choke Anan, but Khiew Sawoey on Choke Anan had higher than on Kaew in the 1st stage (Table 4.52). All scion-rootstock combinations had the C/N ratio of terminal shoots almost the same pattern, as followed: the C/N ratio were low in the 1st stage (1 week before flowering) and increased to the highest in the 2nd stage, the flowering week (whitish tip). Then decreased as linear graph line in the 3rd and the 4th stages (Figure 4.35). These results similar to Juthamanee (1989) which found that Khiew Sawoey had low C/N ratio of terminal shoot in one week before flowering and increased to the highest in the flowering week.

10. Effect of scion-rootstock combinations on the mineral elements level of scions.

Pim Sen Mun and Khiew Sawoey on Choke Anan had significantly higher the average level of phosphorous of leaves than on Kaew. Between both rootstocks, Choke Anan had significantly higher the average level of potassium of scions' leaves higher than on Kaew rootstock; while Kaew and Choke Anan rootstocks had the same average level of total nitrogen, calcium and magnesium of scions' leaves with non significant difference. Among three scions, the average level of potassium, calcium and magnesium were non statistical significant difference; while the average level of nitrogen of Khiew Sawoey was significantly higher than Pim Sen Mun and Nam Dok Mai, respectively (Table 4.60). Similar to Kurian *et al.* (1996), studied the mango cv. 'Alphonso' as scion grafted on nucellar seedling of seven polyembryonic varieties, with that grafted on seedlings obtained from open-pollinated cv. 'Alphonso' as a control. The polyembryonic cultivars used as rootstocks were 'Vellaikolamban', 'Bappakai', 'Chandrakaran', 'Kurukan', 'Muvandan', 'Mylepelian' and 'Olour', found that the differences of leaf nutrient status of 'Alphonso' on various rootstocks were highly significant (P=0.01) for nitrogen and potassium and significant (P=0.05) in the case of calcium , while the levels of phosphorus and magnesium were not significant. The lowest nitrogen leaf concentration was recorded on 'Vellaikolamban' rootstock and maximum on vigorous rootstocks such as 'Muvandan' , 'Bappakai' and 'Olour'. Similarly, the lowest values for potassium was recorded on 'Vellaikolamban' and the highest on 'Olour' and 'Muvanda', respectively. Leaf calcium on 'Bappakai' rootstock and highest on 'Chandrakaran' and open-pollinated 'Alphonso'. According to Kohli and Reddy (1988) studied the influence of various rootstocks on leaf nutrient composition of four-year old 'Alphonso' mango. The various rootstocks tried were Open Pollinated (Alphonso) , 'Vellaikolamban', 'Bappakai', 'Chandrakara', 'Kurukan', 'Muvandan', 'Mylepelian' and 'Olour'. Except the first one, the rest seven rootstocks were polyembryonic, found that difference due to rootstocks of the leaf nutrient composition with respect to N, P, K, Ca and Mg were significant. 'Vellaikolamban' rootstock showed the lowest leaf N, K, and Ca and high value of Mg. 'Olour' rootstock resulted in the highest leaf nutrient composition as compared to 'Vellaikulamban' rootstock but was at par with other rootstocks. Furthermore, Thaku *et al.* (1998) reported that the mineral composition of mango leaves of cv. 'Dashehari' as affected by twenty four rootstocks (10 polyembryonic + 14 monoembryonic), the contents of N, P, K, Ca and Mg of the leaves were significantly influenced by the type of rootstock. 'Rumani' rootstock resulted in higher N content and 'ST-9' showed a tendency to absorb more P and K. While Ca and Mg contents were more in 'Nekkare' rootstock.

11. Effect of rootstock and scion-rootstock combinations on endogenous hormones

11.1 Effect of rootstock on cytokinins content in xylem exudate.

Both rootstocks, Choke Anan had significantly higher Z/ZR level in xylem exudate than Kaew (Table 4.61). These should be observed that Choke Anan had Z/ZR level more than Kaew for 3.54 times; but there were non significant difference between both rootstock for iP/iPA level in xylem exudate (Table 4.62). According to Kamboj *et al.* (1999) experiment by using apple rootstock M27, M9 and MM106 grafted with 'Fiesta' scions found that concentration of zeatin/zeatin riboside in the shoot xylem sap of rootstocks were increased while increased rootstocks vigor. The dwarfing clone M27 and M 29 rootstocks contained zeatin/zeatin riboside 1.13 and 1.41 ng/ml respectively. Intermediate MM 106 rootstock contained 1.9 ng/ml. 'Fiesta' scion grafted on those rootstocks found that the shoot xylem sap containing concentration of zeatin/zeatin riboside in M27, M9 and MM 106 were 1.08, 1.51 and 1.65 ng/ml respectively, and showed that cytokinins content in shoot xylem sap were increased when increasing rootstock vigor, and also found that average shoot length of Fiesta on M27 , M9 and MM106 were 99.60, 105.80 and 134.90 cm. respectively. Indicated that increasing of concentration of cytokinins correlating to increasing of shoot length which were the growth of new plant in juvenile stage, therefore cytokinins definitely affected the growth. Kamboj and Quinlan (1997) found that where the cytokinin concentration of root pressure exudate was measured the results were similar to those obtained from analysis of shoot xylem sap that an increase with increasing rootstock vigor was apparent, and with MM106 shoots exhibiting the highest cytokinin concentration. No significant differences between nongrafted and grafted plants were detected from a given rootstock. These reasons explained that Choke Anan rootstock could be more vigor than Kaew rootstock. Chen (1987) measured the cytokinin content of xylem sap derived from root during various stages of leaf differentiation, in mature green leaves (bud rest), during early flowering, and in full bloom using high-performance liquid chromatography (HPLC) separation couple with soybean cotyledonary callus bioassay. The lowest levels of putative trans-zeatin and its riboside were translocated from roots during the vegetative growth and resting stages, whereas the highest levels were measured during the early flowering and full bloom stages led to the conclusion that cytokinins are involved in stimulation of bud break in flowering of mango; Chen (1991) also found in lychee (*Lichi chinensis* Sonn cv. Hehyeh) that the four cytokinins:zeatin, zeatin riboside N^6-(δ^2-Isopentenyl) adenine N^6-(δ^2-Isopentenyl) adenosine, were detected in buds. There were an increase of cytokinins activity in the buds during flower bud differentiation. In dormant buds, the endogenous cytokinin content was low, and the buds did not respond to exogenous cytokinin application. Furthermore, Chen *et al.* (1997) found that in longan (*Euphoria Longana* Lam.) the cytokinins during dormancy , had amount of zeation riboside-o-glucoside (OGZR), zeatin-o-glucoside (ZOG), zeatin riboside (ZR) and zeatin (Z) were 1.44, 1.20, 0.12 and 0.08 mg/100 g of fresh terminal shoots, respectively. While flower bud initiation had zeatin (Z), zeatin riboside (ZR), isopentenyladenosine (iPA), and isopentenyladenine (iP) were increased up to 3.6, 2.6, 0.38 and 0.27 mg/100 g of fresh terminal shoots respectively, which were higher than the much lower during leaf flush of 0.30, 0.45, 0.19 and 0.12 mg/100 g of fresh terminal shoots respectively, indicated that increased in bound cytokinins in longan buds at dormancy were associated with a marked increase in zeatin-O-glucoside and zeatin riboside-O-glucoside, and a reduction in the levels of zeatin and zeatin riboside. In contrast, an increase in zeatin, zeatin riboside and decline in zeatin-O-glucoside and zeatin riboside-O-glucoside were correlated with flower bud initiation. Where cytokinins have been found to accumulate as their glucoside conjugates in mature leaves they have been observed to be stable (Letham and Palni 1983). And those of previous reports (Taylor *et al.*, 1990) suggested that a basal level of leaf and bud cytokinins were exported or further metabolized during floral initiation and development. They also suggested that the promotion of floral differentiation might require a continuous supply of cytokinins from buds and mature leaves. The elevated cytokinin levels found prior to and during flowering and flowering response to applied BA (N- (phenylmethyl) 1H-purin-6- amine) led to the conclusion that cytokinins are involved in flowering of mango (Chen, 1985, 1987). Cytokinins may be involved in flower induction (F. Bangerth, 2000, personal discussion). The cytokinin concentration in root exudate of Choke Anan rootstocks were higher than Kaew rootstocks, therefore the scions grafted on Choke Anan rootstock migth be giving more flowering than the same scions on Kaew rootstock. These correlated with the total numbers of flowering (Table 4.17), Nam Dok Mai and Khiew Sawoey on Choke Anan rootstock had significantly higher the total numbers of flowering than on Kaew rootstock. So the accumulative foods of leaves and stems were used for reproductive growth to formed flower bud differentiation and fruits development more than for vegetative growth. This point was the important reason to explained why Choke Anan rootstock was not showed the extremely vigorous growth habit. In contrast, there were non significant difference in the growth rate of stem height , canopy width and stem diameter, and percentage and total number of shooting between both rootstocks (Table 4.3, 4.6 , 4.9, 4.10 and 4.13)

11.2 Effect of rootstock on Gibberellin-like substances of terminal shoots during flowering.

The content of GA-like substances of terminal shoots were low in the 1st stage (mature terminal shoots) and increased in the 2nd stage (bud-break), in the 3rd stage and the highest in the 4th stage in all scion-rootstock combinations. According to Tongumpai *et al.* (1991) reported that in the flowering trees, it was found that the content of gibberellin-like substances of terminal shoot decreased before flowering. These substance were not detectable from six weeks before the flowering time. In contrast, the amount of gibberellin-like substance was significantly higher in the non-flowering tree which was agreed with Pal and Pam (1978) who suggested that the total gibberellin activity was markedly higher in "off" year "mango" shoot-tips than in "on" year shoot-tips. Gibberellin activity was at a very low level in "on" year shoot-tips after 15 November, whereas gibberellin concentration was high in "off" year shoot-tips from November to February. Furthermore, Chen (1987) found that in xylem exudate of mango cv. Irwin the gibberellin activities were highest at the leaf differentiation stage, and decreased at the mature green stage. There was no further significant decrease, but a continued low level of gibberellin in the xylem sap at the stage of early flower bud formation and full bloom; Tongumpai *et al.*(1997) found in mango trees cv. Khiew Sawoey that the trees receiving paclobutrazol at the rate of 8, 4 and 2 g.ai per tree started to flower at 76, 96 and 103 days after the application. This flowering may be related to the level of gibberellin-like substances of the terminal shoots, and as it was found that before flowering of mango trees in all treatments, the level of gibberellin-like substances was at the minimal level which could not be detected; Pongsomboon *et al.*(1997) also found in mango cv. 'Nam Dok Mai' that GA_3-like substances were comparatively high at the beginning of the dormant period but declined by about 50% in late November, then increased somewhat and remained relatively stable during the second week of December before dropping in mid December, Finally the levels increased slighly in late December through to inflorescence emergence, and presumed that reduced GA_3-like substances of shoot tips at two weeks before the emergence of inflorescence were also associated with flower induction of mango cv. Nam Dok Mai, and also believed that gibberellin was associated with the enhancement of vegetative growth and inhibited flowering of mango; Nunez-Elisea and Davenport (1998) suggested that applied single foliar sprays of gibberellic acid (GA_3)10-250 mg/g during cool or warm temperatures to determine their effects on shoot initiation and morphogenesis in mango (*Mangifera indica* L.) cv. 'Keitt' and 'Tommy Atkins', and found that GA_3 delayed inflorescence initiation but did not cause vegetative morphogenesis when bud differentiation occurred in cool temperatures. In contrast to delaying inflorescence initiation in cool temperatures, GA_3 did not delay vegetative growth during warm temperatures. Thus, it was concluded that GA_3 prevents initiation of reproductive shoots of mango rather than inhibiting floral induction.

However, the content of GA-like substances of terminal shoots, were increase from mature stage, bud-break, to inflorescence emergence 10-12 cm long because gibberellins were able to promote growth of intact plants by either stem elongation, cell division, or both (Arteca, 1996), so promoting the inflorescence formation process in the mango vegetative growth of mango trees.