Chapter II

Literature review

2.1 Agroecology of the study area

2.1.1 The study area and its location

Luang Prabang is one of the 18 provinces of the Lao PDR. Luang Prabang is located in the mountainous northern part of the country (Figure 1). Its boundary stretches from longitude of 101°40' to 103°30'E and latitude of 19°00' to 21°00'N, with base altitude of about 305 m above mean sea level and ranging to about 1,500 m (Keoboualapha, 1999).

2.1.2 Physical characteristics

Rainfall

Monsoon currents, dividing the year into two distinctive wet and dry seasons, mainly influence the annual amount, distribution and pattern of rainfall in Luang Prabang province, as well as in the rest of the country. Figure 2 shows the rainfall amount for the province (average from five years of rainfall data 1997-2001). Annual rainfall averages about 1,387 mm. The dry season starts in November and ends in April and the rainy season starts in May and ends in October. More than 80% of total precipitation falls during the rainy season. December and January are the two driest months, receiving less than 10 mm $month^{-1}$. In contrast, July and August are the two wettest months of the year, receiving more than 200 mm $month^{-1}$. Rainfall of 100 mm $month^{-1}$ distributed evenly, is preferable to 200 mm $month^{-1}$, which falls in just a few days. Regional or global climate change can be the major factors that affect the amount of rainfall in the area. Reliable forecasting of weather might help to reduce mango production losses from drought.

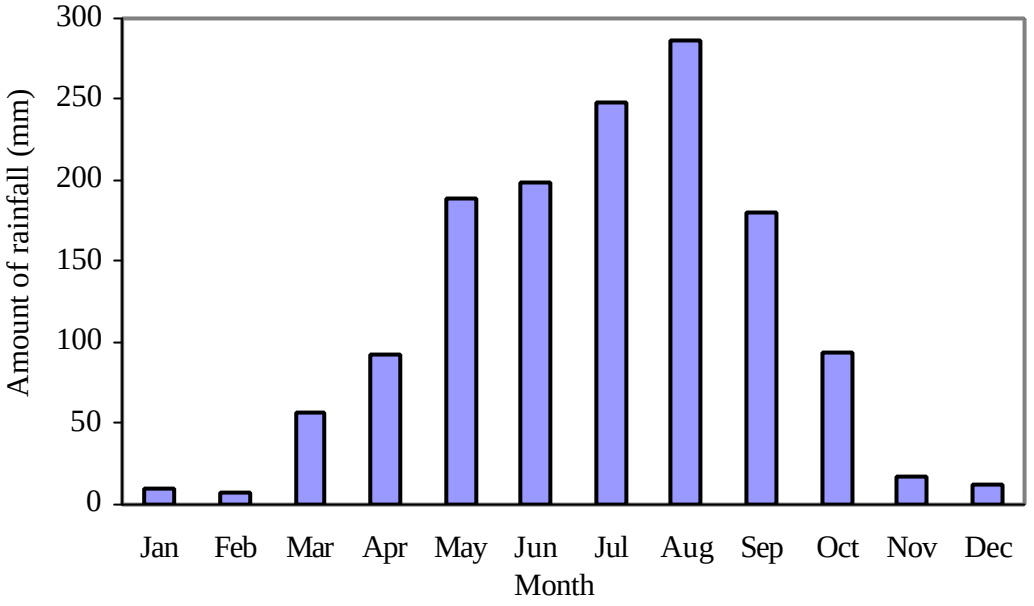

Figure 2 Average monthly rainfall for the Luang Prabang province (1997-2001)
Source: Provincial Agrometeorological Section of Luang Prabang, 2001

Temperature

Average annual temperature was recorded at 25.9°C for the last five years (1997-2001), with average minimum of 20.2°C and average maximum of 31.5°C. During cropping season (May to October), minimum temperature ranges from 16.9 to 24.6°C and maximum temperature ranges from 30.3 to 33.9°C (Figure 3). Considering the optimum temperature requirement for mango growth is between 21.1 and 26.6°C, the prevailing average temperature is considered to be favorable.

Solar Radiation

Solar radiation is the primary energy source for crop growth and profoundly affects temperature and evaporation. Quantitative information on radiation in mango growing in Lao PDR is limited, mainly because reliable requirement to measure is relatively expensive compared to instruments for measuring rainfall and temperature.

Only the measured sunshine duration (actual sunshine hours) can be obtained. Average sunshine duration was recorded at 5.4 hours per day with average minimum of 3.9 hours per day and average maximum of 7.6 hours per day (during 1997-2001).

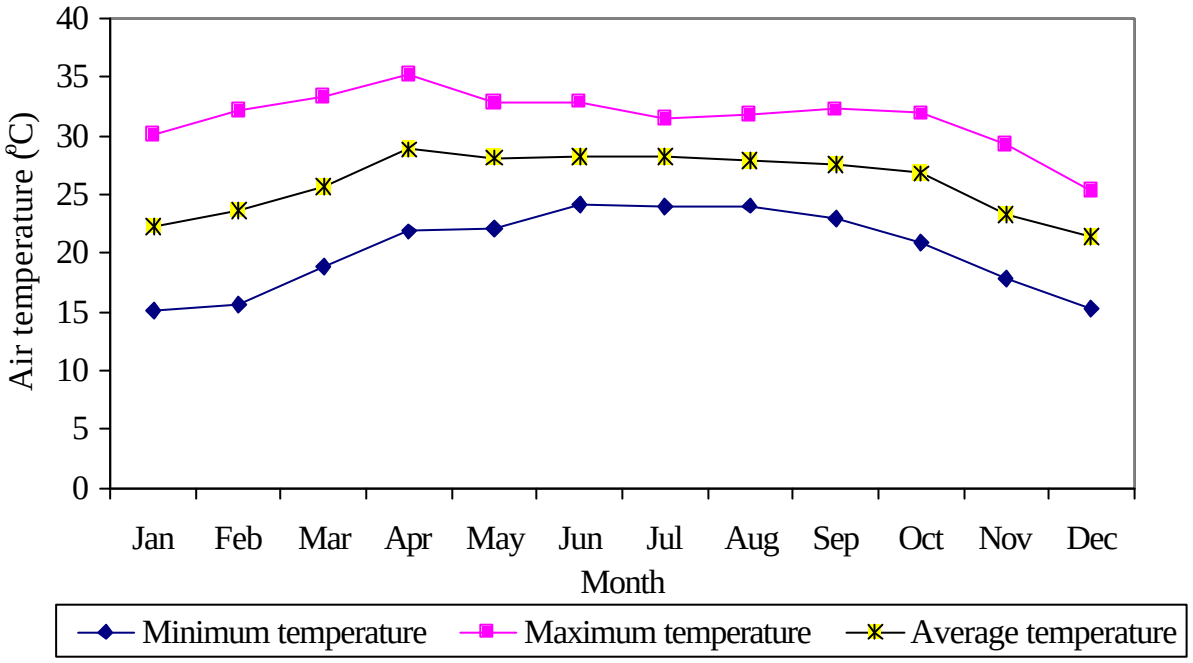

Figure 3 Air temperature for the Luang Prabang province (1997-2001)

Source: Provincial Agrometeorological Section of Luang Prabang, 2001

Landscape and soils

Luang Prabang province is located in the hilly area of northern Laos. Because of mountainous topography, the area for lowland crop production is limited. Most of the areas used for mango growing are at altitudes ranging from 305 to 600 m above mean sea level (Soukhaphonh *et al*., 1992). Land use maps based on slope gradient is presently unavailable for the whole province. However, most of mango growing areas in the province is concentrated on sloping land with most slope gradient of 5 to 30%.

Soils in the province are classified as Orthic Acrisols (red-yellow podsolic and red-brown lateritic soils) with sandy loam to sandy clay topsoil. They are generally heavily leached, fairly acid, with low cation exchange capacity (CEC), low available P content, and have a depth varying from 0.4-1.0 m (Roder *et al.,* 1991) (Table 1).

Table 1 Characteristics of soils in Luang Prabang province

Parameter	Soil depth (cm)					
	0-3	3-10	10-25	25-50	50-75	75-100
pH	5.59	4.76	4.56	4.61	4.73	4.83
Organic matter (%)	6.48	4.23	2.90	1.97	1.53	1.24
Total P (ppm)	758.0	609.0	523.0	469.0	447.0	424.0
Available P (ppm)	28.40	8.90	4.60	4.60	2.90	2.50
Available K (ppm)	358.0	162.0	91.0	60.0	41.0	37.0
Exch. Ca (meq/100g)	4.16	1.30	0.71	0.50	0.47	0.48
Al (meq/100g)	0.45	2.32	3.62	4.09	3.88	3.58
CEC (meq/100g)	14.9	1.90	10.30	9.80	9.10	8.40

Source: Soukhaphonh *et al.,* 1992 and Roder *et al.,* 1991

2.1.3 Biological characteristics

In Luang Prabang province, rice area occupied a high proportion (84% or 51,286 ha) of which paddy rice, upland rice, and dry season rice occupied 8,751, 40,735, and 1,794 ha respectively. And the remaining 16% are under annual and perennial crops i.e. corn, sweet potato, peanut, sesame, sugar cane, vegetables and fruit trees (Figure 4) (National Statistic Center, 2000). In Luang Prabang province as well as in the country as a whole, upland agriculture is practiced by ethnic groups, Lao Soung and Lao Theung may be more dependent on it (Keoboualapha, 1999). Apart from growing rice, annual and perennial crops, 88% of total agricultural households involve in animal production as a part of their farming systems. In the province there were 36,487 cows, 54,360 buffaloes, 120,335 pigs, 14,195 goats and poultry more than 850,000 heads (Figure 5) (Provincial Livestock Section of Luang Prabang, 2001).

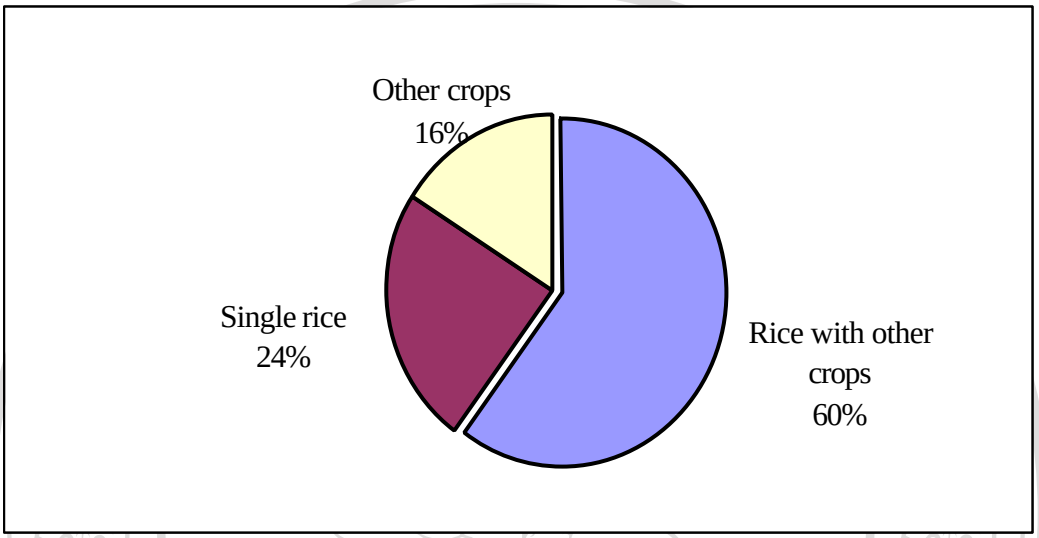

Figure 4 Major cropping systems of Luang Prabang province

Source: National Statistic Center, 2000

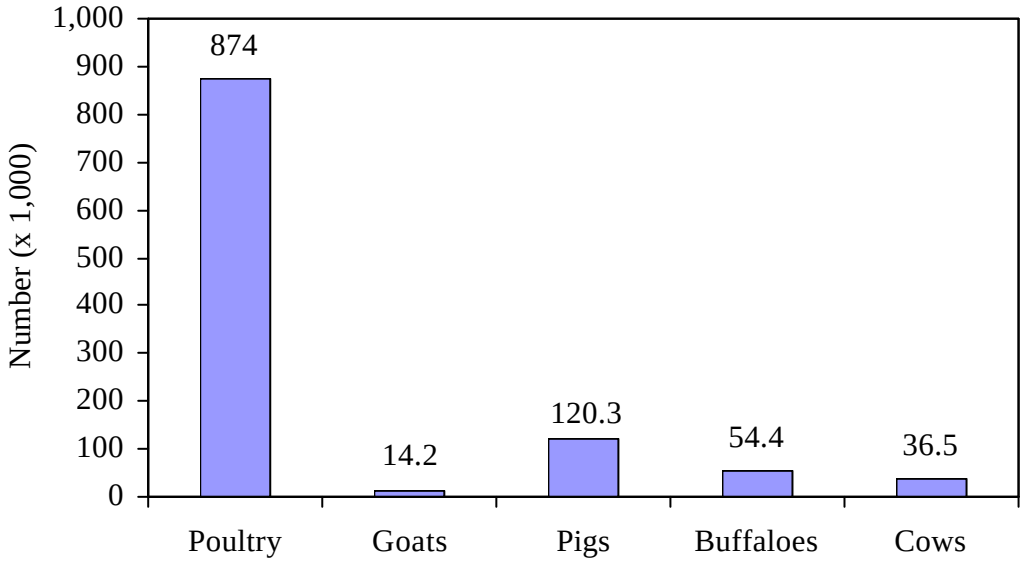

Figure 5 Animal production of Luang Prabang province

Source: Provincial Livestock Section of Luang Prabang, 2001

2.2 Botanical characteristics of mango

The mango is thought to originate from the Indian-Burmese border region and has been under cultivation in India in excess of 4,000 years. The centre of diversity of the genus *Mangifera* appears to be the island of Borneo (Mukherjee, 1985), whereas the species *Mangifera indica* appears to have two centres of diversity – Indo-Burma and Southeast Asia. It is widespread throughout the tropics and subtropics and is consumed fresh in larger quantities than any other fruits.

Mango is classified as flowering plant (angiosperm) and is under the class Dicotyledoneae, order Sapindales and family Anacardiaceae. Family Anacardiaceae consists of 70 genus and 875 species (Mabberley, 1997). Most of trees in family Anacardiaceae are generally founded in tropical and subtropical regions of the world (Wangnai, 1976). The most important genus of the family Anacardiaceae are *Mangifera indica* L., *Spondias* sp. and *Anacardium occidentale* L. *Mangifera indica* L. has chromosome 2n = 2x = 20 (Kostermans and Bompard, 1993).

The mango tree is believed to have evolved as a canopy layer species in the tropical rainforest of South and Southeast Asia (Kaur *et al.*, 1980). Mature specimens can attain a height of 30 m and can survive for more than 100 years. It is a deep-rooted and dome shaped. The leaves are simple, entire, leathery, 8 to 40 cm x 2 to 10 cm, narrowly elliptic or lanceolate and produced in flushes; the young leaves are usually reddish, later turning dark shiny green and retain for approximately 1 year (Mukherjee, 1971).

The inflorescence is a widely branched terminal panicle of 10 to 60 cm long with 1,000 to 6,000 flowers. It is polygamous with male and hermaphrodite flowers in the same inflorescence at the ratio of 1 to 36% of the latter and higher in some cultivar. Both flower types are about 6 mm in diameter when open. They usually have 5 green, pubescent sepals, 5 off-white, pink or purplish petals, and a 5-sectioned, yellow-green nectary disc. Male flowers usually have 1 functional and 4 abortive stamens. Hermaphrodite flowers contain, in addition, a shiny, green, globose superior ovary and a style with a single stigma (URL 4).

The fruit is a fleshy drupe, varying in size from 2.5 to 30 cm long. The shape varies from rounded to ovoid-oblong and is sometime laterally compressed. The fruits are varying in tones of green, yellow and red. The seed is enclosed in a stony endocarp, varying in size with two fleshy cotyledons. Some seeds are monoembryonic with a zygotic embryo only; others are polyembryonic with 2 to 12 embryos in which apomictic embryos are produced from the epidermal cells of the nucellus and in which the zygotic embryo may or may not be suppressed (URL 3).

2.3 Growing areas and yields of mango in Lao PDR

In Lao PDR, mango is favorable fruit tree among the other perennial crops or fruit trees, and it is popularly grown throughout the country. There were 152,500 households or 23% of the total households of the whole country involved with mango growing, which occupied high proportion of various fruit trees if compared with coconut (17%), banana (17%), jackfruit (11%) and tamarind (11%) (Agricultural Census Office, 2000). There are two systems of mango growing**:** compact plantation and scattered trees (home garden). A compact plantation is where the trees are planted in a systematic manner or sufficiently densely to permit the area to be measured. Scattered trees are those not in a compact plantation or less than 100 m^2 in area. For compact plantation systems, about 17,300 households are accounted, and occupied the areas of 3,800 ha with 645,000 mango trees. About 135,200 households are accounted for scattered tree systems and with 782,000 mango trees. (Table 2) (Agricultural Census Office, 2000).

The size of majority mango orchards in Lao PDR is less than 1 hectare. For the compact plantation systems, the mango trees were grown along the riverbank, on slopes of the hills. For the scattered tree systems, the mango trees were grown around the farmers' houses, temples, schools and around the farmers' rice fields and mixed with the other kinds of fruit trees or vegetables that we call integrated home garden. In terms of production, Lao PDR is the 63th country after Cook Island and USA [URL2]. Figure 6 shows that mango production in Lao PDR has slightly increased during the period of 11 years from 1,500 tons in 1990 to 2,500 tons in the year 2000.

Table 2 Characteristics of some fruit trees in Lao PDR in 1999

Crop types	No.of house-holds ('000)	No. of trees ('000)	Compact plantation			Scattered trees	
			No. of house-holds ('000)	Area (ha) ('000)	No. of trees ('000)	No. of house-holds ('000)	No. of Trees ('000)
Mango	152.5	1,427	17.3	3.8	645	135.2	782
Jackfruit	73.8	503	4.5	0.6	155	69.4	348
Tamarind	68.0	1,408	4.1	1.5	255	64.1	271
Orange	34.4	488	3.3	1.0	325	31.4	162
Longan	23.9	253	2.6	0.4	147	21.4	106

Source: Agricultural Census Office, 2000

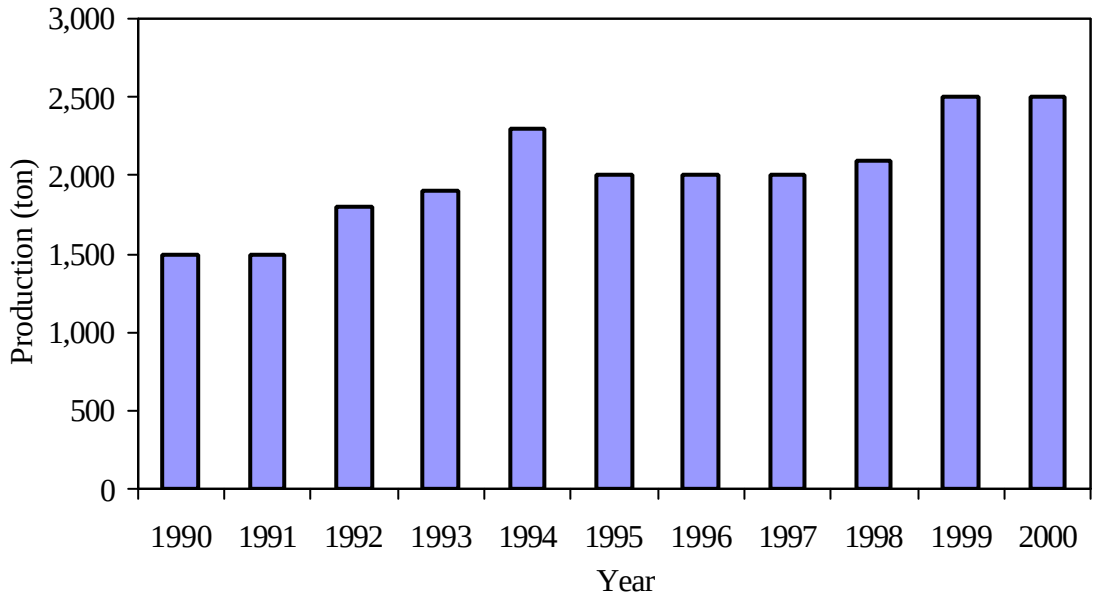

Figure 6 Mango production in Lao PDR from 1990 to 2000

Source: URL2

2.4 Factors affecting successfulness of mango production

Temperature is probably the most important environmental variable to consider when selecting mango cultivars for particular sites. The mean temperature range for optimum growth of mango is 24-30°C (Mukherjee, 1953; Whiley *et al*., 1989). However, mango trees can tolerate air temperature up to 48°C for short periods (Mukherjee, 1953). Also, mango trees have limited tolerance to cold and trees are usually severely damaged or killed after a few hours at temperatures less than 0°C (Carmichael, 1958; Campbell *et al*., 1977).

Mangoes will grow in almost any well-drained soil whether sandy, loam or clay, but avoid heavy, wet soils. A pH between 5.5 and 7.5 is preferred [URL3]. For good growth, mangoes need a good and deep soil to accommodate their extensive root systems (Wangnai, 1986). Mangos can be grown in both rainfed and irrigated areas (Feungchanh, 1995). Rainfed areas have many environmental and resource limitations and growers face many problem in their production systems (Radanachaless and Timm, 1991) as follows:

2.4.1 Mango varieties

There are many mango cultivars, that are grown in Lao PDR, of which including local cultivars and improved cultivars. Improved cultivars were imported from Thailand by Haddokeo Agricultural Station in 1987 (Sanataim,1996). These improved cultivars are Khiew-Sawoer, Fah-Lan, Nam-Dokmai and Shok-Anan. Local cultivars are common and grow in all region of Lao PDR i.e. Og-Hong, Kasen, Kaew, Kaso and Gnaxang. Among these cultivars, Kaew is familiar and popular for farmers up to now (Sanataim,1996). Kaew is the most suitable cultivar for rainfed upland and small scale famers (Radanachaless *et al*., 2002). It has comparative advantages over another cultivars such as drought tolerant, less of care, suitability and good quality for both consumption and processing (Khamlert, 1983).

2.4.2 Survival of mango trees

Mortality rate of 90% was recorded at the first year period of mango tree establishment. Relatively high proportion was occurred during the critical period of January to April (Radanachaless and Krasearchai, 1994; Suttaruk, 1993), this is due mainly to an inadequate water supply (Radanachaless and Timm, 1991). Limited available soil moisture during the dry season is not the sole cause of the first year mango tree mortality. Another important one is that of inappropriate farming practices managed by farmers themselves causing the first year mango tree failed to adapt to rainfed upland environment (Radanachaless *et al.*, 1993). To minimize all eventual losses in accordance with the farmer's opportunities and constraints, it is necessary that some cultural practices should be developed. As suggested by Suttaruk (1993), five technical managements were proposed precisely: water application, nitrogen application, mulching, and management of grafted material and shading.

2.4.3 Water and moisture

Although mango is considered to be drought tolerant and may survive without rain or irrigation for more than 8 months (Gandhi, 1955), soil water deficits during the productive cycle can have severe effects on the retention and early growth of mango fruit. Usually, most of the farmers in a rainfed upland transplant the mango seedlings in August because of the highest moment of soil moisture of a year round (Radanachaless and Krasearchai, 1991a). After planting, it is customary to water frequently these newly planted mango trees during the first year (Samson, 1980; Chadha, 1988). Trees, which are grown in the light soil need irrigated water more frequently than those are grown in the heavy soil (Wangnai, 1986). It is noted that the drought of the first year of establishment is the most critical period for mango trees (Ramingwong, 1987; Suttaruk, 1993). However, the farmers in rainfed upland almost 50% did not apply water and 37% applied only 1-5 times to the first year mango trees, this cause high mortality rate of 10-80% (Radanachaless and Timm, 1991). When soil moisture was maintained by burying clay pots near mango tree base and filling up with water three times monthly, such

practice could reduce mortality of the first year mango trees. It still remained only 2% of loss when compared with above 20% of the conventional ones (Radanachaless and Krasaechai, 1991b). Moreover, it was found that watering at least 2 liters per tree every 2 weeks during January to April with the same method could achieve also the mortality of the first year mango trees less than 20% (Utumpan, 1996).

2.4.4 Diseases and insect pests

Mango production is affected by at least 25 fungal pathogens, five bacterial diseases and possibly a few viruses (IBPGR, 1986). Diseases of mango affect essentially every phase of development and tissue of this important tree. These problems affect the above and below ground portions of orchard trees, or may damage seedlings and grafted plants in the nursery (Ploetz *et al.*, 1994), some are lethal, whereas others reduce the vigor or appearance of trees. Moreover, mango like most fruit tree crops, is usually attacked by two or three key pests, several secondary pests and by a large number of occasional pests in localized areas where it is grown (Pena, 1993). Both diseases and insect pests are one of the important problems for mango production, they can affect the mango trees from the beginning of production such during the process of propagation to produce grafted materials (Saleumkin, 1986) and can be a cause of unsuccessfulness of grafting. In the State of Florida in USA, protection of anthracnose is essential to make grafting successfully (Khamlert, 1983). New flushes of mango are always damaged by mango leaf-cutting weevil and mango tip borer (Kaewworachad, 1996). Besides, fruit flies and seed weevil larvae actually penetrate the fruit pulp and seed, which can cause high losses (Wangnai, 1986). Like in the rainfed areas, disease and insect pest problems also occurred as follows:

Anthracnose

Anthracnose disease caused by *Colletotrichum gloeosporioides* Penz. is the major pre- and post-harvest disease of mango in all mango producing areas of the world and is associated with high rainfall and humidity (Fitzell and Peak, 1984; Jeffries *et al.*, 1990;

Dodd *et al*., 1992). It affects young leaves and flower panicles, and forms quiescent infections on fruit which develop further upon ripening during the postharvest period (Muirhead and Grattidge, 1986; Dodd *et al*., 1989).

Mango stone weevil

Mango stone weevil, *Sterochetus* sp. was commonly found in all mango producing areas of the world. It is an important insect pest and can cause a high loss. Insect that penetrates inside the fruits becomes a significant problem for mango export (Wangnai, 1986). Weevil-damaged seeds may limit plant propagation in nurseries and orchards (Johnson, 1989).

Mango leaf-cutting weevil

Mango leaf-cutting weevil has scientific name as *Deporaus marginatus* Pascoe. The adults of this insect feed on the epidermis of young leaves, causing browning and death of leaves (Tigvattnannont, 1988). In Thailand, the violence of damage of this insect occurred in March and June and it depended on mango varieties (Yachai, 1991).

Mango twig borer

Mango twig borers are larvae of coleopterans insect named *Niphonoclea albata* Newm., and *N. capito* Pasc. They damaged twigs, causing a death of young leaves (Wangnai, 1986). The outbreak of this insect appeared during the period of flushing in September (Werawooth, 1989).

2.5 Mango propagation

Mango can be propagated sexually and asexually. The sexual method of propagation consists of growing plant from seeds (of monoembryonic mangoes), and is rarely used. Asexual propagation is based upon graftage and rootage methods, growing plants from seed (of polyembryonic mangoes) and micropropagation. The various methods of mango propagation are shown in Figure 7.

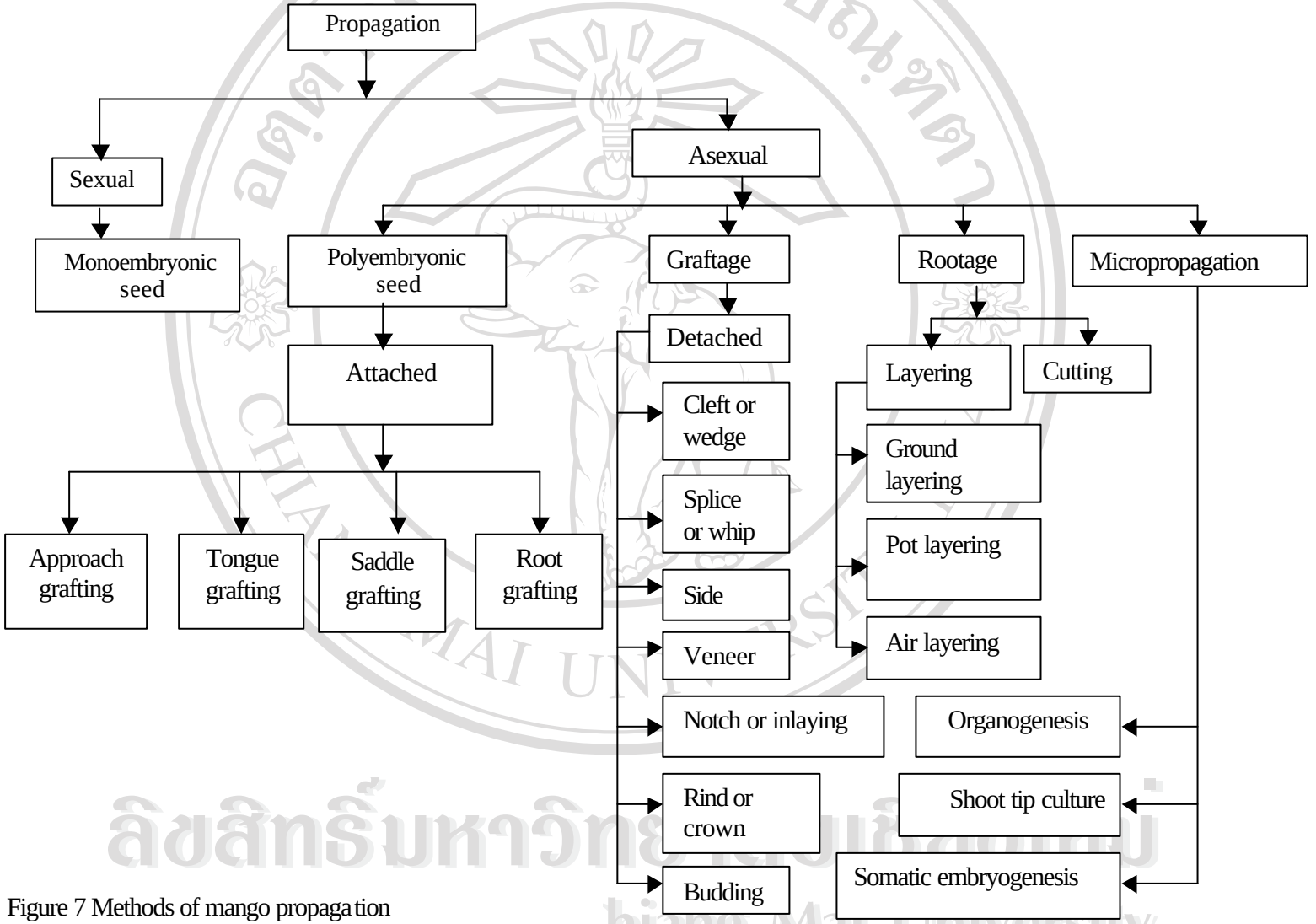

Figure 7 Methods of mango propagation

Source: Litz, 1997

2.5.1 Sexual method

Seed propagation does not ensure true-to-type plant reproduction of monoembryonic mango. However, it was once extensively used before vegetative methods for mango propagation were known (Singh, 1960). Polyembryonic seed is common in mango cultivars grown in the tropics. Trees from nucellar seedlings are identical to the mother plant. In polyembryonic seed, only one embryo is zygotic in origin; it usually degenerates or produces weak and stunted seedlings (Maheshwari *et al.*, 1955). About three to eight seedlings are usually observed that originate from a single polyembryonic seed (Garner and Chaudhery, 1976), although 30 or more embryos have been recorded in a single polyembyonic mango seed (Juliano, 1934). Freshly extracted mango seeds from ripe fruits germinate with higher frequency (76-91%) than those from overripe, firm or green fruits (Shant and Saproo, 1974). Germination and vigor of seedlings are positively correlated with seed weight (Giri and Chaudhery, 1966), and seeds with large endosperm germinate earlier, store better and are more vigorous than those with small endosperm (Naik, 1949; Simao, 1960).

Mango seeds are recalcitrant, rapidly lose viability (Ledin and Ruhle, 1954). Therefore, seeds should be collected and sown within a week after collection. The maximum period for mango seed storage is no greater than 30 days. About 80% seed germination occurs if they are sown within a month after extraction (Stephens, 1960). Parisot (1988) recorded that seeds could not be stored at 30-35^{o}C, and germinated rather quickly at these temperatures. The viability of seeds could be extended for up to 84 days by storing them at 15^{o}C on sterile cotton with deionized water. Selected seeds are sown directly in beds or pots. The endosperm should not be injured. Early sowing is always better to provide the full benefit of the growing season. Propagation of mango by seeds is the easy way to produce a large number of seedlings with vigorous root systems, which are suitable for growing in rainfed areas (Khamlert, 1998), but the trees will have a big shape, which lead to difficulty of maintenance. They also take a long time to bear fruits, so at the

present time seedlings are used mostly for rootstocks for many vegetative methods of propagation (Lelawathanakul, 1990).

2.5.2 Asexual method

Asexual or vegetative propagation produces true-to-type plants through graftage, rootage and micropropagation. Trees propagated by grafting onto seedling rootstocks usually flower in the third or fourth year in comparison to seedling trees which require about 5-6 years. Grafted plants are generally smaller than seedling trees because they begin to bear fruit earlier. Vegetative propagation is the only way to produce large numbers of monoembryonic cultivars while preserving their unique qualities (Litz, 1997).

Rootstock

In India and Mexico, monoembryonic seedlings are generally used as rootstocks. Polyembryonic 'Turpentine' seedlings are used as rootstocks in Florida. Either polyembryonic 'Sabre' or '13-1' seedlings are used in Israel. Polyembryonic 'Kensington' seedlings are used in Australia. Throughout Southeast Asia, polyembryonic seedlings are used for rootstocks, e.g. polyembryonic 'Saing' and 'Thalapt' in Burma (Grant and William, 1949). In the northern part of Thailand, polyembryonic 'Tlap-Nak' and 'Kaew' seedlings are used as rootstocks (Radanachaless *et al*., 2002).

In the northern part of Thailand, there are 2 varieties (Tlap-Nak and Kaew mango) that farmers prefer to use for grafting as seedling rootstocks. Tlap-nak was very popular in using for commercial mango production, because of its strong root systems, good compatibility with various scions, cheap price and easy to find with a large amount (Radanachaless *et al.*, 2002).

Ram (1993) stated that the use of rootstock is one of approach to tree vigor control in mango. By this approach, tree vigor depends on rootstock and scion interaction as well as grafting height in particular cultivar. The selection of suitable rootstock is as important as the selection of scion varieties. It has a strong influence on the growth, yield, and fruit maturity and may be selected for adaptability to soil type and salinity tolerance.

Graftage

To propagate a mango tree, grafting is one of the most popular methods (Samson, 1980). The mango may be propagated asexually by different types of graftage. These methods of propagation have advantage chiefly with respect to a uniform crop and short juvenile phase (Singh *et al.,* 1989; Kunason, 1979). With the result in the shortened juvenility, this caused the reduction in plant size (Sdoodee and Lim, 1989).

Graftage of mango is of two types i.e. attached and detached. In the attached method, the scion is not severed from the mother plant until its union with the rootstock is completed, e.g. approach grafting, tongue grafting etc. In the detached method, the scion is severed from the mother tree and then joined the rootstock, and both are allowed to grow prior to cutting of rootstock above the graft union. Detached methods include cleft or wedge grafting, whip or splice grafting, veneer grafting, stone grafting etc.

For cleft or wedge grafting, Singh (1960) suggested that this technique can be employed using rootstocks of greater diameter than the scion and this method of grafting is appropriate for replacing the crown of young trees. However, with young seedling rootstock, this technique has also been used for large-scale propagation. In Brazil, Pinheiro *et al.* (1970) reported that cleft grafting was more successful (97%) than four other grafting methods tried.

Torres (1960) used splice grafting method with 3-9 month-old seedling rootstock with a high success rate irrespective of the rootstock age. Majumder and Rathore (1970) reported 50% success with splice grafting with 2 week-old seedlings and up to 60% success with 30-day old seedlings, without any plant growth regulator; however, survival of the graft was poor.

Veneer grafting has proved to be more effective than other methods of grafting in most mango producing area, including India (Bhambota *et al.*, 1971). The use of seedling rootstock at different ages (3 months to 2 years) has resulted in 40-100% grafting success, depending upon the season, scion maturity, predefoliation period, storage condition of

scion, etc. (Subra, 1954). Dipping or smearing growth regulator on to the cut surface of the scion and rootstock has not been effective (Kulkarni *et al*., 1989). To achieve a high success, the leaves of scions should be cut 10-15 days before grafting to stimulate the growth of buds, and the graft union is placed at 15-30 cm from the ground (Wangnai, 1986). The length of the scion should be 10-15 cm for good success; smaller scions 5-10 cm have also been used (Ram and Bist, 1982). Age of the rootstock is not as important as the maturity of the scion and good success has always been reported with older shoots (Mukherjee and Majumder, 1961; Jagirdar *et al*., 1968).

Veneer-grafting and chip budding are the most common and successful methods. Young, vigorously growing seedlings are used for rootstocks. Scion wood is selected from young, leafy terminals or mature terminals with swelling buds. Grafting can be done at any time of the year when suitable rootstocks are available, but is most successful during warm weather (URL4).

Veneer grafts and budded grafts were found to be more vigorous than approach grafts and they overtook the initially bigger approach grafts within one year (Kulkarni, 1991). Ram and Sirohi (1989) stated that mango trees propagated by air-layering and veneer grafting were inferior in respect of yield and growth characters than that of stooling and stone grafting but better than inarching.

In the upper north of Thailand, veneer grafting method was used to determine the ability of grafting Kaew scion on interstocks of three commercial cultivars, Khiew Sawoer, Nang Klangwan and Nam Dokmai and evaluate the effect of cultivar and grafting position of interstock on survival and growth of Kaew scions. The cross-section of the grafted materials revealed that the callus of the interstocks originated from Khiew Sawoer and Nang Klangwan fused better with Kaew scion than those from Nam Dokmai at 60 days after grafting. When the Kaew scions were grafted on the primary, secondary and tertiary branching position of 9-10 year-old Khiew Sawoer and Nang Klangwan cultivars in farmer field, the survival rate and growth of the grafted scions were not different (Janngam, 2000).

Epicotyl grafting or stone grafting was first reported by Traub and Auchter (1934) and involves cleft grafting of mature scions onto 2 week-old mango seedling rootstock. In comparison test, the percentage of success of splice and wedge grafting methods which were used in stone grafting were 50% and 33% respectively (Majumder and Rathore, 1970). However, much better success has been reported in other studies (Bhan *et al*., 1969; Gupta *et al*., 1988; Dhunaga *et al*., 1989; Radhamony *et al*., 1989; Srivastava, 1989; Patil *et al*., 1991).

Factors affecting on successfulness of grafting

Success in grafting depends on several factors i.e. age and vigour of rootstock and scion, diseases, insect pests, environment and the skill of the grafter. Climate can affect the growth of scion cultivars under different agroclimatic conditions. The grafting successes differ greatly in the nursery under different techniques and it seems to be a function of climatic conditions (Singh, 1980b).

There are many ways of grafting and budding mangoes reported in the literature. However, experience in south-east Queensland suggests that actively growing rootstocks hardened scion material and warm temperatures (25 to 30^{o}C) are a successful combination. Some success of grafting can be obtained in April and September, but better luck is more likely during May through August. Grafts are most successful if the leaves are allowed to remain below the graft, but remove suckers (URL3).

Ram and Sirohi (1989) stated that moderate temperature and high relative humidity are major factors related to success of stone grafting and this method of grafting can be highly successful (>90%) in protected polyhouses under subtropical conditions.