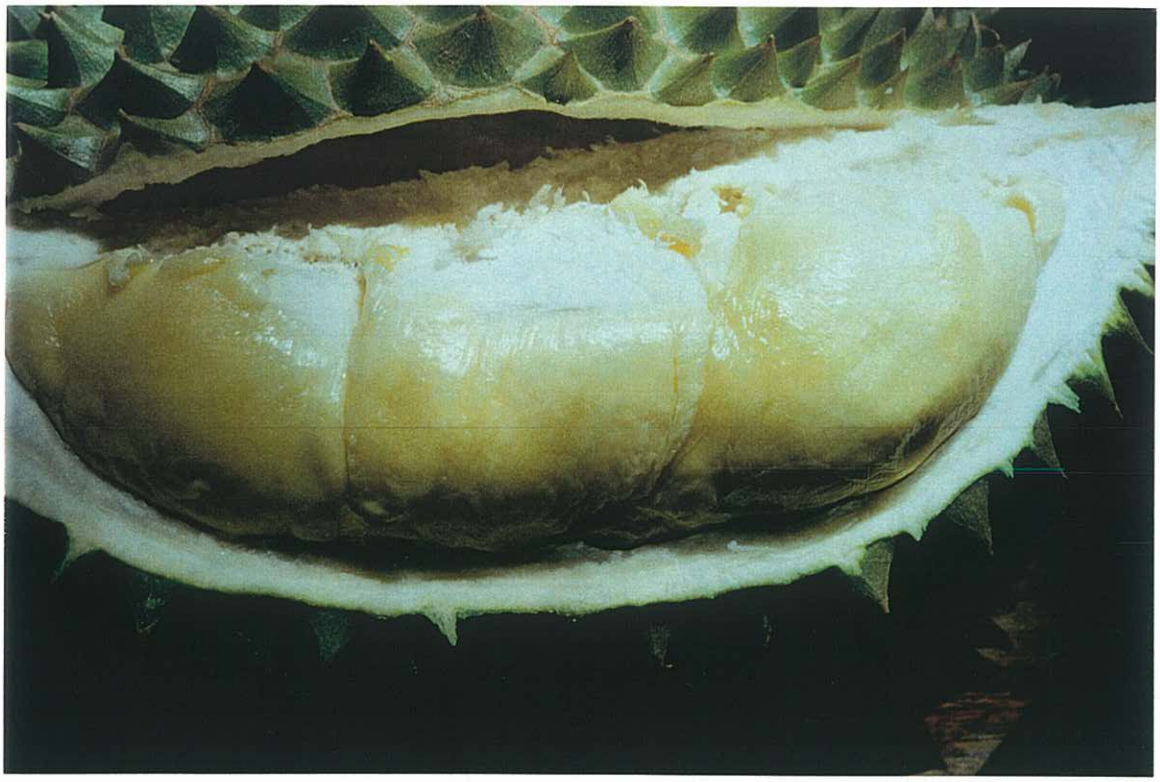
Boosting Durian Productivity

RIRDC Project DNT - 13A

Northern Territory Department of Primary Industry and Fisheries



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EXECUTIVE SUMMARY

Durian has immense potential to be developed into viable fruit crop in northern Australia. The market potential for durian has not been tapped despite a sizeable Asian Pacific minority and European migrant population. There are many production and market impediments that have to be surmounted before it can developed into a viable horticultural industry in northern Australia. Some of these can be summarised as the lack of high-yielding adaptable cultivars, erroneous identification of cultivars, a long juvenile period of 9-12 years, inadequate knowledge of the crop phenology and poor fruit set and development.

This project attempts to find solutions to surmount some of the above constraints. The primary objective is to boost durian productivity in northern Australia. More specifically, this project aims to: i) increase durian productivity by introducing more adaptable, high-yielding and compatible clones; ii) improve our understanding of the crop phenology and reproductive biology of durian with regards to pollination so as to rationalise cultural practices such as assisted pollination and fertilisation; iii) improve fruit yield, size, quality and uniformity by practical cultural measures and proper fertilisation based on soil and foliar nutrient monitoring; and iv) reduce the juvenile period using various precocious rootstock-scion combinations and propagation techniques with introduced *Durio* species and clones.

From the overseas trips to Sarawak and Peninsular Malaysia a total of 440 plants and seeds of 45 plant species were brought back besides durian cultivars and *Durio* species. Besides achieving our objectives, the trip served as the catalyst and springboard for the establishment of collaborative research and exchange of germplasm with the Department of Agriculture, Sarawak.

As a prelude to correct identification a novel method using polygonal graph analysis was developed to correctly characterised and identify cultivars based on leaf parameters. Polygonal graph analysis of leaf characters can be used to differentiate among durian cultivars instead of using reproductive characters which entails a long waiting period of 10-12 years for seedling trees and 6-8 years for grafted trees. Additionally a multiple linear regression model was developed to estimate leaf area in durian based on non-destructive measurements of leaf length and mid width which are commonly employed as indices of growth and development in crop physiological studies and in horticulture.

The crop phenology model developed for durian provided a holistic approach to optimising crop management inputs and cultural practices in particular with respect to the development of assisted pollination methods and sound fertilisation scheduling programs. Assisted manual pollination can be done in early evening instead of later in the night. Manually assisted cross-pollination gave significantly higher fruit set of 31% in contrast to <10% for selfing. Selfing resulted in more fruit drop, lower yields and poorer fruit quality. The maternal parent was found to influence the following fruit traits of flesh colour, taste, flavour, basic fruit shape and spine length. The pollen had a metaxenia effect on fruit weight, size (length), rind weight, number of locules with fertilised ovules, number of well-formed arils per locule, number of arils per fruit, percent flesh recovery and sweetness (Brix). This stresses the importance of mixed clonal plantings.

Diagnosis of crop nutrient demand should be assessed from leaf and soil sampling done in November. Fertiliser scheduling is to be adjusted in accordance to the crop phenology, the crop nutrient requirement and the crop load (yield) produced. Nutrient norms developed on the sufficiency range basis and m-DRIS approaches are to be used as guidelines for nutrition programs.

Objective four is only attainable after 4-5 years from implementation. Basically it involves using multiple rootstocks especially of precocious and dwarf *Durio* species or durian cultivars to obviate the long juvenile period and enhance precocity. Other advantages include better root development and support against wind-throw, and resistance to soil borne diseases by using resistant rootstocks.

ACKNOWLEDGMENTS

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CHAPTER 1

1.1 Introduction

Durian, *Durio zibethinus* Murr.,(2N = 56) dubbed King of Fruits - is the most highly prized fruit in southeast Asia. Revered for its exquisite flavour and taste by most Asians but is abhorred by most Westerners because of its strong and unusually overpowering, repugnant odour. However some Western durian buffs like the Dutch botanist Linschoten described the durian as "a fruit that surpasses in flavour all other fruits of the world" and the great naturalist Wallace stated "To eat durian is a new sensation worth a voyage to the East to experience". To an uninitiated or the abhorrent, the disdainful, pungent, offensive smell emitted by the fruit lead them to defile durian as the skunk fruit of the orchard. Opined the antagonist Bally, " durian has a smell worse than a dead bullock decaying in the sun". Despite the antipathetic view, durian is a money spinner for the crop grower in southeast Asia - the goose that lays the golden eggs. Returns from the crop are high and demand for the fruit is always increasing especially with markets opening in China and Japan and with the rising wave of affluence in Asia. The lucrativeness of durian can be seen by the high retail price paid by consumers for the fruit (Table 1).

Table 1. Retail price* or wholesale price per kg** of durian fruit

Country	Price per fruit* or per kg** in US $
Malaysia*	5.50- 6.60
Singapore** named varieties	10.00-14.00
common village types	3.00-6.00
Thailand*	3.00-4.50
Indonesia*	0.25-5.00
Philippines *	3.00-4.50
(Metro Manila)	6.00-20.00
Australia**	6.40-9.60

* Alim *et al.*, 1994; ** Lim, 1995

Origin and distribution

Durian is indigenous to the Malesia region which comprises Peninsular Malaysia, Sabah, Sarawak, Kalimantan and Sumatra. From its equatorial home it has been introduced into Vietnam, Laos, Kampuchea, Thailand, Myanmar (Burma), Sri Lanka, New Guinea and elsewhere in the Tropics viz. West Indies, Polynesian Islands, Hawaii, Florida, southern China (Hainan island), and north Australia. Durian is of highly significant economic importance in Thailand, Malaysia, Indonesia, Vietnam, Burma, Kampuchea and Laos. It is also a commercial fruit in northern Australia and the Philippines. Large plantations are being established in the Philippines.

Durian is an evergreen, tropical native of Southeast Asia. The fruit thrives under a hot, humid tropical climate characterised by high humidity over 80%, rainfall of 2000-3000 mm evenly distributed throughout the year and uniform temperatures of 28-32 °C. Durian has a protracted juvenile period of 9-12 years, mono-seasonal annual flowering and slow turnover of generations.

Durian producing countries and markets

The leading producers of durian in the world are Thailand, Malaysia and Indonesia in descending order (Table 2). Thailand is the leading producer and exports about 5.5% of their total production both as fresh fruit and frozen fruit to the countries listed in Table 3. Malaysia's durian export was worth US $ 16.3 million in 1992. About 93% of this was exported to Singapore, 5% to Thailand. Also, Malaysia still imports a sizeable amount from Thailand during its off-season. Indonesia's production is mainly for local consumption as is true for the Philippines, Brunei and other ASEAN countries. In 1992 Singapore imported US $ 30 million of durian, mainly from Malaysia and Thailand. Singapore also re-exports durian to Brunei and Hong Kong. Other producing countries include Vietnam, Brunei, Kampuchea, Laos, Philippines, Burma and Australia whose production are mainly for domestic consumption. Australia imports durian from Thailand in the form of frozen arils, slices or frozen whole fruit (Table 3) and also export small quantities eg. in 1992-93, 0.68 tonne and 0.1 tonne were exported to the French Polynesia and the United Kingdom respectively (Lim, 1995).

Table 2. Durian production (metric tons) 1988-1992 in the major producing countries.

Country	1988	1989	1990	1991	1992
Indonesia	193200	139193	242585	205389	152501
Malaysia	289500	319700	353100	389900	384500
Thailand	444145	468645	464959	539190	720607

Source: Nanthachai, 1994

Table 3. Countries importing durian from Thailand

Country	Fresh		Frozen	
	Mt	% share	Mt	% share
Hong Kong	10971	76.2		
Malaysia	2465	17.1		
USA	178	1.2	661	52.4
Taiwan	169	1.2		
Europe	164	1.1	110	8.7
Singapore	148	1.0		
Canada	114	0.8	169	15.5
Brunei	109	0.8		
Australia	0		268	21.3
Japan	0		20	1.6

Source: Alim *et al.,* 1994

Production (fruiting) periods

Most of the major producing countries are situated in southeast Asia and have their production peaks around the middle of the year as shown in the Table 4 below. There may be slight variation of the fruiting period from year to year depending on the weather conditions giving rise to off-season fruiting. Malaysia and Indonesia have two fruiting seasons because durian is grown in various localities. East Malaysia's (Sarawak and Sabah) main season straddles across June through August and Sabah has a small one in November-December. Both states do not export their crop as they are mainly consumed locally. Main harvest in Indonesia is from October to February, but Sumatra produces a crop around June to September.

In Thailand locality and cultivar also influence the spread of the fruiting period. The cultivar Kradumtong provide fruits early in the season. The eastern provinces produce fruit from mid April- June-July, the south in July to September and the north in June-July. Northern Australia as represented by north Queensland and the Northern Territory produce crops at the end and beginning of the year mainly for the domestic market. In the Northern Territory, the fruiting period usually occurs from November to the end of January (some years as early as October to as late as early February) and in north Queensland ie. from Tully to Cape Tribulation from late January to the end of April)

Table 4. Production periods in durian growing areas

Production Area	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
W Malaysia										■	■	■	■	■	■						■	■	■	
E Malaysia											■	■	■	■	■									
Thailand								■	■	■	■	■	■	■	■	■	■							
Indonesia	■	■	■								■	■	■	■	■	■	■		■	■	■	■	■	■
Vietnam									■	■	■	■	■	■										
Laos										■	■	■	■	■										
Kampuchea										■	■	■	■	■										
Philippines																■	■	■	■	■	■			
Brunei													■	■										
Burma											■	■	■	■										
Singapore	■								■	■	■	■	■										■	■
N Queensland		■	■	■	■	■	■	■																
Northern Territory	■	■	■																		■	■	■	■

Current status of the durian industry in Australia

The climate in northern Queensland is very conducive to the cultivation of durian especially around Cairns to Cape Tribulation. In north Queensland, plantings are found along the coastal strip from Tully 18 S to further north Cape Tribulation 16 S. Thus the paramount environmental constraint appears to be the absolute minimum temperature and its duration. The crop can be grown in the harsher climate of the Northern Territory around Darwin with a distinctive wet and dry season and rainfall of around 1600 mm per year. Durian does not thrive well in Katherine, or in Kununurra in north Western Australia.

Currently, in the Northern Territory there are 8 growers with plantings ranging from a dozen to more than 300 trees totaling 1000 trees, and about 8 more potential growers. An update of durian growers in north Queensland revealed that there are currently 30 growers and around 3200 trees planted. More trees are to be planted in the near future.

Durian has immense potential to be developed into viable fruit crop in northern Australia. The market potential for durian has not been tapped despite a sizeable Asian Pacific minority and European migrant population. Excellent market prices of Aust $8-12/kg durian have been realised by many growers in north Queensland as well as in the Northern Territory. One durian fruit weighs between 2-4.5 kg. Prospects for the export of durian to southeast Asia and other Asian countries like China via Hong Kong, Taiwan, Japan and South Korea and European countries is also good as the fruiting season here in the Northern Territory and north Queensland is slightly out of phase with those in the major growing areas in Southeast Asia. The natural production period for durian in north Queensland is from October to April with a peak in January and February while in the NT our preliminary studies showed that fruiting occurs from mid-October to very early February with a peak in December.

Production and market constraints

There are many production and market impediments that have to be surmounted before it can developed into a viable industry in northern Australia.

- Many of the named durian clones introduced into northern Australia were erroneously identified and may not represent the authentic clones from their original sources in southeast Asia. There is an urgent need to bring in authentic high yielding, compatible clones and *Durio* species from Southeast Asia as the difficulties in obtaining germplasm are increasing as more countries are becoming concerned with the transfer of germplasm out of their countries and contacts for the locality of *Durio* species are old people and they are a dying breed. The confusion of cultivars can have a serious impact on the durian industry, extending across the whole spectrum from research to production to marketing. Marketing the wrong clones will damage the industry and cause its premature demise.
- Durian has a long juvenile period of 9-12 years, exhibiting mono-seasonal, annual flowering in northern Australia and hence a slow turnover of generations. Such traits pose major constraints to fruit breeding, selection and adaptability studies. By proper grafting techniques, the precocity can be advanced by 4-6 years, as has been

shown in Thailand. Grafting onto appropriate clonal or other *Durio* species as rootstock can also endow the plant with resistance to the devastating root and trunk disease caused by the fungus, *Phytophthora palmivora.*

- Durian suffers from the ravages of pest and diseases. *Phytophthora palmivora* and *Pythium* spp. cause devastating diseases on durian . Significant crop damage occurs from fruit spotting bugs, mealy bugs and stem girdling borers. Additionally, from without, the threat of introduction of fruit, seed and rind insect borers from southeast Asia is real.
- Poor fruit set and development are a paramount constraint in durian productivity. They can be caused by many factors such as low pollen viability, failure of pollination, failure of fertilisation, self-incompatibility, clonal incompatibility, poor nutrition, inadequate irrigation, damage of flowers and developing fruits by insect pests and diseases. They are influenced also by the onset of adverse weather conditions during flowering and fruit development.
- Our knowledge of the flowering phenology of durian is still minuscule compared to many temperate fruit and classical herbaceous test plants. The interaction of vegetative phases to floral initiation and the impact of fertiliser and irrigation scheduling, pruning practices to carbohydrate partitioning, flowering and fruiting is little understood.
- Market constraints are many such as the uncertainty of a consistency of supply of good quality mature durian; the lack of uniform market quality standards; the absence of a method to curb the pungent odour of ripe fruits during transportation by road and air; and the importance of maintaining a clean green image on the produce which necessitates a balance between the use of chemicals to reduce pest and disease damage and pesticide residues on fruit. There is a need to implement practical and effective integrated pest management (IPM) strategies to achieve this. Also currently there is a dire lack of industry vision and strategic directions, and a lack of cohesiveness among growers.

Objectives of studies

This project attempts to find solutions to surmount some of the above constraints. The primary objective is to boost durian productivity in northern Australia. These studies will also help to create a broad-based, diversified horticultural industry in northern Australia. An industry size of Aust $10 million is possible in northern Australia. More specifically, this project aims to: i) increase durian productivity by introducing more adaptable, high-yielding and compatible clones; ii) improve our understanding of the crop phenology reproductive biology of durian with regards to pollination so as to rationalise cultural practices such as assisted pollination and fertilisation; iii) improve fruit yield, size, quality and uniformity by practical cultural measures and proper fertilisation based on soil and foliar nutrient monitoring; and iv) reduce the juvenile period using various precocious rootstock-scion combinations and propagation techniques with introduced *Durio* species and clones.

The first objective will be realised by the introduction and grafting of promising, high-yielding durian clones and various *Durio* species from Malaysia and Indonesia onto compatible rootstocks. The second objective will be achieved by a thorough study of the flowering biology with the ultimate aim of devising a practical system of assisted pollination through selfing and outcrossing studies to identify compatible pollen sources and by laboratory pollen germination, viability and storage studies. Monitoring of vegetative and reproductive cycles with respect to fluctuations in meteorological factors, leaf and soil nutrient levels and existing cultural practices will also address the second and third objective. The monitoring of leaf and soil nutrient status will also aid in the understanding of the crop nutrient requirement which is essential for the development of a sound fertilisation program for durian to increase yield. The fourth objective will be realised using various grafting techniques for different precocious scion-rootstock combinations viz. single and double rootstock.

CHAPTER 2

2.1 Introduction Of Durian Varieties And *Durio* Species

In July 1993, 300 durian seeds and 48 bare-rooted, grafted durian seedlings comprising 23 different clones were introduced from Peninsular Malaysia by the principal investigator during his recreation leave. From the 300 seeds, 270 seedlings were obtained to be used for rootstock purposes for propagation of clonal material and for the precocity studies. Unfortunately all the grafted seedlings died in quarantine after they were fumigated with methyl bromide on arrival by the Australian quarantine inspection Service (AQIS).

Subsequently another plant collection trip was made this time to Sarawak via Peninsular Malaysia by the principal investigator and three colleagues from the 9th to 24 th January 1994. Besides *Durio* species and commercial durian cultivars, a total of 440 plants and seeds of 45 plant species were brought back from Sarawak and Peninsular Malaysia (Appendix 1). After special arrangements were made with AQIS regarding post-entry treatment of plants sensitive to methyl bromide or with unknown sensitivity to methyl bromide, survival rates of plants in the screenhouse were much higher. A much higher success level was obtained by bringing scionwood and budding them onto rootstocks in the screenhouse than by introducing bare-rooted grafted durian seedlings. On the whole the plant collection trip to Sarawak was extremely fruitful. Besides achieving our objectives, the trip served as the catalyst and springboard for the establishment of collaborative research and exchange of germplasm with the Department of Agriculture, Sarawak. Another spin-off from our efforts was that we helped establish contacts between the Deputy Chief Minister of Sarawak who is also the Minister for Agriculture and Joe and Alan Zappala of Cairns. Joe and Alan Zappala subsequently visited and brought back more durian cultivars and plants from Sarawak.

Attempts will be made to bring in more *Durio* species and durian cultivars in the near future. There are 28 Durio species (Table 5) and at least nine are known to produce edible aril (Kostermans 1958, 1992). Some of their fruit characteristics are listed in Appendix 2. Currently at least six species have been introduced into Australia

Table 5. Edible* and non-edible *Durio* species and their centre of distribution.

Species	Centre of distribution
D. acutifolius (Mast.) Kosterm.	Borneo (Kalimantan, Sabah)
D. affinis Becc.	Borneo (West Kalimantan, Sabah)
D. beccarianus Kosterm. & Soegeng.	West Kalimantan
D. carinatus Mast.	Peninsular Malaysia, Borneo
D. crassipes Kosterm.	Sabah
D. dulcis Becc.*	Borneo (Kalimantan, Sabah, Sarawak)
D. excelsus (Korth.) Bakh.	Kalimantan
D. grandiflorus (Mast.) Kosterm. & Soegeng*	Borneo (Sabah, Sarawak)
D. graveolens Becc*	Sumatra, Borneo, Peninsular Malaysia
D. griffithii (Mast.) Bakh.	Peninsular Malaysia, Sumatra, Borneo
D. kinabaluensis Kosterm & Soegeng	Sabah
D. kutejensis (Massk.) Becc.*	Borneo
D. lanceolatus Mast.	Borneo
D. lissocarpus Mast.	Borneo
D. lowainus Scorb. & King.*	Peninsular Malaysia, Sumatra, Borneo
D. macrantha Kosterm.*	Sumatra
D. macrolepis Kosterm.	Peninsular Malaysia
D. macrophyllus Ridley	Peninsular Malaysia
D. malaccensis Planch.	Peninsular Malaysia, Sumatra
D. mansoni (Gamble) Bakh.	Myanmar (Burma)
D. oblongus Mast.	Sarawak
D. oxyleyanus Griff.*	Peninsular Malaysia, Sumatra, Borneo
D. pinangianus Ridley	Peninsular Malaysia (Perak, Penang)
D. purpureus Kosterm. & Soegeng.	West Kalimantan
D. singaporensis Ridley	Peninsular Malaysia
D. testudinarum Becc.*	Borneo (not in East Kalimantan)
D. wyatt-Smithii Kosterm.	Peninsular Malaysia (Trengganu)
D. zibethinus Murray*	Malaysia, Borneo, Sumatra, Burma, Thailand, IndoChina

Source: Kostermans 1958, 1992

(cf. 2.2). Beside yielding edible fruit and timber, many of the *Durio* species are important for breeding and rootstock purposes to improve the productivity of the most economic important species, *Durio zibethinus*, the commercial durian. They can be used to impart resistance against pest and diseases, precocity of bearing, dwarfness and increase in productivity.

In May 1995, budwood of a dozen clones were brought back from Queensland and budded onto the seedling rootstocks. The clones included Limberlost, Monthong ex Thailand, Gob Yaow, Gaan Yaow, Hew 3, Pomoho Monthong, Luang, Chompoosri, Parung, Sunan and KK 8. During the trip it was found that many of the clones were not authentic and were erroneously labelled and misidentified. Thus we found that it was necessary to characterise the clones introduced from Queensland as well as from Malaysia. To help this exercise a full description of clones available in the growing countries (cf. 2.2) was gleaned from various sources and the principal

Table 6. Durian varieties and *Durio* species growing in the Northern Territory.

Durio species	Malaysian clones	Thai clones	Indonesian clones	Queensland selection
Durio dulcis	D 2	Chanee	Hepe	Johnson
Durio graveolens	D 10	Chompoosri	Parung	Limberlost
Durio kutejensis	D 16	Gaan Yaow	Petruk	
Durio oxyleyanus	D 24	Gob	Sitebel	
	D 96	Gob Yaow	Sitokong	
	D 98	Gumpun	Sunan	
	D 99	Luang		
	D 102	Monthong		
	D 123	Pomoho Monthong		
	D 175 (Ang Hea)			
	DS 2			
	Hew 1			
	Hew 2			
	Hew 3			
	Hew 5			
	Hew 6			
	Hew 7			
	KK 8			
	MDUR 79			

investigator's personal notes, a leaf area model was developed for durian leaves (cf. 2.3) and polygonal analyses of durian morphometric leaf characteristics were initiated to differentiate among clones (cf. 2.4). A perusal of the descriptive list (cf. 2.2) reveals that there are many more interesting commercial clones to be introduced from Malaysia and Indonesia. Also, there is a dearth of information on the commercial durian varieties in countries like Vietnam, Kampuchea, Laos, Burma and Sri Lanka. The durian plants introduced into the Northern Territory by our Department and private growers are listed in Table 6.

2.2 Characteristics of Durian Cultivars

Most of the commercial cultivars of durian in Asia have been selected over the years from open pollinated seedlings. In most cases these were from random, casual selection for fruit quality. These cultivars were subsequently multiplied by various vegetative propagation methods notably by budgrafting, layering, marcotting, and recently by side veneer and cleft grafting. Recently the Department of Agriculture and the Malaysian Agriculture Research and Development Institute (MARDI) in Malaysia separately developed some clones by hybridisation. It takes more than twenty years to develop and test hybrids before they can be vegetatively propagated and released for commercial plantings.

Descriptions of the ASEAN cultivars are gleaned from many sources (Anon., 1980, Tinggal, *et al.*, 1994) including translation by the author from articles written in Indonesian in various Trubus magazines and from Widyastuti and Paimin, (1995) "Knowing Indonesian Primary Fruits" and articles in Malay (Zainal Abidin *et al.*, 1991) and from the author's personal notes and observation. Many of the description for the Thai cultivars are written in Thai and those that are available in English have brief information eg. Hiranpradit *et al.*, (1992a;1992b).

Malaysia

Malaysia has abundant open pollinated varieties because of frequent outcrossing. In 1920, the then Malayan Department of Agriculture initiated a registration of durian cultivars. All durian accessions were given the prefix D to denote durian as distinct from other fruits such as rambutan which was given the prefix R. Many of these cultivars were usually prize winners selected from durian fruit competitions held in agricultural/horticultural shows at the district and/or state levels eg. the popular MAHA shows. Also entry into the register was made from durian collection and evaluation trips made by Agricultural officers. However, not all the registered clones were collected, grown and evaluated by the Department in their durian germplasm plantings as such only a portion of the registered cultivars are available today especially those registered before 1970. This register is still being maintained with approximately 200 being registered with the Department of Agriculture. Although the register system has its merit one drawback is that it contains scanty information on the tree or fruit characteristics of the registered cultivar and in the early days no photographs were kept of the registered clone. To complicate matters, many states eg. the Department of Agriculture in the state of Penang, Sarawak and the Perak state Department of Agriculture especially the district of Kuala Kangsar also have their own registers of durian clones. For example, Kuala Kangsar has its KK series. Some growers also select their own outstanding lines and keep their own registers eg. a fruit nursery cum orchard in Kajang, Selangor, Hew Nursery has its own Hew series. Recently MARDI in Malaysia also established their own register with the prefix MDUR and has 516 accessions. In the early 1980s the Department of Agriculture's Experimental Station at Serdang also registered several hybrids which they developed. Lately, MARDI developed some clones by hybridisation which were released for commercial planting after 20 years of testing. These are designated as MDUR 78, MDUR 79 and MDUR 88.

The current recommended clones listed by the Department of Agriculture Malaysia include:

D 24, D 99 (Gob Kecil), D 123 (Chanee), D 145 (Berserah), D 158 (Gan Yau), D 159 (Monthong), D 169 (Tok Litok), D 188 (MDUR 78), D 189 (MDUR 79) and D 190 (MDUR 88). Additionally, in Penang popular clones planted are D 163 (Hor Lor), D 164 (Ang Bak), and D 175 (Ang Hea); in Perak - D 120 (Manong or KK5), D 146 (Lempur Emas), D 148 (Durian Paduka) and D 150 (Empang Emas); in Selangor - D 160 (Buluh Bawah), D 162 (Tawa) and Penu (MDUR 505); and in Johore - D 168 (Mas Hajah Hasmah).

D 2

Locally called "Dato Nina", this variety comes from Malacca and was registered in 1934. A medium -large, erect tree which flowers well but yields poorly. It exhibits good tolerance to *Phytophthora* stem canker. Its average fruit size is about 1.3-1.8 kg. The fruit is mostly deformed, kidney-shaped, lopsided with small sharp spines and difficult to open despite its thin wall. Its aril is thick, bronze- yellow, firm and of excellent taste. Its deformed shape means only a few locules are present and each has 1-2 arils.

D 3

This was registered in 1939. It bears thin-fleshed fruit with large seeds.

D 4

The local name is Repok B2, from Batu Kurau, Perak. This clone was registered in 1934. It has moderate sized fruit with low quality, thin flesh and many seeds.

D6

This was registered in 1936. The moderate sized fruit has thick flesh of moderate quality and abundant seeds.

D 7

This variety comes from an orchard at 11th mile Kajang, Selangor and was registered in 1934. It produces average size round ellipsoid fruit with a yellow thick rind and average quality sweet flesh. This variety has poor shelf-life.

D 8

This variety comes from Kuala Lumpur and was registered in 1934. It bears large fruit and yields heavily. The fruit pulp is thin, white in colour, and of average flavour.

D 10

Also called "Durian Hijau", this variety comes from 13th mile Kajang, Selangor. It was registered in 1934. The tree is of medium size with a large canopy, moderate to high yielding and is susceptible to *Phytophthora.* The fruit is round to oval, 1-1.7 kg in weight, with moderately thick, yellowish-green rind which tends to split open, imparting it with poor keeping quality. The aril is thick, bright yellow, sweet and nutty, and overall good quality. This clone is similar to D 7.

D 16

This clone was registered in 1936. Despite being a high and consistent yielder, it bears average size fruit with thick white creamy pulp of average quality and many seeds.

D 24

The is the most sought after clone and originated from Bukit Merah, Perak. It was registered in 1937. The tree is large with a broad, pyramidal canopy. It flowers regularly and bears 100-150 fruits/tree/year. Each fruit is about 1-2 kg, ellipsoid to oval shape with thick, light green rind and 1-4 arils/locule. The flesh is yellow, thick, firm, smooth, sweet and nutty with a slightly bitter taste. Unfortunately it is extremely susceptible to *Phytophthora* and also exhibits physiological uneven pulp ripening.

D 29

This cultivar originated from Kuala Kangsar and was registered in 1938. It bears moderately large, ellipsoidal fruit. The seeds are large and the flesh is watery hence of low quality.

D 30

This clone is locally called "Ho Kuen No. 1." and comes from Bentong, Pahang. It was registered in 1939. The flesh is thin, pale yellow but creamy sweet. The seeds are large and abundant.

D 33

This accession is called "Sakai No.1", this cultivar comes from Bentong, Pahang and was registered in 1939. The fruit is of inferior quality with watery flesh and large seed.

D 38

This cultivar is named "Haji Abu" after its owner, from Kg. Ulu Pilah, Negeri Sembilan. This accession was registered in 1939. It bears moderate sized fruit with white, thick, fibrous flesh.

D 66

This clone is called "Durian Raja" and comes from Ulu Sungkai, Batang Padang, Perak, and was registered in 1948. The fruit is small, seedy with thin, tasteless flesh.

D 84

This cultivar comes from South Perak and was registered in 1948. The fruit is large with pale yellow flesh of mediocre taste. It has poor shelf life. There is a line along the fruit stalk.

D 88

Locally called "Bangkok 8" from Thailand, this accession was registered in 1950. It has large fruit with sweet, thick, white flesh. It suffers occasionally from watery pulp and uneven ripening.

D 90

This local cultivar comes from Jasin in Malacca was registered in 1951. The fruit is large with thin pulp but is sweet and delicious.

D 92

This cultivar is also called "Biancheng" from Bagan Jernal, Penang. It was registered in 1952. Reportedly from Thailand, it bears large globose, fruit with thick, golden-yellow flesh, high quality, sweet with some bitterness.

D 96

This clone is called "Bangkok" indicating its origin from Thailand. It was registered in 1955. The mother plant is found in Pusat Pengeluaran Tanaman in Serdang, Selangor. It has fruit characteristics similar to D 2. Generally its fruit is of average size and tastes excellent.

D 97

This has a local name "Foo", from Penang and was registered in 1970. It has moderate sized fruit with thick, golden-yellow high quality flesh. Yields are low.

D 98

Popularly known as "Katoi", this clone was registered in 1970. It has been reported to be introduced from Thailand. It bears large fruit with thick, white pulp, but of average flesh quality.

D 99

This is also called "Gob", an introduction from Thailand which was registered in 1970. A medium-sized tree, low branching with loose canopy and it exhibits biennial bearing, A 10-15 years old tree produces 100-130 fruits/season. This variety crops early and is tolerant to *Phytophthora* as well as to dry environment. This variety is a good pollinizer clone for other varieties. Fruits are usually bell-shaped to lychee shaped sometimes round with a slight depression at the apical end, lobed with distinct grooves delineating the locules. Average fruit weighs 1-1.5 kg, yellowish-brown, light green with densely packed, long spines which are recurved at the tip. The fruit peduncle is medium length and thick. The rind is uniformly thin and easily split open exposing the very thick, creamy , sweet, nutty, firm and golden-yellow flesh. The aroma is pleasant. There are usually 2 -3 large arils/locule.

D 100

This clone is from Thailand and was first registered in 1970. It has large fruit with creamy, sweet, thick, white flesh.

D101

This clone is called "Bangkok T16", from Thailand and was registered in 1970. The original tree is grown at the Pusat Pengeluaran Tanaman (PPT) Serdang, Selangor. It bears large fruit with thick, dry yellow pulp and is of good flavour.

D 102

This accession is called "Bangkok T 17", from Thailand, and was registered in 1970. It produces large oblong fruit with thick, dry, yellow flesh.

D 103

Designated "Bangkok T 28", this entry was registered in 1970. It bears moderately large fruit with thick, white, watery flesh. the flesh is bitter and not very delicious.

D 105

Also known as Durian Ganja, this clone originated from Kg. Cheh, Taiping, Perak and was registered in 1970. The fruit is ellipsoid - tapering slightly towards the polar ends, 2-2.5 kg in weight, brownish -yellow when mature ripe with straight, short spines widely spaced apart. The peduncle is moderately long and the rind is thick. usually there are 3 arils/locule with creamy, firm, yellow flesh.

D 109

This accession is called "Seberangan", from Kuala Kangsar, Perak, and was registered in 1970. It bears moderately large, ellipsoid fruit, with sweet, creamy, firm, orange-yellow flesh. It has high yields.

D 110

This is also called "Seberangan" from Kuala Kangsar. The fruit has long spines with thick, red rind. The flesh is thick, yellow, creamy sweet without bitterness.

D 111

This is known as "Emas Senggang" from Kuala Kangsar. No fruit description was given.

D 112

This is called "Emas Perak" from Kuala Kangsar. No fruit description was given.

D 113

The local name is "Raja Patani", from Kuala Kangsar. This entry is an introduction from Thailand and was registered in 1970. It has large fruit with large spines and soft, white flesh.

D 114

Called "Kampun", from Kuala Kangsar, no description of the cultivar was given but the name indicates that the cultivar is from Thailand.

D 115

This accession is called "Mas Pahang I" from Kuala Kangsar. No description was given in the register.

D 116

This entry is called "Durian Batu". No other information was provided in the register.

D 117

This variety was registered as "Durian Gombak" in 1971 and comes from Gombak, Selangor. The fruit is small and elongated fruit with thick rind, yellow pulp and good flavour flesh.

D 120

This clone is designated KK 5 or "Manong" as it comes from Kg. Jeliang, Manong, Kuala Kangsar, Perak. It was registered in 1971. Its fruit shape is similar to D 2 ie. ellipsoid and deformed. The flesh is thick, creamy, yellowish and very sweet with a slightly bitter taste.

D 121

Despite is local name "Emas Pahang II", this variety comes from Kg. Loh, Enggor, Kuala Kangsar in Perak. It was registered in 1971 and is supposed to be clone D 15. It produces greenish fruit with creamy, yellowish flesh of good flavour. It produces few well-formed seeds.

D 125

This was registered as "Gob T21" in 1973 and comes from Sik, Kedah. A Thai clone with large, ellipsoid fruit. The flesh is watery yellow, creamy sweet, fine textured and soft. The seeds are moderately large.

D 126

This entry is called "Kop T24". A Thai clone with large, ellipsoid fruit from Sik, Kedah. the flesh is creamy sweet, soft, fine-textured and yellow. The aril is small aril with small seed.

D 127

This entry is called "Kop T25", from Sik, Kedah and was registered in 1973. This cultivar comes Thailand. It has ovoid, 2 kg fruit with creamy sweet, thick, soft, slightly fibrous, yellow flesh and moderately large seeds.

D 128

This is also an introduction from Thailand, called "Pakta 66" from Sik, Kedah and registered in 1973.

D 129

A Thai clone called "Chanee T41", registered in 1973 from a planting in Sik, Kedah. It bears large, heart-shaped fruit with, creamy sweet, yellow flesh and large seed.

D 130

A Thai clone designated as Gan Yaow T 63 and registered in 1973. The mother tree is found at Pusat Latihan Pertanian, Charok Padang, Sik, Kedah. The fruit is globose, flattened at the peduncle end and indented at the stylar end, lobed with groove between the locules. The peduncle is short and thick. The spines are broad, short, straight and widely spaced. Each fruit weighs 3-3.25 kg. The fruit is brownish to yellowish-green when mature ripe, with thin rind which is thicker at the stylar end. The central placenta area is prominent and large making the locules kidney shaped. There are 3-4 arils/locule. The flesh is yellow and firm.

D 131

This is called "Katoi T9" and was registered in 1973. The mother tree is found in Charok, Sik, Kedah. A Thai clone with large, heart-shaped fruit. the flesh is yellow, soft, sweet and bitter, quite thick, with little fibrous and quite large seeds.

D 132

This entry is called "Eddie Special" and its owner is the RIM Nursery, Sg. Buloh, Selangor. It was registered in 1973. Its fruit is similar to D 8, moderate taste, white flesh but a high yielder.

D 133

Locally called "Durian rambutan", this clone comes from Larut Tengah, Air Kuning, Taiping, Perak. The clone was registered in 1973. The flesh is thick, creamy, golden-red and of pleasant texture. The seeds are small and shrunken.

D 134

This clone was registered in 1973 and comes from Slim Village, Perak and often designated as Slim. The fruit is medium size and has thick rind and thick, golden-red flesh.

D 135

This entry is designated "Foo Fatt" and was registered in 1973 from Slim village, Slim river, Perak. The only information available is that it is a Thai introduction.

D 136

This entry is called "Senggarang I", from Senggarang and was registered in 1973. it produces round to ellipsoid fruit with long stalk, and short, wide spines. The taste is average.

D 137

This entry is known as "Senggarrang 2" from Senggarang. The fruit is creamy and bitter.

D 138

This entry is called "Senggarang 3" from Senggarang but no information was given in the register.

D 139

This is also labelled " Senggarang 4", from Senggarang. The fruit is elongated, with small long spines and thin rind. The thin, white flesh is bitter-sweet.

D 140

This entry is labelled as " D X Rogue D24" from Pusat Pengeluaran Tanaman Serdang and was registered in 1981. The fruit is moderately large, ellipsoidal with long, sharp spines, dark brown rind which is easily open. The golden yellow flesh is sweet and fairly thick. Yields are high.

D 141

This is a hybrid of D 101 x D 2 (Tree No. 300) from Pusat Pengeluaran Tanaman Serdang, registered in 1981. The fruit is brown, moderately large, elongated with a thin rind. The thick, golden-yellow flesh is sweet and dry.

D 142

This is a hybrid D 66 x D 2 (Tree No. 34) from Pusat Pengeluaran Tanaman , Serdang and registered in 1981. The fruit is moderately large, elongated, brown with a thick rind and large spines. The flesh is creamy yellow, fairly thick and fine texture.

D 143

This is a hybrid of D 2 x D 7 (Tree No. 57) from Pusat Pengeluaran Tanaman Serdang, registered in 1981. The fruit is fairly large, ellipsoidal-elongated, brown skin with large spines. The flesh is thick, slightly dry, golden-yellow and of high quality. Yields are moderate.

D144

This is a hybrid of D 24 x D 2 (Tree No. 118) from Pusat Pengeluaran Tanaman Serdang and registered in 1981. The large, heart-shaped fruit is brown with fairly large spines. The flesh is slightly dry, golden-yellow and of excellent quality.

D 145

This clone is called "Durian Hijau" as it ripens green and also as Durian Berserah, or Tuan Mek. It comes from Berserah, Pahang and was registered in 1991. It produces moderately large, 1.3-1.5 kg, round to oval fruits. It bears less frequently but yields a good crop. The fruit rind is moderately thick and encloses 1-4 arils/locule in a single row. The flesh is thick, bright yellow, fine-textured, sweet and nutty with a good aroma. This clone is susceptible to *Phytophthora.*

D 146

This clone is commonly called "Lumpur Mas" (golden mud). It was registered in 1985 and comes from Kg. Lumpur Ulu, Kuala Kangsar in Perak. It won the top prize at the Perak State Durian Competition in Taiping in 1983. The fruit weighs 1-3 kg, ellipsoid in shape and dark green. The aril is large with yellowish, sweet and delicious flesh.

D 147

This variety is called "Paya Lintah" or "Kuning" locally. It was registered in 1985 and comes from Kg. Paya Lintah, Kuala Kangsar, Perak. It won the second prize at the durian competition in 1983. Its fruit characteristics and taste are similar to D7. The fruit is brown with cream-coloured flesh.

D 148

This entry is called "Paduka" - winner in the Durian State Competition held in Perak in 1985 the year of its registration. The tree is found in Kg. Gajah. Perak. the fruit is moderately large, round with delicate spines. The sweet yellow flesh is of moderate quality.

D 149

This entry is called "Pulut Emas". This entry is the winner of the Durian Competition held at the Larut and Matang District level in 1985 in Batu Kurau. No description was available in the register.

D 150

This clone comes from Bukit Sempeneh, Batu Kurau, Perak and is called "Emping Emas". It was registered in 1985 after capturing the second prize in the Perak Durian competition held at Kg. Gajah in 1985. The fruit is elongated, tapering at the apical end and brownish green, with a moderately long, 9 cm peduncle. The aril is thick and large with fine-textured, yellow flesh.

D 151

Its local name is "Kanchong Darat" and originated from Banting, Selangor. It was registered in 1986 after winning the overall top prize in the durian competition held at Banting, Selangor in 1985. The fruit is elongated, large and green . Its cream-coloured flesh is of excellent taste.

D 152

Locally called "Katak" (Frog), this clone originated from Jitra in Kedah. It took the overall winner prize in the durian competition held on Farmer's Day at Seberang Prai, Kedah. It produces large fruit 3-4 kg, oval to ellipsoid in shape with a long, 9-10 cm peduncle. The spines are sharp, straight and quite widely spaced. The arils are thick, large with moderately fine-textured, yellow flesh with flat and shrunken seeds.

D 153

Designated "Kuala Kangsar 2" (KK 2), the clones comes from Kuala Kangsar, Perak and was registered in 1986. It bears medium sized fruit, round to ellipsoid, with rough, short, sharp and widely spaced spines. The fruit is often cleft and has a thick peduncle and thick rind. There are 3-4 arils/locule and the flesh is thick, medium fine-textured, yellow and dry. It is reported to be a good yielder.

D 154

This entry is called "Sepandak:. It won the Durian Competition Larut-Matang District l level held at Kg. Gajah, Perak in 1984. No description was available in the register.

D 155

Also known by its local name "Srikaya", this clone comes from Kuala Kangsar. It was registered in 1987 after it took the overall winner prize in the State durian competition held in Ipoh in 1987. It resembles D 24 in shape and aril characters but has layered, yellow flesh.

D 156

Called "Kg. Perak", this clone comes from Batu Kurau, Perak and was registered in 1987. It chalked up the second place winner in the 1987 State durian competition at Ipoh the same year. It bears moderate size, oval, green fruit. The aril is large with sweet, pale bronze flesh of excellent quality.

D 157

This entry is called "Seberang" from Gopeng, Perak and registered in 1987. The moderately large fruit is round to ellipsoid with creamy sweet, white flesh.

D 158

A Thai clone, also known by the name "Gaan Yaow" which means long stalk (10-15 cm). It produces round or globose, brownish -yellow fruit with moderately thick rind and sharp, straight, dense spines. There are 3 large arils/locule. The flesh is thick, creamy, firm, sweet, golden-yellow with a pleasant aroma which is not strong.

D 159

Colloquially called "Bantal Mas" ie. "Golden pillow" or "Monthong", this clone was introduced from Thailand and was registered in 1987. It bears very large, elongated, oval fruit with a tapering sharp apex, weighing 4-6 kg,. The large, yellow aril is sweet and of excellent quality.

D 160

Locally named "Buluh Bawah", this clone originates from Banting, Selangor and was registered in 1987. The fruit is large, 3 kg, oval to ellipsoid, green and rough, with short, widely spaced spines. The thin rind can be easily opened. The large aril has thick, firm, brownish-yellow, creamy sweet flesh of excellent quality.

D 161

Called "Merah" ie. red, this variety comes from Banting, Selangor and was registered in 1987. The large brownish-green fruit weighs 3 kg, elongated to oval with short, sharp widely spaced spines. There is 1-2 large aril/locule. The pulp is orange-yellow, slightly fibrous, dry and of excellent quality.

D 162

This is more popularly known as "Tawa". It comes from Banting, Selangor and was registered in 1987. The fruit is medium large, elongated, and yellowish-green. The aril is medium large with firm, yellow-white pulp of excellent bitter but creamy sweet taste.

D 163

Popularly called "Horlor" (Labu), from Balik Pulau, Penang, this variety captured the overall winner prize in the durian competition in Balik Pulau in 1987. The fruit is oval, cylindrical, medium size fruit with a thick rinds and short peduncle. The spines are closely spaced and of medium length. There are 2-3 arils/locule. The arils are moderately thick, yellow coloured and the flesh is smooth, creamy sweet and of excellent quality.

D 164

Its local name is "Ang Bak" meaning red flesh. It won the third prize in the durian competition at Balik Pulau in 1987, the year of its registration. It bears medium size, elongated to ellipsoid fruit with medium length, sharp, conical, densely spaced spines; medium thick rind and short peduncle. The pulp is moderately thick, orange yellow, fine textured, creamy sweet and of excellent quality.

D165

Colloquially called "Cheh Chee" or green durian, the clone comes from Balik Pulau, Penang and was registered in 1987. it produces medium size fruit, ellipsoid to round with large, long, densely spaced spines. The large aril has cream coloured, medium thick, smooth, creamy, excellent quality flesh.

D 166

Named "Balik Pulau", after its place of origin in Penang, this clone was registered in 1987. The fruit is medium large, oval, green with large, short, sharp and widely spaced spines. The aril is moderately thick and the flesh is yellow, sweet and of good quality. The tree yields well.

D 167

Also known by its local name "Buaya" meaning crocodile, this clone originates from Kuala Langat, Selangor and was registered in 1987. It won second prize in the durian competition in 1985 Selangor. The fruit is large, oval elongated, brown-green with thick rind. The large aril is orange-yellow, creamy sweet, delicious and of good quality.

D 168

Called "Mas Hajah Hasmah" after its owner or "Mas Muar" ie Muar Gold, this cultivar originates from Muar, Johore. The tree is moderately large and bears frequently with high yields. The fruit is round, weighs 1.4-1.6 kg, brownish green with a short peduncle. The fruit is easily open exposing 3-4 moderately large arils per locule. The pulp is orange yellow, firm, sweet and creamy. Some of the seeds are small and shrunken.

D 169

This accession is called "Tok Litok" from Kelantan and was registered in 1989. The fruit is fairly large 1.5-3 kg, ellipsoid, yellowish-green with sharp, long spines. The flesh is thick, yellow with a slight bitterness.

D 170

This durian is called "Kepala Babi". It originates from Biawak, Sarawak and was registered in 1989. The fruits are ellipsoid.

D 171

This entry is called "Durian Sg, Sut" after it place of origin in Kapit, Sarawak and was registered in 1989. The fruit has lots of aborted, shrunken seeds.

D 172

This is called "Durian Botak" and comes from Tangkak, Johore and was registered in 1989. It has fairly large, round fruit without spines.

D 173

This local clone is called "Durian Siew" from Mantin in Negeri Sembilan and was registered in 1989. The fruit is fairly large, round and green-brown. The flesh is yellow, thick, sweet, slightly fibrous, dry and bitter.

D 174

This is called "Haji Sani" after its owner from Semenyih, Selangor who registered it in 1990. The fruit is fairly large (1.5 kg), round, and orange-brown. The flesh is copper-yellow, thick, soft, excellent quality like D 2, sweet and delicious, creamy and slightly bitter. The yield is high 200-400 fruits/tree/season.

D 175

This is called "Udang Merah" meaning red prawn. It comes, from Penang and was registered in 1990. the fruit is fairly large (1.5-3 kg) elongate-ellipsoid with brown green rind and small spines. The flesh is creamy sweet, thick, soft, fine and yellow.

D 176

This is called "Kuning Sentul" from Maran, Pahang and was registered in 1990. The fruit is round, copper-green with a short stalk and easy to open. the flesh is sweet, soft, fibrous, slightly thick and creamy-yellow.

D 177

This was labelled "Juara 90 Penang" after it won the Durian competition in 1990 Penang. It comes from Balik Pulau, Penang and was registered in 1990. The fruit is elongate-ellipsoid, brown with short, sharp spines. The golden-yellow flesh is delicious, creamy, soft, fine, sweet and slightly bitter. One locule has 3-4 arils.

D 178

This was labelled "Penang 88". It originated from Balik Pulau, Penang and was registered in 1990. The fruit is small, globose, green with a thick rind. The flesh is creamy sweet, golden-yellow with slight bitterness.

D 179

This entry was called "Penang 99" from Balik Pulau, Penang and was registered in 1990. the fruit weighs 1-1.5 kg, elongate with golden-yellow rind. The flesh is creamy sweet, fine and soft. One locule has 2-3 arils.

D 180

This entry is labelled "Penang Bintang" ie Penang Star. It originated from Balik Pulau and was registered in 1990. It bears fairly large ellipsoid fruit (1.5-2.5 kg) with soft yellow rind and thick arils. The flesh is creamy sweet with some bitterness, fine textured.

D 181

This is called "Ghani Gilong" after its owner from Guar Chempedak, Kedah and was registered in 1990. The fruit resembles Chanee, with sweet, large, thick, orange arils.

D 182

This was nicknamed "Duri Panjang" because of the long spines which resemble a wild durian. The plant is found in Pusat Pengeluaran Tanaman, Serdang and was registered in 1990. The fruit is round with long green spines. The large aril has yellow flesh which is sweet, creamy, delicious and slightly bitter.

D 183

This entry is called "Kop Besar" from Bukit Besar, Kota Sarang Semut, Kedah. It was registered in 1991. It bears large, round fruit 3-5 kg, with a thick, brown rind. The flesh is creamy, fine, thick and yellow. The seeds are shrunken.

D 184

This entry is called locally "Titi Kerawang" after its place of origin in Balik Pulau, Penang. It was registered in 1991. The fruit is fairly large (1.7-2.5 kg), elongate to ellipsoid with a thick rind which can be open easily. The flesh is creamy, sweet, fine-textured, and orange-yellow.

D 185

This is known as "Durian Pikat", from Kg. Darat, Stesen Kijal, Trengganu and was registered in 1991. The fruit weighs 1-1.5 kg, round to ellipsoid with fairly thick, greyish-green rind and rough spines. The flesh is creamy sweet, fine-textured like D 2.

D 186

This is referred to as "Nasi Kunyit Trengganu". It comes from Kg. Darat, Stesen Kijal, Trengganu and was registered in 1991. The fruit is brown with slightly thick rind and rough spines. The flesh is bitter sweet , creamy, orange-yellow but sightly fibrous.

D 187

This is called "Sadam" from Segamat, Johore and was registered in 1991. The fruit weighs 1.4 kg and is heart-shaped with fine, sharp spines and a thin, green rind which opens easily. The flesh is moderately thick, firm, dry creamy, sweet and soft.

D 188 (MDUR 78)

A hybrid of D 10 (female) X D 24 (male). A small but high yielding tree which is comparatively resistant to *Phytophthora* stem canker. It bears ellipsoid, yellowish light green, 1.5-1.8 kg fruit. The aril is thick with orange-yellow, fine textured, sweet, creamy and nutty flesh. The fruit has a shelf-life of 70 hr.

D 189 (MDUR 79)

A hybrid of the reciprocal cross of D 24 (female) X D 10 (male). A small tree which fruits regularly but produces average yields. It is resistant to *Phytophthora* stem canker. It bears oval, ellipsoidal dark green fruit that weighs 1 -1.6 kg. The aril is thick and large with orange yellow, fine textured, creamy, sweet and nutty flesh. The fruit is easily open and has a short storage life of 27 hr.

D 190 (MDUR 88)

This is also the reciprocal hybrid of D 24 (female) X D 10 (male). The tree is medium large, high yielding and a consistent bearer. At 7 yrs 2 fruiting season/year have been observed. It produces oval to ellipsoid, light green or yellowish green fruit with short peduncle, straight, sharp, pyramidal, quite closely spaced spines. Each fruit averages 1.5- 2 kg. The pulp is thick, golden-yellow, dry, sweet and nutty. There are on the average 3-4 arils/locule ie. with 15-20 arils per fruit. This variety has a long storage life of 78-86 hr.

D 191

This is called "Pk 110" from PKK Serdang and registered in 1992. The fruit is ellipsoid, weighs 2 kg with greyish-green, 0.6 cm rind. The flesh is fine-textured, orange-yellow, creamy sweet, firm and mildly odorous. The seeds are moderate weighing 18.3 g/seed.

D 192

This is called "Pk 285" from PKK Serdang registered in 1992. The fruit is globose to ellipsoid, 21 x 16 cm and weighs 2.4 kg. The green rind is 1 cm thick . The flesh is golden-yellow, fine-textured, firm, dry, mildly odorous, creamy and sweet. The aril is large aril and seed moderately large.

D 193

This entry is called "Jurung 3" from Slim Village, Perak registered in 1992. It bears globose-ellipsoid fruit, 19 x 16 cm in dimension and weighing 1.72 kg. The fruit is yellow-green with a 0.6-0.8 cm thick rind and 1-3 fairly large arils/locule. The flesh is thick, yellow, fine-textured, soft and dry The seed is ellipsoid, 5.5 x 3 cm and weighs 70g/seed.

KK 11

This clone bears oval to obliquely ellipsoid to lychee shaped fruit. The fruit is yellowish-brown-green short stalked, with curved, broadly spaced spines and a thick rind especially at the stylar end. The pulp is thick, creamy, and strong yellow in colour. There are 2-4 arils/locule and each fruit weighs 2-2.5 kg.

Singapore

Three named clones are selected and grown by local growers (Tinggal *et al.*, 1994).

H.C. Tan No.2

This variety bears 1-2 kg , light green, pear-shaped fruit with medium length spines. The aril is thin but creamy, sweet with some bitterness. The seeds are shrunken and flat.

H. C. Lim

The fruits are 1-2 kg, elongated oval, brownish with medium length spines. The aril is pink, thin sweet, not fibrous enclosing small seeds.

Lim Keng Meng

The fruits are globose, 1-2 kg, brownish with medium length spines. The aril is yellow, medium thick, creamy and bitter-sweet.

Indonesia

Indonesia has abundant named and recognised clones but only 15 have been released as superior national varieties by the Minister of Agriculture: - cv. Bokor, Kani, Otong, Perwira, Petruk, Si Dodol, Si Hijau, Si Japang, Si Mas, Sitokong, Siwirig, Sukun and Sunan. In 1995, the Minister of Agriculture registered another 5 cultivars from Kalimantan Barat as superior national clones:- cv. Aspar, Sawah Ma, Raja Mabah, Kalapet and Mansau. There are many more varieties found in the other Indonesian islands especially in Sumatra.

Durian Ajimah

This variety comes from Pelaman Mabah, Kalimantan Barat. This variety is also known as "Durian Bung Karno" as this was one cultivar that the late President Sukarno liked most. This cultivar is found around Ciomas, Bogor. It bears globose, greyish-green fruit with large, sharp, widely spaced spines. The rind is thin. The aril is large, thick, pale yellow, dry, slightly fibrous, sweet and somewhat bitter. the seeds are small. Each fruit weighs 1.5-3 kg/fruit and exhibits uniform ripening.

Durian Aspar (Sarwono, B. Trubus 308, July, 1995 pp.20-21)

This variety was classified as a superior national variety by the Agriculture Minister in 1995. The mother tree is about 100 years old and produces 150-200 fruits/year. The tree grows to a height of 35 m with a 20 m canopy and branching from 4 m high. The flowers buds are globose with 6-10 flowers in a cluster producing 1-3 fruits/cluster. The fruit is ellipsoid, light brown with short, conical widely-spaced spines. Each fruit weighs 6-8 kg and the fruit can easily be open. The rind is 1-1.5 cm thick. Each fruit bears 5 locules with 18-22 arils. The flesh weight is 2.5-3.75 kg, golden yellow, fine-textured, dry, sweet, delicious and aromatic. There are 14-22 seeds/fruit. The seed is ellipsoid and weighs 25 g.

Durian Bokor

This variety originated from Sukahaji, Majalengka, West Java and was released as a superior national variety in 1993. The large fruit weighs up to 4 kg/fruit, oblong, yellowish-green, with medium thick rind (3-5 mm) and large, conical, widely spaced spines. The pulp is pale yellow, fine textured, smooth, medium thickness, sweet and odorous. There are 15-20 arils/locule and 10-20 seeds. Old tree yields 150-200 fruits/tree/year and the variety is tolerant to *Phytophthora* but susceptible to fruit borers.

Durian Bubur

This comes from Semarang near the district of Brongkol. The fruit is large, 4-5 kg/fruit, oblong to cylindrical, greenish -yellow, distinctly lobed with pointed closely spaced spines and has small seed. It yields 300-400 fruits/tree/year.

Durian D-02 (Sarwono, B., Trubus 308, July, 1995, p. 19)
This is a very productive variety with 800-1000 fruits per tree. The fruit is uniformly round and weighs 1.2 kg. The pulp flesh is bright yellow, thick, fine-textured, sweet, sticky , smooth and mellow. Its aroma is mild and not pungent.

Durian D-04 (Sarwono, B. Trubus 308, July, 1995, p. 19)
This variety bears large fruit weighing 6-8 kg with 3 arils per locule. The pulp flesh is yellow, thick, smooth, delicious and dry and the seeds are small.

Durian D-05 (Sarwono, B., Trubus 308, July, 1995, p. 18)
This variety originates from Desa Pesing, Kecamatan Sekayam, Kabupaten Saanggau, Kapuas. Very old trees bear 300-400 fruits/year. Each fruit weighs 1.5-3 kg with 3-5 filled locules. Each locule has 3-5 arils. Pulp weighs 0.8-1.8 kg and 95% of the seeds are small, flattened and shrunken. The flesh is yellow, fine-textured, dry, creamy, sweet and delicious with a fragrant aroma.

Durian D-06 (Sarwono, B. ,Trubus 308, July, 1995, p. 18)
This variety originates from Desa Sejajah, Kacamatan Sanggau Ledo, Kabupaten Sambas. A 40 year old tree yields 200-300 fruits per year. Each fruit weighs 2-3 kg with 5 locules bearing 15-19 arils, with 3 arils per locule. The seeds are very small. Flesh weight ranges from 0.7-1.4 kg, ie. 45% fruit weight The flesh is dark yellow, dry, fine textured, sweet, delicious and very aromatic like the chempedak.

Durian D-07 Sarwono, B., Trubus 308, July, 1995, p. 19
This cultivar originates from Desa Sejajah, Kacamatan Sanggau Ledo, Kabupaten Sambas. the tree produces 200-300 fruits per year. Each fruit weighs 2.5-3 kg with 5 locules and 15-20 arils. The flesh weight is around 0.7-1.4 kg. and is dark yellow, fine-textured, dry, sweet, sticky, delicious, sweet and aromatic.

Durian Gandaria (Paimin, F.R., Trubus 319, June, 1996, p. 38)
This variety comes from Kampung Cikakak, Desa Sukamaju, Sukabumi. The fruit is large weighing 4-7 kg, elongated, brownish-green with short, widely spaced spines.

The rind is thin and can be easily opened. There are 4-5 arils/locule. The pulp is cream-coloured, slightly fibrous, sweet with an alcoholic taste. The seeds are shrunken and flat. It yields 400 fruits/tree/year.

Durian Hepe

This variety is found in Jonggol, Bogor. The fruit is ovoid (egg-shaped), brownish-green with a thick rind and sharp, pointed closely packed spines. The pulp is thick, dry, fibrous, bitter sweet and cream coloured. Each fruit weighs 1-2 kg and it produces 300-400 fruits/tree/year. The seeds are flat and shrunken.

Durian Kalapet (Sarwono, B. Trubus 308, July, 1995, p.21)

This a superior national clone that was registered by the Agriculture Minister in 1995. This cultivar comes from Kayutanam, Kalimantan Barat. The mother tree is about 60 years old and bears 150-200 fruits/year. The tree is about 30 m high and 20 m wide. It bears 1-4 fruits /cluster from the 8-12 flowers in each cluster. The fruit is elongated ellipsoid, yellowish-green, with sparse, conical spines and a rind of 1- 1.3 cm which can be opened with ease. Each fruit weighs 2- 3.5 kg. There are 5 locules producing 15-18 arils. Flesh weight is 0.6-1 kg, ie. 30% of total fruit weight. The flesh is golden yellow, thick 1.5-2.5 cm, fine-textured, dry, delicious, sweet and aromatic. All seeds are shrunken, and flat, each weighing 5-8 g.

Durian Kamun

This clone is popular in the district of Banjarnegara. The fruit is oval, weighing 2-2.5 kg, with conical, closely spaced spines. The pulp is dry, creamy, sightly fibrous and bronze-yellow (golden- yellow), sweet and slightly odorous. The seeds are flat and shrunken.

Durian Kani

This is an adulterated name of Chanee cultivar from Thailand and was released as a superior national variety. The fruit is large, 2-4 kg, globose, brownish-yellow, with a thin rind and conical, closely packed spines. The pulp is thick, dry, creamy yellow and sweet. There are 5-18 arils/locule and 5-12 seeds per fruit. The seeds are small and oval seeds, It yields 20-50 fruits/tree/year and is susceptible to *Phytophthora* and fruit borer. This variety exhibits early ripening/maturity.

Durian Kendil

This originates from Brongkol district, Semarang. The fruit is oblong - stand like a pot without rolling, five lobed with short, straight, sharp spines, The yellow flesh is sticky-sweet. Each fruit weighs 3-3.5 kg and the variety yields 50-70 fruits/tree/year.

Durian Koclak (Jaya, U. Trubus 307, Jun 1995, pp. 22-23)

This seedling comes from Lenteng Agung -Jarkata Selatan. The fruit is small, 1.5-2 kg/fruit, oval to ellipsoid. The short spines are densely packed. The rind is thinner rind than Manalagi and green-coloured. The flesh is golden-yellow, thick, sweet with a tinge of bitterness, slightly fibrous, dry and strongly odorous. There are 1-2 well-formed arils/locule.

Durian Lambau

This comes from Desa Wadas. Kecamatan Bener, Purworejo, Central Java. The fruit is oblong, five-lobed, thick rind, brownish-yellow with dense conical, medium-length spines. The large, thick arils are yellow, dry ,fibrous, sweet and strongly odorous, enclosing small seeds. It yields 30 fruits/tree/year.

Durian Lalong

This sweet variety was released in 1992. The variety produces 100-150 fruits /tree/year. It is resistant to *Phytophthora* and fruit borer.

Durian Lutung

This variety is grown in the district of Kendal. Fruit shape is not uniform - from oval to roughly globose. The greyish rind has large, densely packed spines. There are 1-4 arils/locule. The flesh is thick, firm, yellowish-ream, sweet with an alcoholic taste and a strong odour. Some seeds are flat. It produces 100 fruits/tree/year.

Durian Manalagi (Jaya, U.Trubus 307, Jun 1995, pp. 22-23)

This is from a seedling growing in Lenteng Agung -Jarkata Selatan. The fruit is round to oval, 2-2.5 kg/fruit, brownish-yellow, with short densely arranged spines and a thin rind which is easy to open. There are usually 2 large arils/locule. The flesh is thick, yellow, sweet, smooth, dry with a slight odour.

Durian Mansau (Sarwono, B. Trubus 308, July, 1995 p.21)

A superior national clone registered by the Minister of Agriculture in 1995, originates from Nanga Pinoh, Kalimantan Barat. The mother tree is 50 years old and bears 200-350 fruits/year, reaching a height of 25 m and a spread of 20 m. Each flower cluster has 5-10 large round flower buds with red petals and reddish-yellow stigma. Each cluster produces 1-3 fruit. the fruits are ellipsoid, yellow with small sharp, conical dense spines. Each fruit weighs 0.9-1.5 kg. the rind is thin 0.9 cm and easily open. There are 5 locules with 14-17 arils. Flesh weight is 277-460 g, dark red, 0.5-1 cm thick, fine-texture, dry, sweet and odourless. the seed number 14-16, small and ellipsoid. The tree is resistant to fruit borers and root rot.

Durian Nglumut

This was released in 1993. The sweet variety is a low yielder, producing 10-50 fruits/tree/year.

Durian Otong

This variety was introduced from Thailand and released as a superior national variety. It bears the adulterated name for the Thai Monthong. The fruit is oval shaped with tapering ends, yellowish-green with small, conical, densely packed spines. The yellow flesh is thick, dry, slightly creamy, very sweet, fine textured, and mildly odorous. Each fruit bears 5-15 aril and 5-15 seeds, and weighs up to 4 kg. It yields 20-50 fruits/tree/year.

Durian Parung

This variety is found in Darmaga, Bogor and Cilandak Barat, Jakarta Selatan. The fruit is oblong and greyish green, with thick, yellow, slightly fibrous ,dry, sweet flesh, and small seeds.

Durian Perwira

A superior national variety comes from Sinapeul, Majalengka and was released by the Minister of Agriculture in 1993. The fruit is round with thin green rind and large, conical, dense spines. The thick, yellow is dry, sweet and strongly odorous. There are 15-20 arils/fruit with same the number of ovoid seeds. Each fruit weighs 2-3 kg. It produces 200-300 fruits/tree/year. The variety is resistant to *Phytophthora* and fruit borer.

Durian Petruk

This variety is very popular originating from Randusari, Japara, Central Java, it was released as a superior national variety. The fruit is reverse ovoid shape, thin rind (3 mm), yellowish-green with small, conical, dense spines. The yellow flesh is fine-textured, soft, extremely sweet, not odorous and pungent There are 5-10 arils/fruit with 5-10 small, oblong seeds. each fruit weighs 1-1.5 kg. It yields, 50-150 fruits/tree/year. Petruk is relatively resistant to *Phytophthora* and fruit borer.

Durian Raja Mabah (Sarwono, B. Trubus 308, July, 1995, p.21)

Another superior national clone registered by the Agriculture Minister in 1995, it originates from Mabah, Kalimantan Barat. The 100 years old tree bears 150-200 fruits/year. Each cluster bears 3 fruits. The fruit is green and elongated with widely spaced, conical spines. The rind is 1-1.3 cm thick and easy to pry open. Each fruit weighs 3.5-5 kg. The five locules contains 14-18 arils. The flesh makes up 1.5-2.5 kg and is golden-yellow, dry, fine-textured, sweet and delicious and aromatic. Well-formed seeds number 10-15/fruit. They are ellipsoid and each seed weighs 23 g.

Durian Saleja

This is a major clone found in Desa Sukaya, Kecamatan Ciomas, Kabupaten Bogor. the fruit is oblong cylindrical with thick yellow flesh which is slightly fibrous and slightly dry with a sweet alcoholic taste. the seeds are small.

Durian Sawah Ma (Sarwono, B. Trubus 308, July, 1995, p.21)

This is another superior national clone from Mabah, Kalimantan Barat that was classified by the Agriculture Minister in 1995. The mother tree is about 100 years old and reaches a height of 25 m and has a canopy spread of 20 m. It bears globose, green fruit with widely-spaced, conical spines. Each fruit weighs 2.5-4 kg and is easy to open, the rind is 1- 1.3 cm. .There are 5 locules with 14-16 arils. Flesh weight is about 1.3-1.8 kg, yellow, fine-textured, dry, delicious, sweet and aromatic. There are 12-14 well-formed seeds. The seed is ellipsoid and weighs 22 g.

Durian Si Dodol

This is a superior national variety which originated from Karang Intan, Kalimantan Selatan. The fruit is round, five-lobed, yellowish-green with blunt, conical, dense spines. The fruit is easy to open. The flesh is thick, golden-yellow, soft, fine-textured, sweet and delicious. It has 20-25 arils/fruit with 15-20 small, elongated seeds. Each fruit weighs 1.5-2.5 kg. The variety is resistant to *Phytophthora* and fruit borer.

Durian Si Hijau

Another superior national variety that comes from Kalimantan Selatan. The fruit is round, green, five-lobed with sharp, conical, dense spines. The fruit is easy to open. The golden-yellow flesh is soft, fine-textured, sweet, delicious and aromatic. Each fruit weighs 2-2.5 kg and each tree can bear 300-400 fruits/tree/year. The variety is resistant to *Phytophthora* and fruit borer.

Durian Si Japang

This is released as a superior national variety and comes from Awang Bangkal, Karang Intan, Banjar, Kalimantan Selatan. The fruit is elongated oblong, five-lobed. greenish-yellow with widely spaced, conical spines. The flesh is yellow-ivory dry, smooth, creamy and has a coconut taste. It is sweet and high in alcohol content and strongly odorous. Many of the small seed are shrunken and flat. Each fruit weighs 1.5-2.5 kg. It yields 300-600 fruits/tree/year and is resistant to *Phytophthora* and fruit borer.

Durian Si Kirik

This variety comes from Singomerto, Banjarnegara, Central Java. The fruit is oblong, large (>3 kg) but many fruits are deformed. The rind is greenish-dark brown with short, large, dense spines. Each fruit has 3-4 large arils/locule. The flesh is cream-coloured, firm, soft, free stone, aromatic, Sweet with an alcoholic taste. The seeds are large and light brown in colour. It produces 200 fruits/tree/year.

Durian Si Mas

This variety originates from Rancamaya, Bogor, West Java and was released as a superior national variety. The fruit is oblong with tapering pointed stalk end, golden-yellow, 5-10 mm rind. the spines are pointed and dense. The golden-yellow flesh is thick, dry, creamy, fine-textured aromatic and very sweet. Each fruit has 20-35 arils and 20-30 seeds and weighs 1.5 - 2 kg. It yields 50-200 fruits/tree/year and is resistant to *Phytophthora* but susceptible to fruit borer.

Durian Si Mimang

This variety comes from the district of Banjarnegara. The fruit is oval, small and distinctly 4-5 lobed. The yellowish-green rind has blunt spines at the convex cheeks and conical spines at the convex ends and is difficult to open. The flesh is thick, fibrous, dry, yellow, strongly aromatic and taste of alcohol. Each fruit has 3-4 arils/locule and small oval seeds. It yields 400-500 fruits/tree/year.

Durian Siriwig

Released a superior national variety, this cultivar comes from Rajah Galuh, Majalengka. The fruit is ovoid, large, yellowish-green, five lobed with long, conical, widely spaced spines. Although the rind is thick (10-20 mm) it is relatively easy to open. The milk-white flesh is fine-textured, non-fibrous, medium thick, sweet and strongly aromatic. Each fruit has 13-15 arils and 10-15 seeds, and weighs 1.5-2 kg. It yields 100 fruits/tree/year and is resistant to *Phytophthora* and fruit borer.

Durian Sawerigading

Another sweet variety released in 1992. It yields 100-160 fruits /tree/year and is resistant to fruit borers and *Phytophthora.*

Durian Sitokong

Released as a superior national variety, this cultivar comes from Ragunan, Pasarminggu, Jakarta. The fruit weighs 2-2.5 kg, oblong with yellowish-green rind which is 5-8 mm thick. The thick flesh is creamy, dry and strongly aromatic. Each fruit has 5-25 arils and small, oval seeds. The cultivar is resistant to *Phytophthora* but not to fruit borers.

Durian Si Welaki

This cultivar originates from Banjarnegara around Benderan district, Punggelan, thus is often called "Durian Punggelan". The fruit is roughly globose, distinctly lobed, with a greenish-brown rind and small, widely spaced spines. The thick, creamy, yellow, firm flesh is somewhat fibrous. The arils are less thick and not well arranged when compared with Sikirik but produces similar size fruit.

Durian Sukun

A superior national cultivar which comes from Gempolan, Karanganyar, Central Java. It has a thick rind > 10 mm, and small. conical spines. The flesh is yellowish-white, thick, dry, creamy, soft, sweet and aromatic. There are 5-15 arils/fruit. Each locule has the same number of seeds as arils; the seeds are small and elongated. Each fruit weighs 2.5-3 kg. The cultivar yields 100-300 fruits and is resistant to *Phytophthora* and fruit borers.

Durian Sunan

A superior national clone which originates from Gendol Boyali Central Java. The fruit is reverse egg -shaped, brownish-green with conical, small, and widely spaced spines and a thin rind 5 mm which makes it easy to open. The thick, cream-coloured flesh is dry, creamy, fine-textured, very aromatic and sweet. There are 20-35 arils/fruit but only 1-2 well-formed, elongated and small seed. The average weight per fruit is 1.5-2.5 kg. The tree produces 200-800 fruits/tree/year and is resistant to *Phytophthora* and fruit borers.

Durian Tamalatea

This sweet cultivar was released in 1992. It yields 150-250 fruits/tree and is resistant to fruit borers and *Phytophthora.*

Durian Tembaga

This sweet cultivar was released in 1992. It yields 100-300 fruits/tree and is resistant to fruit borers and *Phytophthora.*

Philippines

There are six cultivars recommended for commercial planting in the Philippines.

DES 806

The fruit is ellipsoid, weighs 2-4 kg, yellowish-green with a thick rind, medium length densely spaced spine and a short stalk. The flesh is yellow, sweet, very glutinous with a slightly bitter taste. The fruit has 25% recovery edible portion.

DES 916

It bears ellipsoid fruit, 2-4 kg, greenish-brown with long, sharp, dense spines, The yellow flesh is sweet and glutinous and make up about 25% edible portion.

Chanee

This was introduced from Thailand. The fruit is ovoid with a broad and obtuse tip and greenish-brown rind. Each fruit weighs 2-5 kg. The golden yellow flesh is sweet and make up 32% edible portion.

Monthong

Another introduction from Thailand. The fruit is elongated with a pronounced beak at the base. Each fruit weighs 2-5 kg and has yellowish-brown rind. The flesh is creamy yellow, sweet and make up 30% edible portion.

Umali

This cultivar was selected from a seedling introduced from Thailand by the late Dean Umali of University of the Philippines at Los Banos (UPLB). The fruit is globose to elongated, 2-3 kg, yellowish-brown with golden yellow flesh. The recovery ratio is about 32% edible portion.

CA 3266

This cultivar comes from Indonesia. The fruit is globose, 1.5-2.5 kg, greenish-yellow and produces pale yellow and sweet flesh. The recovery ratio is about 25 % edible portion.

Thailand

More than 200 cultivars are known but only 60-80 are grown commercially. Depending on the scientific source, durian in Thailand are classified according to their earliness to bearing from planting (Inthong, 1964) viz. early, medium and late, fruit maturity (Bamroongragsa and Yaacob, 1990) or lately according to the leaf and fruit characteristics (Hiranpradit *et al.*, 1992a). Bamroongragsa and Yaacob (1990)classified the Thai varieties into early maturity, 103-105 days - Chanee, Gra-dum-tong and Lueng; medium maturity , 127-130 days - Monthong, Gob, Kan Yau; and late maturity, 140-150 days - Gumpan, Enak, Tong-yoi-chat. Hiranpradit *et al.*, (1992a) classified Thai varieties into 6 groups based on fruit and leaf parameters:

1. Kob - 38 varieties including Kob-lep-yeow, Kop-pikul, Kob-wat-kuey, Kleep-sa-mut.
2. Lueng - 7 varieties examples Chanee, Chompoosri, Leung-tong
3. Kan Yau - 7 varieties including Kan Yau, Kan-yao-wat, Med-nai-kan-yau.
4. Kumpun or Gumpun - 11 varieties including Monthong, Gampan-leung, Chai-maphai.

5. Tong-yoi - 12 varieties like Tong-yoi-chat, Nok-yib, Chat-sri-tong
6. Miscellaneous 47 varieties such as Kra-dum-tong, Pueng-ma-nee, Bang-kum-non.

Monthong comprises 41% of the total durian area, Chanee 33% , Gaan Yaow 6 5%, Gradumtong 2% and the miscellaneous cultivars the rest (Alim, *et al.*, 1994). Most of the description of Thai cultivars are reported in Thai and scanty information is available in English (Hiranpradit *et al.*, 1992a, Hiranpradit *et al.*, 1992b) The description below are also drawn from the author's own personal notes and observation.

Kob

This cultivar is spelt "Gob" or "Kob" and has its own group, "Gob". Gob means frog. The fruit is usually globose sightly compressed at the polar ends with a slight depression in the apical end, or lychee shaped. The peduncle is relatively short and thick, the rind is thin with long, recurved, sharp, densely packed spines. Each locule has 2-3 arils with pale yellow to yellow, thick, sweet, creamy pulp. Generally the fruit is small, 1-2 kg. and yellowish-green brown. It bears fruit 6-8 years after planting.

Monthong

This is the prima donna of Thai durian clones and the Thai name means "Golden pillow" in English or "Bantal Mas" in Malay. It produces large, elongated, oval-cylindrical, tapering at the stylar end ie. pronounced beak, lobed, yellowish-brown large fruit of 2-6 kg weight. The peduncle is thick and moderately long and the rind is thick and covered with sharp, pointed, small, conical, densely packed spines. Each fruit has 10-15 arils and many small, shrunken (aborted) seeds. Each locule has usually 3 large, thick, creamy, smooth, pale yellow arils. The pulp is mildly odorous and of excellent quality, constituting more than 30% edible portion and has little physiological disorders This cultivar is extremely amenable for processing of preserved frozen pulps. It bears fruit after 8 years. Gumpun and Enak closely related cultivars in the same group. Its poor fruit characters include the coarse-texture flesh, the high flesh fibre and the flesh exhibit non-uniform ripening. It is susceptible to *Phytophthora.*

Chanee

"Chanee" means gibbon in Thai and belongs to the Luang cultivar group (Hiranpradit *et al.*, 1992). This is an early variety which bears fruit 4-6 years after planting. The fruit is 2-4.5 kg, oval to broad cylindrical, lobed and greyish-brown. The peduncle is thick and moderately long, and the rind is brownish-yellow, thin with blunt, large, widely spaced spines. Each locule has 3-4 arils. The bright yellow pulp is thick, fine textured, firm, creamy, smooth, sweet and of excellent taste. The flesh exhibits uniform ripening. The inferior qualities include high flesh fibre, frequent physiological disorder, watery at full ripening stage, poor fruit setting and is it is susceptible to *Phytophthora* and fruit borer.

Gaan Yaow

"Gaan Yaow" or "Kan Yau" means long stalk in Thai. The fruit is characterised by a long, thick peduncle of 10-14 cm. The fruit is lychee-shaped to globose, greyish-brown, rough with a moderately thick rind bearing short, sharp, straight, moderately dense spines. There are 3-4 large, thick arils per locule. The pulp is golden -yellow, smooth, creamy, sweet with a pleasant aroma. This variety has little fruit physiological disorder, low flesh fibre and good fruit setting characteristic. Each fruit weighs 2-4.5 kg. The inferior fruit characters include the large seed and the high number of seeds/fruit, high incidence of wet core, branch dieback, low *Phytophthora* resistance and poor processing properties.

Gradumtung

"Gradumtong" or "Kradumtung" means golden button in Thai. This cultivar bears fruit 4-6 years after planting and is also an early season variety in Thailand, fruiting around March. It belongs to the miscellaneous group of Hiranpradit *et al.*, (1992b). The fruit is large, 2-4 kg, oval and symmetrically or uniformly distinctly lobed (5). The rind is brownish-green, thin and bears short, sharp, densely packed spines. The fruit peduncle is moderately long. There are 3-4 large, thick arils/locule with yellow flesh.

Tongyoi

This cultivar is common but not as popular or as good as the ones described above and belongs to the Tongyoi group (Hiranpradit *et al.*, 1992).. The fruit is heart-shaped or lychee-shaped, small 2-3 kg, brownish-grey -green with a very short, thick peduncle. The rind is thin and bears small, sharp, dense spines. The arils usually number three per locule and have pale yellow, thick pulp. It bears fruit 6-8 years after planting.

Australia

All the clones currently found in Australia have been introduced from south east Asia in the main by growers themselves and to a lesser extent by Department of Primary Industry in Queensland and NT Department of Primary Industry and Fisheries in the Northern Territory. Only a dozen or so have been evaluated when they came into bearing but most are being evaluated for adaptability and productivity. which is a slow process because of the long gestation period. Another problem is the erroneous identification of clones which may prove disastrous to the infant durian industry in Australia. Thus far, about 40 clones have been introduced into Australia including 7 *Durio* species eg:-.

From Malaysia

Ampung, Capri (MDUR 59), Chin, D 2 TE, D 2 SJRS,, D 7, D10, D 16, D 24 Ng, D 24 Siah, D 24 CYK, D 96, D 99 TE, D 99 (Gob Siah),D 118 (Tembaga), D 120 (KK5 Manong), D 123 (Chanee), D 140, D 143, D 144, D 145, D 160, D 163 (Hor Lor), D 164 (Red Flesh), D168, D 175 (Red Prawn), D 178 (P 88), D 179 (P 99),D 186 (Nasi Kunyit), D 188 (MDUR 78), D 190 (MDUR 88), Eden 5, , Hew 1, Hew 2, Hew 3, Hew 4, Hew 5, Hew 6, Hew 7, Hew 9, KK 11, P 21, P 601, P 604, Permasuri, Sahom, TLK/YEAO, Taiping 1, XA

From Indonesia

Hepe, Petruk, Sitokong, Sukun, Sunan,

From Thailand

Chanee, Chompoosri, GaanYaow, Gob, Gob Yaow, Gradumtong, Gumpun, Kampun-Luang Monthong DPI, Monthong TE, , Luang,

From Thailand via Hawaii

Pomoho Monthong

Local Australian Selections

Johnson, Limberlost, Z1, Diedre 1, Diedre 2

Durio species besides *Durio zibethinus*

Durio dulcis (Lahong)

Durio graveolens (Durian merah)

Durio kutejensis (Lai)

Durio oblongus

Durio oxleyanus (Isu)

Durio macrantha

2.3 Comparisons Of Different Leaf Parameters For Leaf Area Prediction Models In Durian

Leaf area, leaf length, width and dry weight are common leaf parameters employed as indices of growth and development in crop physiological studies and in horticulture. Direct measurements of leaf area using electronic area meters or photoelectric planimeters give a high degree of accuracy but the exercise can be expensive and time consuming. A common approach is to use linear dimensional or dry weight measurements to compute mathematical models to accurately and speedily estimate leaf areas. The use of leaf dry weight involves destructive processing and is rather laborious and time consuming. Models using the non-destructive measurements of leaf length and width offer a reliable and inexpensive alternative to leaf area meters (Wiersma and Bailey 1975; Robbins and Pharr 1987; Gameily *et al.* 1991; NeSmith 1992).

Many mathematical prediction models for leaf area had been published for vegetables and annual crops. Robbins and Pharr 1987; Gameily *et al.* 1991; NeSmith 1992; and Wiersma and Bailey 1975; computed leaf area models based on leaf length and breadth viz. on cucumber, onion , squash and soybean respectively. Rhoden and Croy (1988) used leaf dry weights to estimate leaf area of peas. In contrast, meagre studies on leaf area prediction models had been carried out on fruit trees eg. on guava by Dhopte *et al.* (1995). The objective of this study was to develop and evaluate linear regression models that would accurately and rapidly predict durian (*Durio zibethinus* Murr.) leaf area using non-destructive linear leaf measurements.

Materials and methods

Thirty healthy ,undamaged leaves were randomly picked from four quadrats of a tree from three trees growing in the Berrimah Farm labelled as Luang, Gumpun, and Gob which were later rectified as Gaan Yaow and the latter two as D96 (cf. 2.4, Lim *et al.*, 1996a). Linear measurements were made of the leaf length along the midrib from the tip to the base at the point of attachment of the petiole, the middle width Wm, perpendicular to the midrib, and the widths Wt and Wb at the middle of the top and bottom portions of the lamina on either side of Wm respectively (Fig. 1). Lamina widths Wm, Wt and Wb were selected as they were used successfully in the polygonal analysis of leaf parameters in differentiating among durian cultivars (cf. 2.4, Lim *et al.*, 1996a). The average of the three widths per leaf was also computed and designated AW. Values were recorded to the nearest 0.1 cm. Leaf area in sq mm was measured using a electronic planimeter (Paton Electronic Planimeter). Plant materials were then dried at 65°C for 72 hours in the oven.

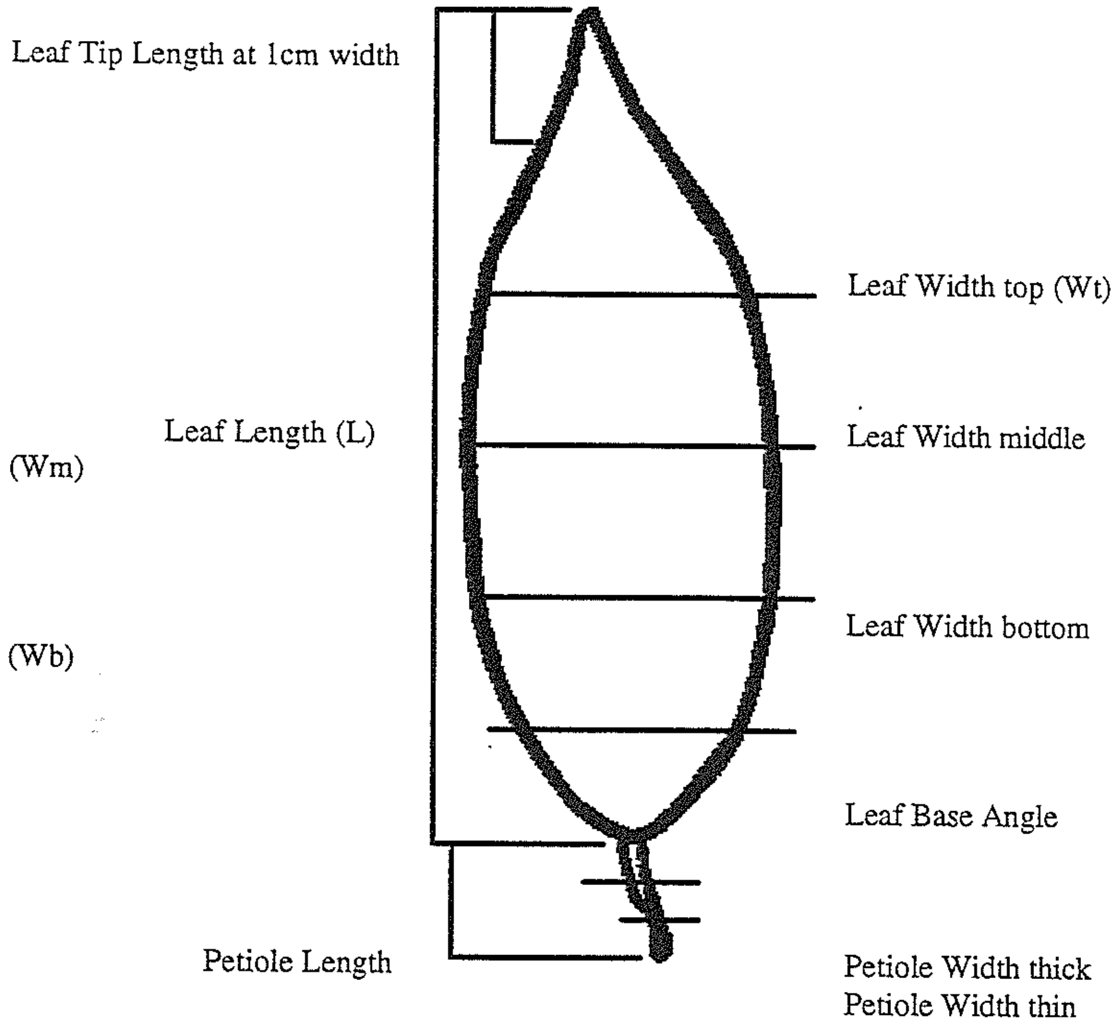


Figure 1. Schematic profile of a durian leaf showing the leaf parameters length (L) and width positions top (Wt), middle (Wm) and bottom (Wb).

Regression analyses were performed on the combined 90 leaves of the three trees as well as the 30 leaves sample of the three trees separately. A search for the best model for predicting area (A) was conducted using Sigmastat statistical software for Windows (R). Linear regression models were processed on individual subsets of each independent variables: length, widths Wm, Wt and Wb (only for combined cultivar sample), and average width AW, and product of LxWm, LxAW. Multilinear regression models of the variables were also carried out. All regressions models were evaluated on the basis of the coefficient of determination (R^2), F value and error mean square (MSE).

The selected regression model was also tested for its proximity of fit to area measurements from the electronic planimeter of 15 samples (20 leaves/sample) of various durian cultivars using a two-factor with replication analysis of variance.

Results

The linear regression accounted for > 80 to 99% of the variance in leaf area of all three cultivars when regressed separately or combined (Tables 7-9).

Evaluation of the coefficient of determination (R^2) at P=0.01 level of probability, F value and error mean square (MSE) for each calculated regression on the combined cultivar data indicated that several combinations yielded equations that would adequately predict durian leaf area (Table 7). A single measurement of length or width at position Wt and Wb was less accurate in predicting leaf area with low R^2 values of 0.786, 0.765 and 0.642 respectively (Table 7). Dry weight of leaf was also less accurate with comparatively lower coefficient of determination, 0.792. The single measurement of mid width, Wm or the average width, AW (ie. average of Wt, Wm and Wb) gave higher predictability (R^2=0.90) of linear additive relationship with leaf area (Table 7). Besides high R^2 values, equations were selected with high F values but low mean square errors (MSE) as these gave a higher degree of predictability and accuracy. On this basis, multiple regression equations involving leaf length, L and mid width (Wm), or L and average width (AW) were selected over those involving individual variables or the product of LxWm or LxAW (Table 7). Multiple linear regressions using all the variables Wt, Wm, Wb and L together caused multicollinearity among the independent variables. Eliminating the unnecessary variables such as Wt and Wb overcame this problem.

Similar regression trends were obtained for the three trees analysed separately. (Tables 8-9). Individual variables of average width (AW) and mid width (Wm) gave

Table 7. Regression prediction models for durian leaf area based on coefficient of determination, error mean squares and F values using combined leaf parameter measurements(N=90) for three trees.

Variable	Model	R	R^2	MSE	F value
Length (L)	A=-35.2+6.07L	0.886	0.786**	10033	3223
Width top 1/4 (Wt)	A=-23.4+16.4Wt	0.874	0.765**	9767	286
Width mid (Wm)	A=-43.1+19.3Wm	0.950	0.902**	11519	808.9
Width bottom (Wb)	A=11.3+17.3Wb	0.801	0.642**	8199	157.8
Av width (AW)	A=-38.2+20.5AW	0.943	0.890*	11366	711
Dry weight (DW)	A=6.49+67.3DW	0.890	0.792**	10111	334
L x Wm	A= 0.712+0.713(LxWm)	0.981	0.963**	12299	2285
L x AW	A=0.87+0.795(LxAW)	0.991	0.981**	12531	4567
L + AW	A=-51.7+2.98L+13.7AW	0.991	0.983**	6277	2501
L + Wm	A=-52.1+2.67L+13.3Wm	0.983	0.967**	6173	1257

** $P< 0.01$

higher predictability (R^2=0.90 and 0.91-0.94 respectively) than length or dry weight (R^2=<0.90). Multiple linear regression models of length and mid width or length and average width gave high predictability (R^2=0.980-0.994) and lower mean square error and thus were more statistically appropriate for selection. In contrast, multiple linear regression models of product of L x Wm or L x AW gave high R^2=0.972-0.995 but higher MSE and thus were less accurate.

There was no significant difference at $P<0.05$ between area estimation using the multiple linear regression model, A=-52.1+2.67L+13.3Wm and the electronic planimeter readings indicating the closeness of fit (Table 10 & 11). There were highly significant differences between leaf samples as expected but there were no significant interaction between methods of area measurement and leaf samples (Table 11).

Table 8. Regression prediction models for durian leaf area based on coefficient of determination, error mean squares and F values using leaf parameter measurements (N=30) for the D96 (ex Gumpun) cultivar.

Variable	Model	R	R^2	MSE	F value
Length (L)	A=-41.2+6.62L	0.926	0.857**	3360	168
Width mid (Wm)	A=-43.3+19.7Wm	0.955	0.911**	3572	287
Av width (AW)	A=-43.9+22AW	0.950	0.902**	3536	258
Dry weight (DW)	A=1.37+77DW	0.909	0.827**	3242	133.9
L x Wm	A=1.37+0.733(LxWm)	0.991	0.983**	3853	1614
L x AW	A=0.354+0.83(LxAW)	0.998	0.995**	3901	5673
L + AW	A=-55.1+3.41L+13.5AW	0.997	0.994**	1949	2327
L + Wm	A=-52.6+3.2L+12.3Wm	0.991	0.981**	1923	715

** $P< 0.01$

Table 9. Regression prediction models for durian leaf area based on coefficient of determination, error mean squares and F values using leaf parameter measurements (N=30) for the Gaan Yaow (ex Luang) cultivar.

Variable	Model	R	R^2	MSE	F value
Length (L)	A=-33.7+5.85L	0.903	0.815**	3794	123
Width mid	A=-49.8+20.7Wm	0.967	0.935**	4354	405
Av width (AW)	A=-3939+21AW	0.949	0.900**	4188	251
Dry weight	A=1.9+69.9DW	0.905	0.819**	3811	127
L x Wm	A=0.274+0.702(LxWm)	0.986	0.972**	4523	965
L x AW	A=0.947+0.776(LxAW)	0.996	0.992**	4619	3534
L + AW	A=-51.3+2.91L+13.7AW	0.997	0.994**	2314	2207
L + Wm	A=-53.9+2.3L+14.6Wm	0.990	0.980**	2281	673

** P< 0.01

Table 10. Durian leaf area measurements using the electronic planimeter and multiple linear regression model.

Sample	Planimeter*	Multiple linear regression model*
D98 T3 SJRS	45.00	46.28
Gob T10 SJRS	54.12	53.89
Gob Yaow T18 SJRS	30.22	29.33
Gaan Yaow Z Hse	59.32	58.57
Luang T32 SJRS	54.49	53.78
Hew 3 Z Hse	71.84	71.33
Hew 3 Z Hall	71.51	71.13
Hew 3 T34.SJRS	80.55	78.76
D 102 T9 SJRS	41.83	40.17
D 102 Z Hse	52.32	53.05
Gumpun T23 SJRS	54.95	54.72
Pomoho Monthong Z Hall	36.47	36.84
KK 8 T17 SJRS	50.94	49.52
Sunan T16 SJRS	47.46	48.63
Parung T21 SJRS	55.67	55.01

* No significant difference at P<0.05

Table11. Analysis of variance summary table.

Source of	SS	Df	MS	F	P value	F critical
Method	22.08405	1	22.08405	0.188507	0.664326	3.857821
Samples	98786.49	14	7056.178	60.23087	1.5E-102	1.70915
Interaction	123.5016	14	8.821544	0.0753	0.999998	1.070915
Within	66776.74	570	117.1522			
Total	165708.8	599				

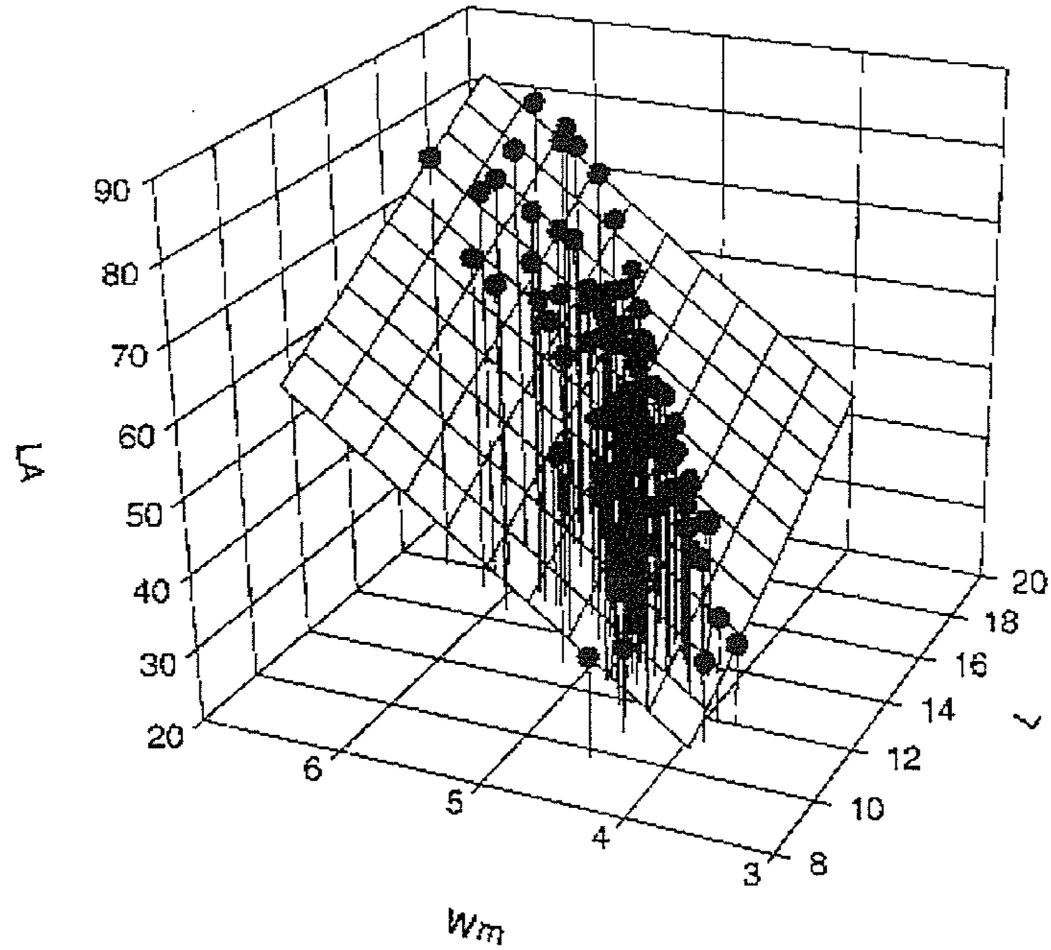


Figure 2. Graph of the multiple regression model showing the relationship between leaf area (LA), length (L) and leaf mid-width (Wm) and governed by the equation $LA = -5.21 + 2.67L + 13.3Wm$ with $R^2 = 0.967$.

Discussion

In durian mid width of leaf gave a higher predictability of leaf area than leaf length or dry weight. Measuring one leaf parameter eg. mid width would be very rapid and convenient, however the results showed that to have both high predictability and accuracy, both leaf length and mid width measurements had to be taken. Both leaf length and mid width (Fig. 3) were found to be significant determinants of leaf shape in durian, and the L:Wm ratio was found to be consistent in any cultivar regardless of the growth stage or locality grown (cf. 2.4, Lim *et al.*, 1996a). Hence, in durian it would be prudent to develop leaf area estimation models using both parameters although this meant that the time taken for measurement was doubled. The model that was selected for durian is based on the multiple linear regression model involving length and mid width ie. A= -52.1+2.67L+13.3Wm (Fig. 2) with a coefficient of determination of R^2= 0.967 and lowest error mean square.

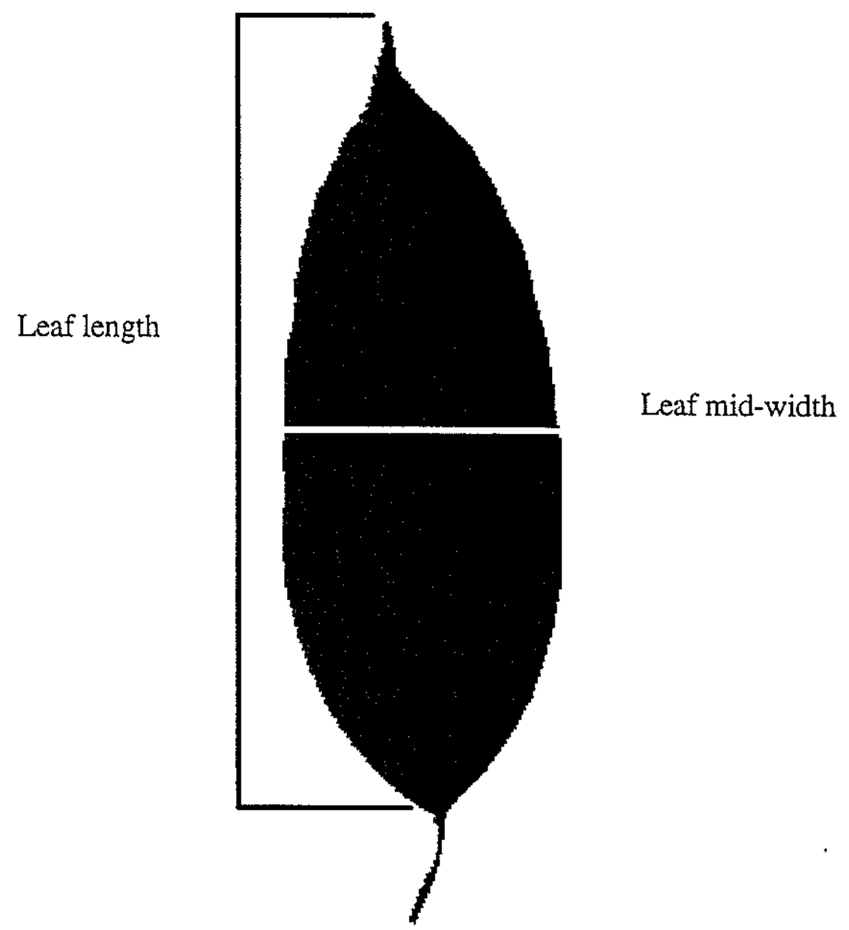


Figure 3. Schematic diagram of a durian leaf showing the positions of the parameters measured.

The multiple linear regression model for leaf length and average width was equally accurate and predictable with a slightly higher coefficient of determination and low error mean square. However, in this case four leaf parameters had to be taken - length, mid width, top width and bottom width of the lamina. This would quadruple the time taken for measurement, more complex and longer calculations would have to be done, and thus,was slow and not convenient.

In summary, durian leaf area could be accurately and fairly rapidly predicted using a multiple linear regression model based on non-destructive measurements of leaf length and mid width. The results also showed that there was no significant difference between area estimations using this multiple linear regression model and the electronic planimeter readings.

2.4 Polygonal Graph Analyses Of Durian Cultivars Using Leaf Characters

A major problem prevailing with durian cultivars in Australia and also in other countries in southeast Asia is the misidentification and erroneous labelling of cultivars and individual durian trees. Presently many of the introduced cultivars have different characteristics to their namesakes in their sources of origin. Two widely planted Thai cultivars Monthong and Chanee which were respectively imported via Singapore in October, 1979 and Thailand in September, 1978 were renamed Gumpun and Gob respectively after the trees fruited some 10-12 years later. Similarly the cultivars D 123 and D 16 are not the true cultivars of their namesake in Malaysia. In north Queensland there is a cultivar called KK 8 which is reported to be introduced from Kuala Kangsar, Malaysia but no such cultivar exists. Also there are two different genotypes subsumed under the cultivar Hew 3 and one of them is different from the true Hew 3 from Malaysia. Another suspicion is that the cultivar Luang is not the true Thai Luang cultivar.

The confusion of cultivars can have a serious impact on the durian industry, extending across the whole spectrum from research to production to marketing. Imagine the frustration and tremendous waste on the time, money and effort spent on research and development as well as the cultivation of wrong clones with low market acceptance. Additionally, marketing the wrong clones will damage the industry and cause its premature demise. There is an urgent need to surmount this problem.

In Malaysia and Thailand, the main durian cultivars have been described and keys developed to distinguish between the main cultivars. Brief descriptions of registered durian clones are kept in registers by the Department of Agriculture, Malaysia (Anonymous 1980; Anonymous 1994). In Malaysia, Lye (1980) reported that durian clonal identification is possible using floral bud characteristics at the full bud stage. He distinguished 12 clones using this technique. Hiranpradit *et al.*, (1992) observed that specific leaf characters, flower shape, fruit shape and spine shape are highly hereditary and he broadly placed 122 cultivars into six groups. There is a dire need to do similar work in Australia to erase the existing confusion and obviate potential damage to the durian industry. We need a concerted effort to develop an inventory database, quantitative descriptions of clones, keys to aid in identification, and vouchers for morphological comparisons.

The use of reproductive characters ie. flower and fruit for clonal identification can only be done on mature, bearing trees. This means a waiting period of 10-12 years for seedling trees or 6-8 years for grafted trees before identification can be confirmed. This is not satisfactory as growers have no assurance that what they planted out are the correct clones and this can lead to undue wastage of time and investment if the clones planted are not the commercially acceptable ones. The use of both vegetative and reproductive characters especially fruit size and leaf size can also be influenced by environmental factors such as temperature, amount of radiation, and soil fertility, as well as age of the tree, health status of the tree and the genotype. Albeit the use of DNA finger printing techniques would provide the determinative confirmatory identification of clones but the technique can be costly and has not been developed yet for durian. In view of this, some morphometric identification technique using vegetative morphological characters of seedling or young tree is needed to overcome the taxonomic confusion of durian clones instead of reproductive characters which entail a long waiting period. In this paper we report on the use of polygonal graph analyses of durian leaf characters to differentiate between durian clones. Polygonal graph analyses have been used to compare graphically the variation patterns within a taxa (Radford *et al.*, 1974). This taxonomic tool permits visualisation of biometric measurements and observations of differences and similarities. This paper reports on the use of a polygonal graph analysis method which is rapid, easy and does not require the use of expensive instrumentation to differentiate among durian cultivars.

Materials and methods

A total of 55 leaf samples encompassing 32 different designated clones collected from the Zappala orchard (Z) in Bellenden Ker and QDPI South Johnstone Research Station (SJRS) in North Queensland, Eden Farm (E) in Tapah, Malaysia, and several localities around Darwin viz. Berrimah Agricultural Research Centre (BARC), and growers' orchards - B. Lemcke (B), T. M. Siah (S) and B. Jaminon (J) in the Northern Territory were analysed.

Each leaf sample consisted of twenty healthy and undamaged leaves collected from individual trees or from a population of young grafted seedling plants of the clone (Monthong T41, T43, T44, SJRS). Leaf surfaces were cleaned or wiped with a mild detergent solution to remove dust and sooty deposit which could interfere with surface colour measurements. Photocopy imprints of both surfaces were made of every leaf in a sample to avoid difficulty in measurement of dried or shrunk samples. All leaf characters selected were quantified including colour of leaves. The following leaf characters were measured: length (LL); width at three positions - middle equatorial position (Wm), top half median (Wt), and bottom half median (Wb); tip length (TL) measured from the apical extremity to the 10mm width at the base of leaf apex (Fig. 3); petiole length (PL), broadest and narrowest diameter of the petiole; sum of leaf blade basal angles; colour of adaxial and abaxial surfaces, scale density, and leaf venation pattern. Selected ratios and leaf area were calculated. Except for the two parameters of leaf venation and scale density, variance and standard deviations of all the measurements were calculated. Those with high variance within a cultivar were not selected and those with high variance between cultivars were selected.

Leaf area was measured by an electronic planimeter (Patton Electronic Planimeter.) and was also computed using a multiple linear regression model $A=-52.1+2.67L+13.3Wm$ developed specifically for durian leaf area estimation (cf. 2.4, Lim and Luders 1996a). Leaf colour of leaf surfaces was measured by a Minolta chroma meter CR 300 measuring in CIELAB: L = lightness, a^* = bluish-green/red purple hue component, b^* = yellow/blue hue component, C^* =chroma and h^o = hue angle (McGuire 1992). Scale density was measured using a compound microscope. Petiole diameter was measured by a Toledo Digital calliper, model no. PDC 200, and leaf blade base angles by a protractor. Leaf venation was studied after tissue clearing using the methods outlined in Radford *et al.*, 1974. After preliminary investigations leaf colour, venation, and scale density were found to be laborious and unsuitable and the following eight segregating morphometric parameters viz. leaf tip length, petiole length, sum of leaf blade basal angles, and the ratios LL:TL, LL:Wt, LL:Wm, LL:Wb, and LL:PL were chosen for the axes in the polygonal graph. A series of axes were drawn equidistant through a central point. All parameters were plotted by points on each axis representing direct measurements or ratios. Each plotted point on an axis was connected by straight lines resulting in a polygonal image of the sample. These polygons were then compared with polygons of other samples for similarities and differences.

Results and discussion

Based on the significant and high correlation between leaf length and area (R=0.89**) the samples could be broadly classified into very large, large, medium, small and very small leaved cultivars (Table 12) or into different groups based on petiole length (Table 13), tip length or sum of base angles.

Table 12. Durian cultivar groups classified on the basis of leaf area and length.

Locality	Very large leaved cultivar	Large leaved cultivar	Medium-large leaved cultivar	Small leaved cultivar	Very small leaved cultivar
	> 70 sq cm	60-70 sq cm	50-59 sq cm	40-49 sq cm	< 40 sq cm
SJRS	Luang T19, Luang T32, Luang T37, Hew 3 T34,	Gumpun T12, Gumpun T23, Gumpun T27, Monthong T41, T43, T44	D 102 T9, KK 8 T17, Parung T21, Sunan T16, D 98 T3, Gob T10		Pomoho Monthong T33, Chompoosri T14, Gob Yaow T18, Limberlost T1
Zappala	Hew 3 Z Hall, Hew 3 Z Hse, Hew 3 R2T6 Z Hse, Cipaku R2T11 Z Hall	D 96 R2T16 Z Hall	D 102 Z Hse, KK 8 Z Hall, Chanee Z Hse, Kradumtong Z Hse, Sunan R1T18 Z Hall, Gaan Yaow Z Hse, D 16 R2T14 Z Hall, D 16 R2T16 Z Hall		Pomoho Monthong Z Hall
BARC		Gob?, Gumpun?	Luang ?		
T.M Siah	Hew 6 S	Hew 7 S, Gumpun ? S	Hew 1 S	D 24 S	
B. Jaminon	Hew 5 J, Luang J	Johnson J	Chompoosri J, D 102 J, D 98 J	D 24 J	
B. Lemcke	Luang L				
Eden Farm, Malaysia	Monthong 1 E, Monthong 2 E, D 2 E, D 99 SF E		D 99 LF E	D 24 E	

Using a single leaf parameter or leaf area (function of length and width) as is seen above, the samples can be broadly categorised into superficial arbitrary groupings but this does not give any indication of phylogenetic relationships or population differentiation at the cultivar level. To do this several parameters have to be considered together like in the polygonal graph. The following parameters were not useful in segregating between taxa within species: leaf adaxial and abaxial surface colour, scale density and leaf venation. Moreover, to study leaf venation, leaves have to be processed entailing laborious techniques while measuring leaf scale density and leaf surface colour require equipment such as a microscope and a chroma meter. However, the following parameters: sum of leaf blade base angles, leaf tip length, petiole length and ratios LL:LWt, LL:LWm, LL:LWb, LL:LTL and LL:LPL, used in combination were useful in segregating between clones. These selected ratios were more consistent and had the lowest standard deviation (s.d.) and thus were more reliable determinants

Table 13. Durian cultivar groups classified on the basis of petiole length.

Locality	Long petiolate cultivar	Medium-long petiolate cultivar	Short petiolate cultivar
	> 22 mm	18-21.9 mm	< 18 mm
SJRS	Luang T19, Luang T32, Luang T37, Gumpun T12, Gumpun T23, Gumpun T27, Gob T10, Monthong T41, T43, T44	D 102 T9, Parung T21, Hew 3 T34, Pomoho Monthong T33, KK 8 T17, Chompoosri T14, Gob Yaow T18, Limberlost T1, Sunan T16	D 98 T3
Zappala	Gaan Yaow Z Hse, D 16 R2T14 Z Hall, D16 R2T16 Z Hall	D 102 Z Hse, Chanee Z Hse, D 96 R2T16 Z Hall, Hew 3 Z Hse, Hew 3 R2T6 Z Hse, Cipaku R2T11 Z Hall, KK 8 Z Hall, Sunan R1T18 Z Hall, Kradumtong Z Hse, Hew 3 Z Hall, Pomoho Monthong Z Hall,	
BARC	Luang?	Gumpun?, Gob?	
T.M Siah		Gumpun? S, Hew 1 S, Hew 6 S, Hew 7 S,	D 24 S
B. Lemcke	Luang L		
B. Jaminon	Luang J	D 102 J, Hew 5 J, Chompoosri J, Johnson J,	D 98 J, D 24 J
Eden Farm, Malaysia	Monthong 1 E, Monthong 2 E	D 99 SF E, D 99 LF E, D 2 E	D 24 E

of leaf shape. Leaf shape is controlled by genotypic factors in comparison to leaf size ie. area and leaf length which can vary according to the physiological age of the leaf, position of the leaf on a shoot, and nutrient status of the plant and environmental factors.

Using the selected 8 parameters and plotting the polygonal graphs many cases of misidentification were revealed. It was also possible to confirm very close similarities between samples collected indicating similar population source or genotype as well as closely related cultivars belonging to similar morphological groups. All distinct clones have different polygonal graphs (Fig. 4-7) which can be used like a rough finger print base for identification. The 55 samples of 32 designated cultivars were reduced to 21 cultivars and phylogenetic/ phytomorphological groups.

The cultivar labelled as Luang (J and B) in the Northern Territory and grown at the South Johnson Research Station in north Queensland (T19, T32, T37) have identical profiles indicating similar phylogenetic make up and same population source. Besides their distinctive very large leaves and long petioles, they all produce fruits with identical fruit characteristics - large, obovoid to broadly obovoid fruit, with creamy, sweet, mildly odorous, yellow flesh. The leaf profiles of these "Luang" trees closely resemble those of the recently introduced Monthong from Thailand that is being established at SJRS after successful propagation by grafting and the Monthong trees in Eden Farm in Malaysia (Fig. 4). The only difference is that the Malaysian Monthong have marginally bigger basal angles.

The Gumpun samples (T12, T23, T27 SJRS) evaluated have similar leaf profiles as the recently introduced Monthong and the "Luang". To establish the status of this recent introduction as the true Monthong, polygonal leaf profiles of samples of the true Monthong in Thailand need to be done to confirm this. A Thai durian scientist Songpol Somri identified that the Gumpun trees in a growers orchard in Merriwini, Queensland, to be the real Monthong after examining the tree and fruit and tasting the fruit. Thus it could well be that we already have the true Monthong all along. The Gumpun trees and the SJRS Monthong differ marginally from the "Luang" and the Malaysian Monthong in having smaller leaf areas and slightly shorter petioles but have identical basal angle magnitude as the Malaysian Monthong (Fig. 4). Also the Gumpun

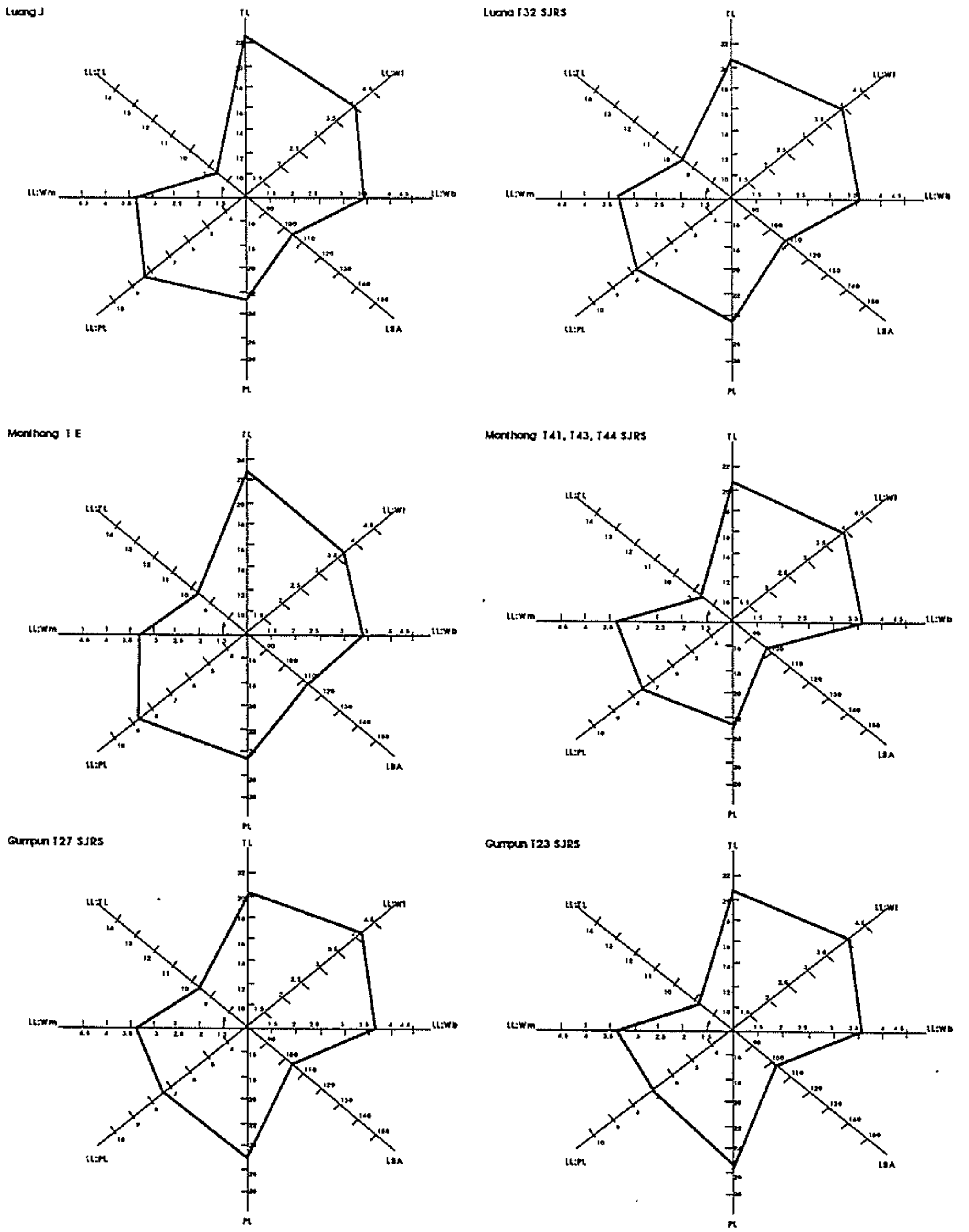


Figure 4. Polygonal graphs of durian cultivars showing similarities in leaf profile: Luang J and Luang T32 SJRS (top), Monthong 1 E and Monthong T41,T43,T44 SJRS (middle), and Gumpun T27 SJRS and Gumpun T23 SJRS (bottom).

produce obovoid to broadly obovoid with or without the distinct tapering beak with similar fruit properties and aborted seeds. This indicates that the Gumpun, "Luang" and the Malaysian and SJRS Monthong are closely related phytogenetically. We

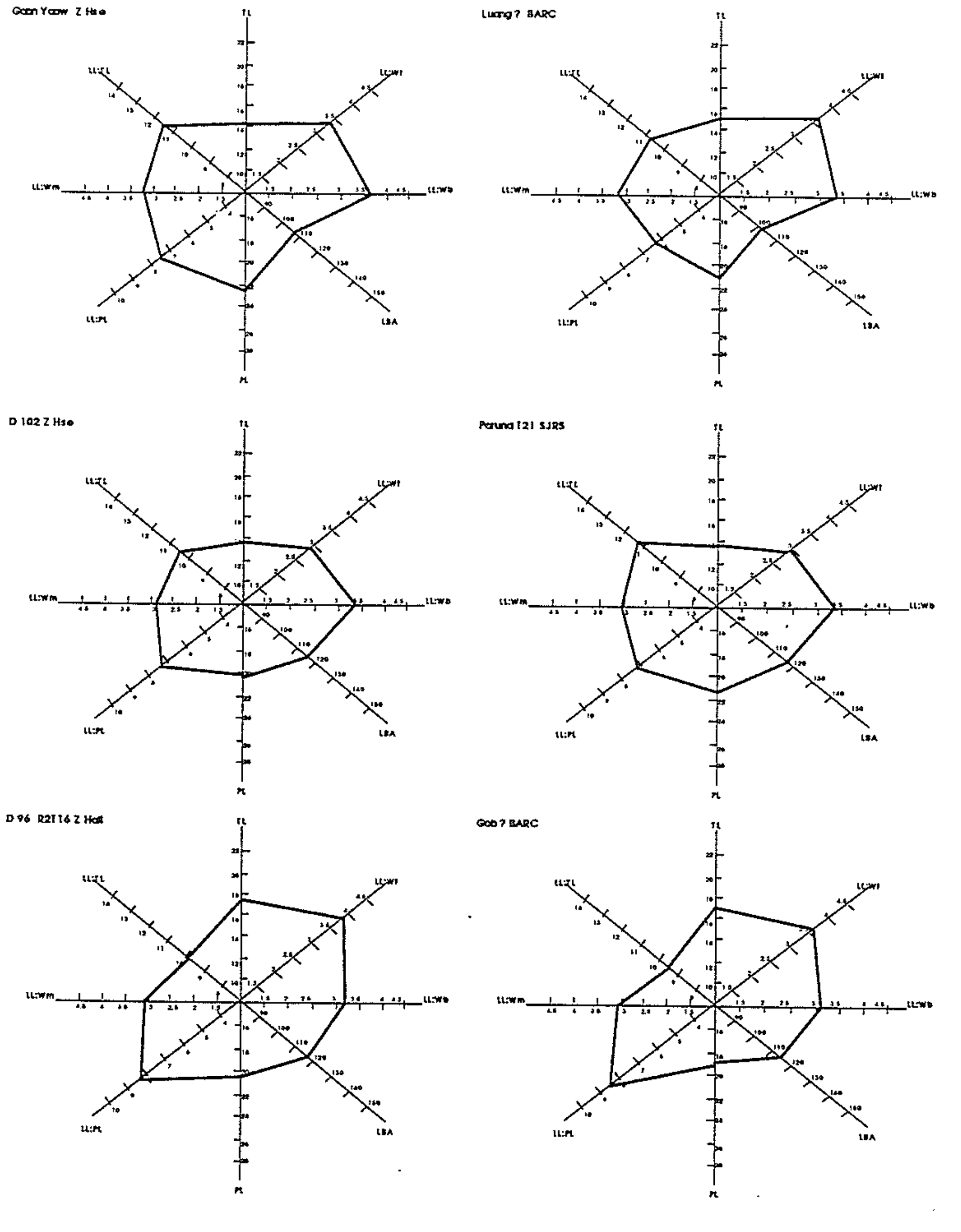


Figure 5. Polygonal graphs of durian cultivars showing similarities in leaf profile: Gaan Yaow Z Hse and Luang ? BARC (top), D 102 Z Hse and Parung T21 SJRS (middle), and D 96 R2T16 Z Hall and Gob ? BARC (bottom).

proposed that the "Luang" cultivar should be renamed as Gumpun-Luang and is not the true Thai Luang cultivar which is in the Luang group with Chanee and Chompoosri (Hiranpradit *et al.,* (1992).

The cultivar designated Luang BARC at the Berrimah Farm has an identical leaf polygonal profile to the Gaan Yaow Z Hse in north Queensland (Fig. 5). That the former is also a Gaan Yaow is further confirmed by similarities in fruit characteristics. It produces spheroid to obovoid, 1.5-2.5 kg fruit with very long stalks and has thick, creamy, sweet, bright yellow arils as reported for the cultivar from Thailand, its place of origin.

The trees labelled as Gumpun? BARC, Gob? BARC, Gumpun? S and D 102 J have all been erroneously identified. Their polygonal profiles are similar to D 96 R2T6 Z Hall (Fig. 5) and Hew 6 S. D 96 is a Malaysian clone called "Bangkok", an introduction from Thailand. We proposed that Gumpun? BARC, Gob? BARC, Gumpun? S and D 102 J be labelled as D 96. This is also evidenced from their similar fruit characteristics of large 2.5-5 kg, obovoid shaped fruit with yellow, creamy, sweet flesh and the presence of aborted seeds.

D 102 T9 SJRS and D 102 Z Hse have fairly similar profiles to that of Parung T21 SJRS (Fig. 5). D 102, a Malaysian clone has its origin in Thailand and is named Bangkok T17 and described as having large oblong fruit with thick, dry, yellow flesh (Anonymous 1980, 1994). Parung is a superior national Indonesian clone from Darmaga, Bogor, south Jakarta and produces oblong, greyish-green, thick, yellow, dry sweet fleshed fruit (Widyastuti and Paimin 1993). Again whether the D 102 in Australia and the Parung are true representative of their namesake in Malaysia and Indonesia is doubtful as D 102 in Australia bears round fruit and the Parung here has pale yellow to white flesh.

Gob SJRS has its own distinct profile and is different from the Gob BARC which is reidentified as D 96. Both are not the true Gob cultivar as both are different from D 99 SF E and D 99 LF E which represent the Gob from Thailand. D 99 LF E produces larger ovoid to spheroid fruits with thick, yellow sweet flesh and has shorter and smaller leaves whereas D 99 SF E produces smaller spheroid fruits with thick, yellow sweet flesh and has longer and larger leaves. Both are in the Gob group of Hirandpandit *et al.,* (1992). The polygonal profiles of Hew 5 J and Johnson J are quite similar to D 99 SF E and is also in the Gob grouping. Others in the Gob group which is characterised by the large, broad, puckering and bulbous basal laminar portion and very large basal angles include Hew 3 T34 SJRS, Hew 3 Z Hse, Hew 3 R2T6 Z Hse.

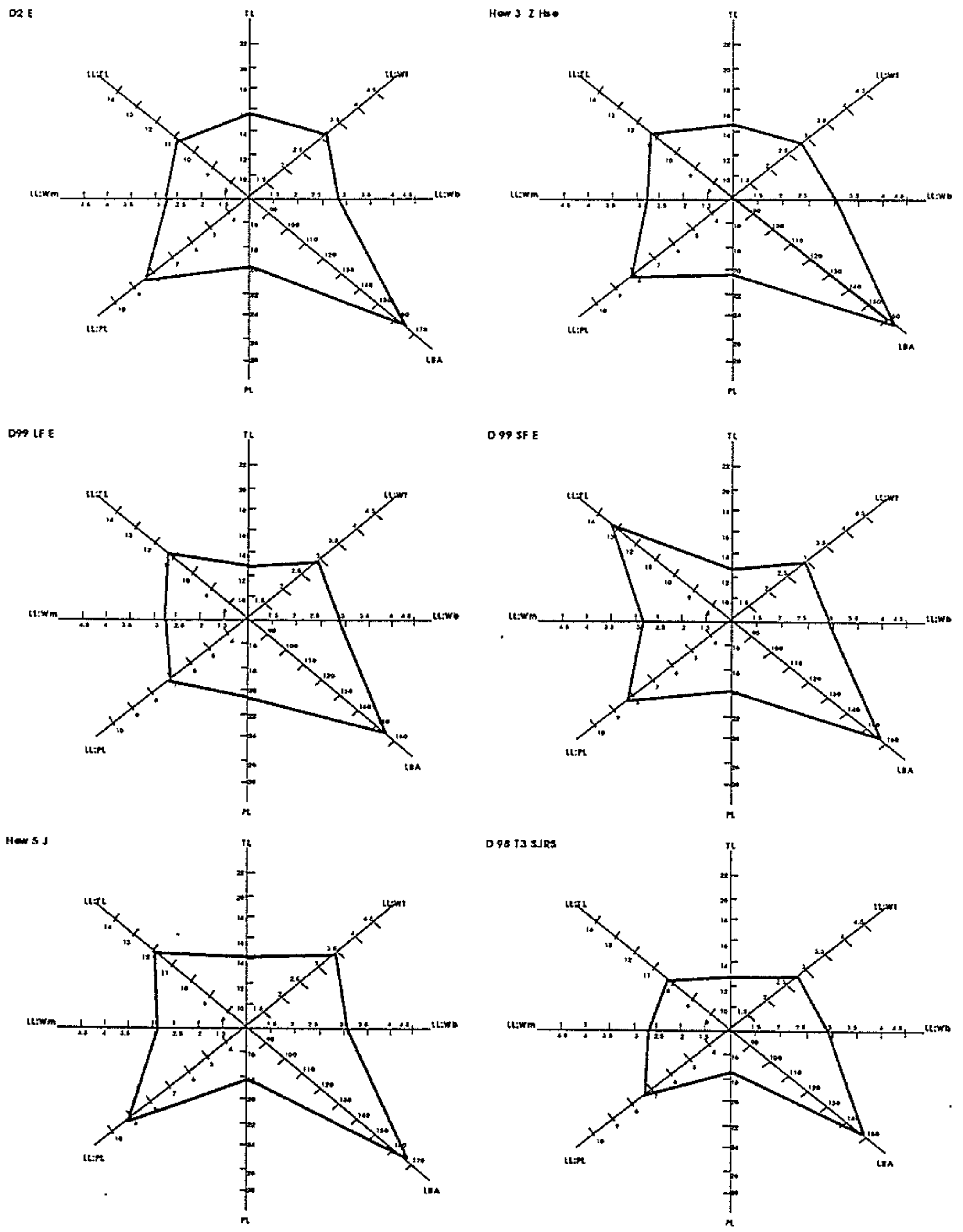


Figure 6. Polygonal graphs of durian cultivars showing similarities in leaf profile: D 2 E and Hew 3 Z Hse (top), D 99 LF E and D 99 SF E (middle), and Hew 5 J and D 98 T3 SJRS (bottom).

These have very identical profile to D 2 E and is renamed as such and this is also evident from common ellipsoid to ovoid fruit characteristics (Fig. 6). D 98 samples from B. Jaminon in the Northern Territory and D 98 T3 SJRS from north Queensland have identical leaf profiles which are similar to the leaf profile of Hew 5 J except that

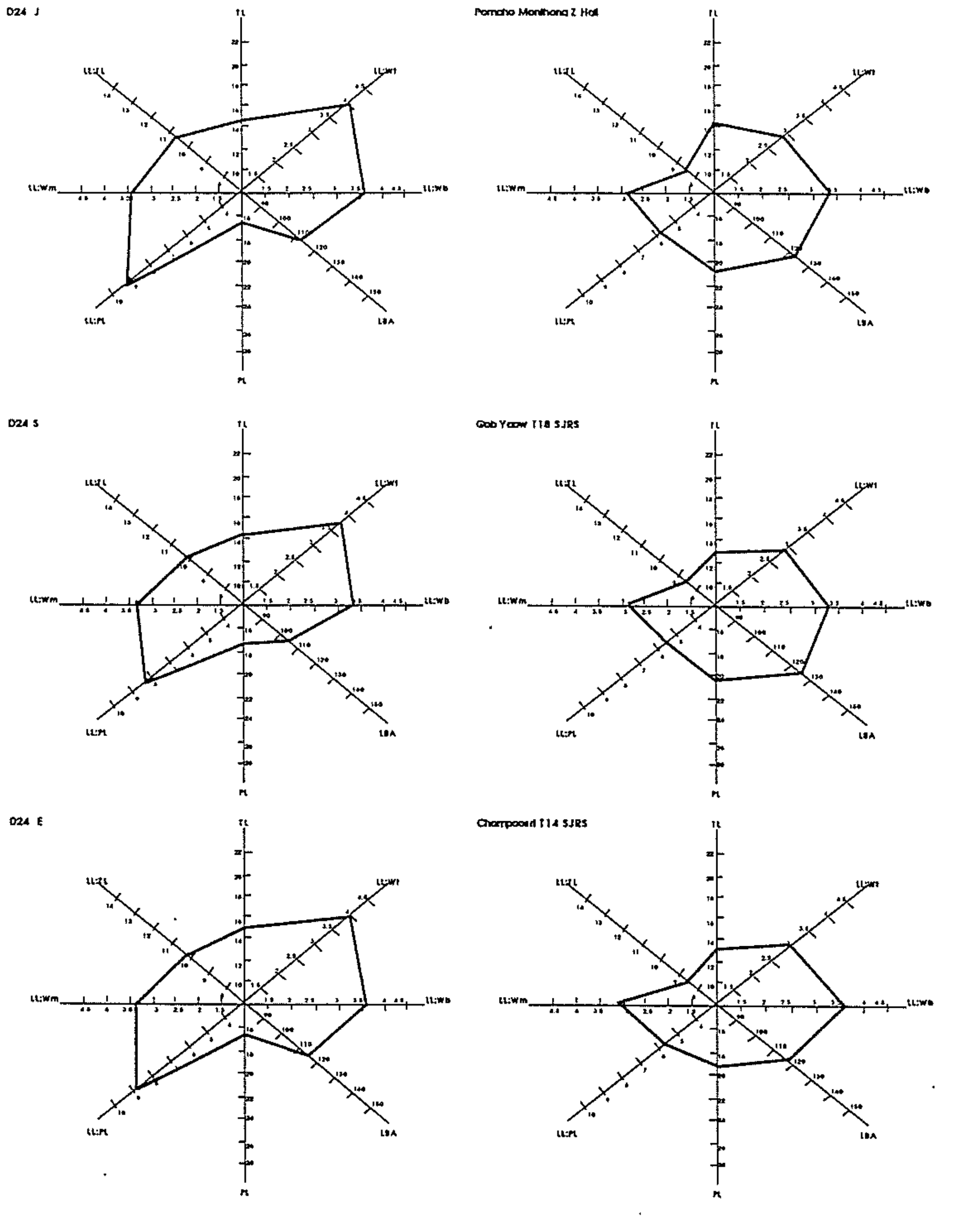


Figure 7. Polygonal graphs of durian cultivars showing similarities in leaf profile: D 24 J, D 24 S and D 24 E (left), and Pomoho Monthong Z Hall, Gob Yaow T18 SJRS and Chompoosri T14 SJRS (right).

they have smaller leaf areas (Fig. 6). All of them can be grouped under the Gob grouping of Hiranpradit *et al.*, (1992). The Australian D 98 bears spheroid fruit with yellow flesh and is not the same as the D 98 in Malaysia which has white flesh (Anonymous 1980, 1994).

The so called "Monthong" from Pomoho , Hawaii, ie. Pomoho Monthong Z Hall, Pomoho Monthong T33 SJRS is not the true Monthong and has a totally different leaf profile from the Gumpun group described above. It shares identical profile to Chompoosri T14 SJRS, Gob Yaow T18 SJRS. All of these have very small leaves with short tips (Fig. 7). All the D 24 samples (D 24 E from Malaysia, D 24 S, D 24 J) have identical profiles (Fig. 7) again indicating a common phylogenetic relationship and population source ie. Malaysia. KK 8 has been listed to be the same as Kradumtong (Watson 1988). KK 8 T17 SJRS and KK 8 Z Hall have a very different polygonal profile to that of Kradumtong Z Hse. Also in Malaysia there is no such clone labelled as KK 8

All the remaining samples namely Chanee, Hew 1, Hew 7, D 16 (R2T13 Z Hall, R2T14 Z Hall), Sunan (T16 SJRS, R1T18 Z Hall), Limberlost T1 SJRS, and Cipaku R2T11 Z Hall have distinct individual polygonal leaf profiles. Cipaku is described as an Indonesian clone (Watson 1988) but is not listed in the comprehensive list of Indonesian durian cultivars by Widyastuti and Paimin (1993).

Thus, it can be seen that polygonal graph analysis of leaf characters can be used to differentiate among durian cultivars from various localities, regions and countries instead of using reproductive characters which entails a long waiting period of 10-12 years for seedling trees and 6-8 years for grafted trees. However, similar polygonal profiles can be done for fruit characteristics or a combination of leaf and fruit characteristics as identification aids that can be conveniently and accurately developed and used by growers without the employment of sophisticated expensive instrumentation. This technique offers a good alternative to differentiate among cultivars in the absence of a determinative DNA finger printing test for durian and other tropical fruits.

a

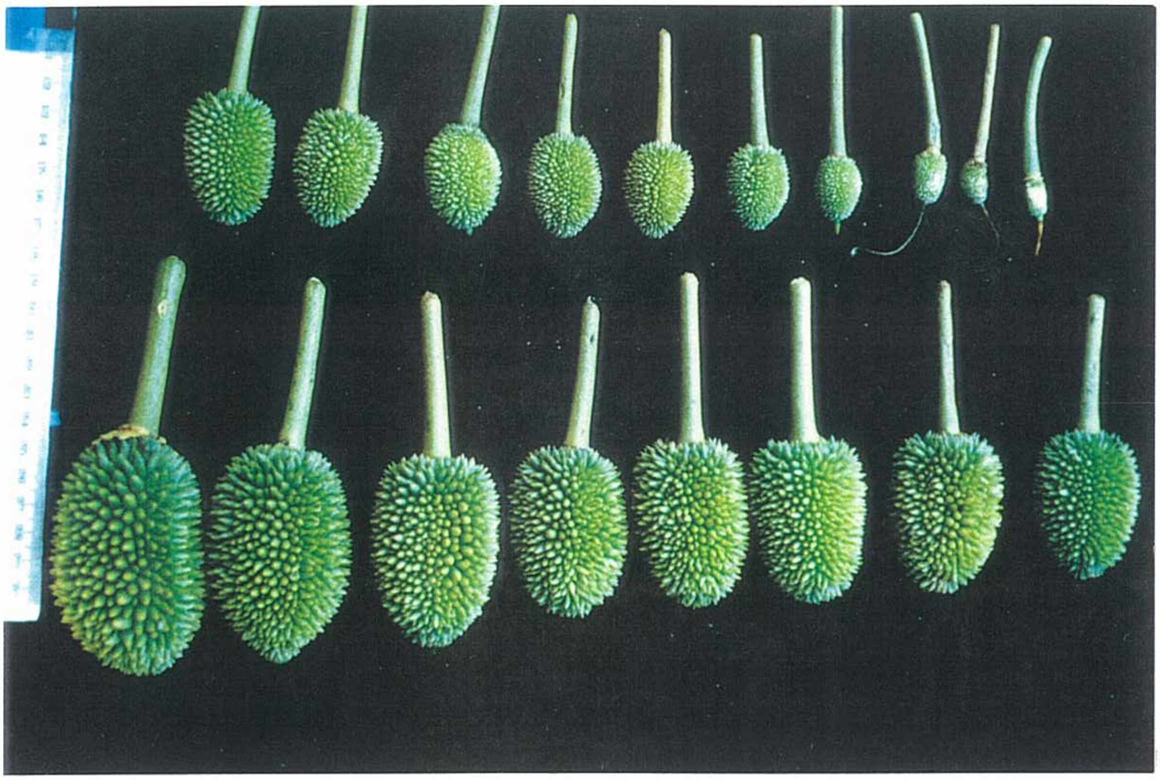
b

Plate 1. Flowering Phenology. a) Appearance of pimple protuberances, b) extension growth of protuberances,

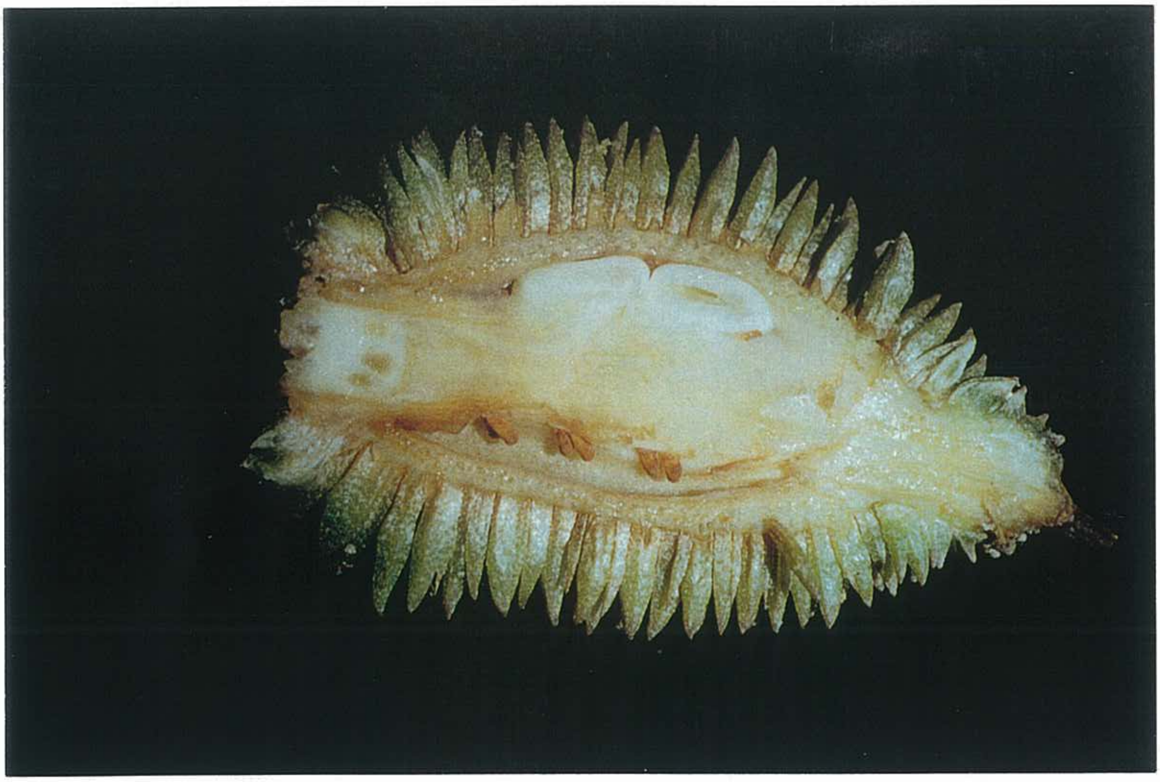
c

d

Plate 1. Flowering Phenology (continued). c) fascicle of corymbose flower buds and d) flower anthesis.

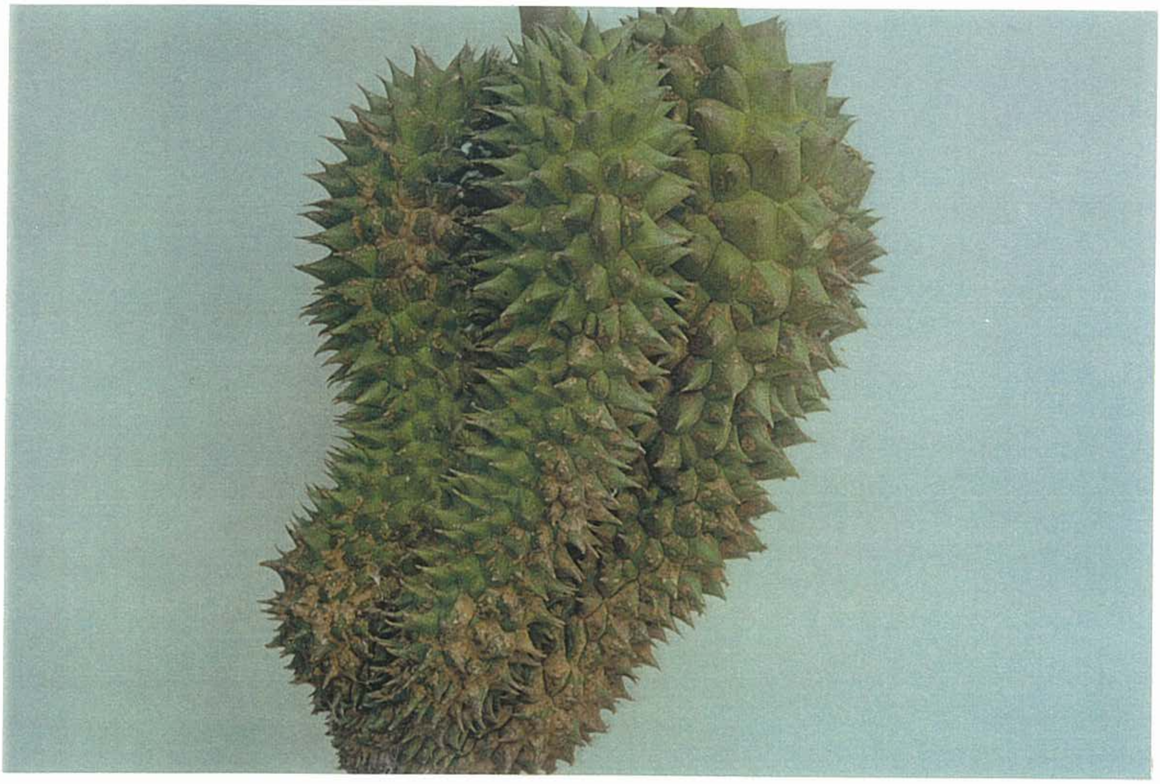


a



b

Plate 2. Assisted pollination and self incompatibility studies. a) Post anthesis fruit drop, b) section of an aborted fruit showing fertilised and unfertilised ovules,



c

d

Plate 2. Assisted pollination and self incompatibility studies (continued). c) self pollinated deformed fruit and d) cross pollinated fruits.

a

b

c

Plate 3. Durian pollen germination (magnification = 40X). a) Pollen with straight germ tube, b) curved germ tube and c) club-like swelling at the end of the germ tube.

a

b

Plate 4. Cultural practices and insect damage. a) Successful graft by modified Forkert budding, b) thinning of flower bud clusters

c

d

Plate 4. Cultural practices and insect damage (continued). c) meat ants devouring durian flower and d) damage of flower inflorescence by mealy bug - green ant association.

CHAPTER 3

3.1 Durian Crop Phenology and Reproductive Biology

An understanding of the crop vegetative growth patterns and flowering/fruiting phenology in response to fluctuations in environmental factors and cultural inputs is an important prerequisite to boosting the crop's productivity. Such knowledge provides a holistic approach to optimising crop management inputs and resources in particular with respect to the development of sound fertilisation and irrigation scheduling programs as well the implementation of cultural practices. For instance in durian as with most tropical fruit species biotic pollination is the most predominant. To maximise fruit productivity the maintenance and continuos presence of such pollinating agents is of vital importance. Thus it is imperative that indiscriminate and excessive use of pesticides during this period be drastically reduced or avoided.

Additionally, the study of the crop's reproductive biology is a fundamental prerequisite for the development of a sound selection and breeding program. On the whole such study is important for the development and conservation of the crop.

Material and methods

Flowering phenology and biology

Durian vegetative and flowering phenology were monitored on durian trees at Berrimah Farm in Darwin and two growers' orchards at Lambells Lagoon 55 km away from 1992-1996. Simultaneously meteorological monitoring of temperature, rainfall, relative humidity, evaporation and sunshine hours were carried out in the nearby Coastal Plain Research Station near Lambells Lagoon. Floral initials were monitored and their development measured at weekly intervals from the first appearance of pimple protuberance through to anthesis and through fruit development to harvest drop at Berrimah Farm.

Vegetative flushing was assessed by measurement of shoot growth extension and visually. Ten shoot terminals on each of two trees were tagged in one property in Lambells Lagoon and fortnightly measurements were taken on shoot growth extension from May April 1993- May 1994. Vegetative flushing was also assessed visually simultaneously and in the following years. Assessment was made from a distance of 8 metres by separating terminals in the canopy into flushing and mature categories and recording the percentage of each. Shoots classified as flushing comprised those with growth from budbreak to the stage when all new leaves were fully expanded and exclude those with fully expanded light green hardening foliage.

Results and discussion

Durian vegetative growth phenology

Generally the area around Darwin has two main seasons, the "Dry" with dry, cool nights and warm dry days from May to September and a "Wet" from November to April; interspersed by a warm, humid build-up in October. Rainfall is around 1659 mm and falls unevenly during the wet months from November to March. During the Wet the relative humidity at 0800h hovers around 80% and at 1500h it varies from 65-75%; and during the Dry the R. H. is about 65-70% at 0800h and 40-50% at 1500h. During the Wet the mean daily maximum temperatures is around 33°C and the mean daily minimum about 25°C. In the Dry the mean maximum is around 29°C and the mean minimum about 20°C. The highest daily maximum can reach 35-38°C in the Wet, and the lowest daily minimum can drop to 8°C in the Dry. The highest monthly evaporation is greater than 220 mm from September to November and the lowest around 180 mm from January to March.

Durian crop phenology in the Darwin area was found to be governed closely by changes in the local weather conditions (Fig. 8). There were three flushes of vegetative growth as measured by terminal shoot extension and visual assessment. In May 1993-May 1994, growth extension occurred on terminal shoot from 9 September to 6 October, 3 December to end December and Feb to late April (Fig. 9). Generally vegetative flushing is extensive and more pronounced in February to late April and less so in September/October which coincided with fruit development and December, vegetative growth is slow during the dry, cool months from June to August (Fig. 8). The minor flushes at the end of the year depends on the extent of the preceding cool period from June to August which also influenced the magnitude of successful fruit setting.

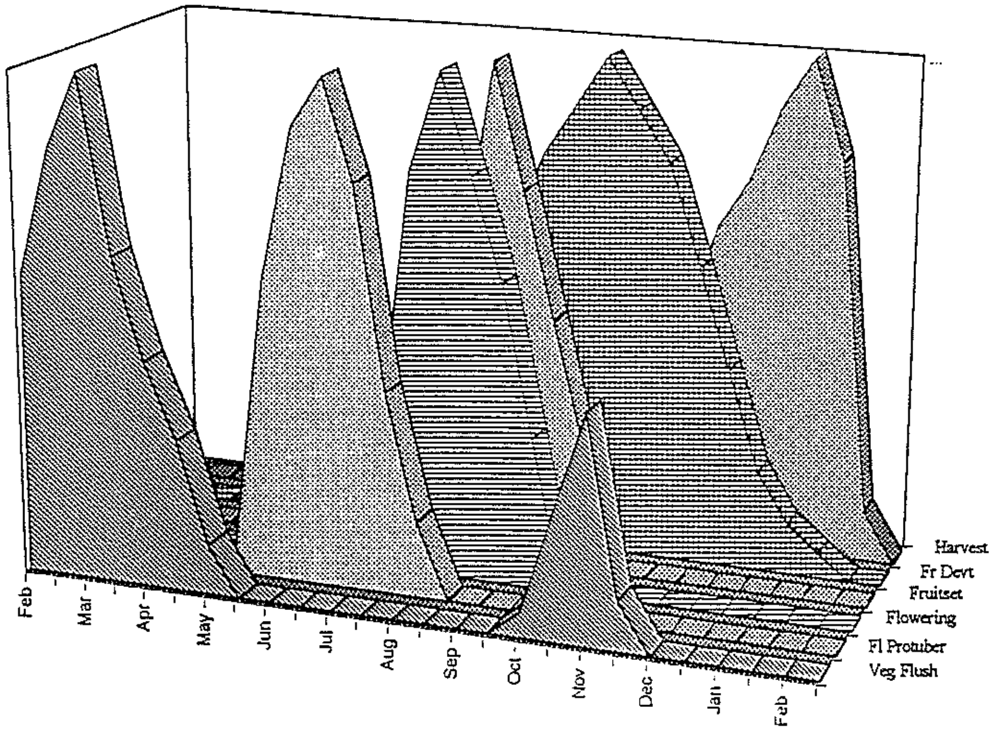


Figure 8. Durian crop phenology in Darwin. The months that events occur are: vegetative flush from January to May and October to November; flower protuberances from May to August; flowering from July to September; fruitset from August to October; fruit development from August to January; and harvest from October to February

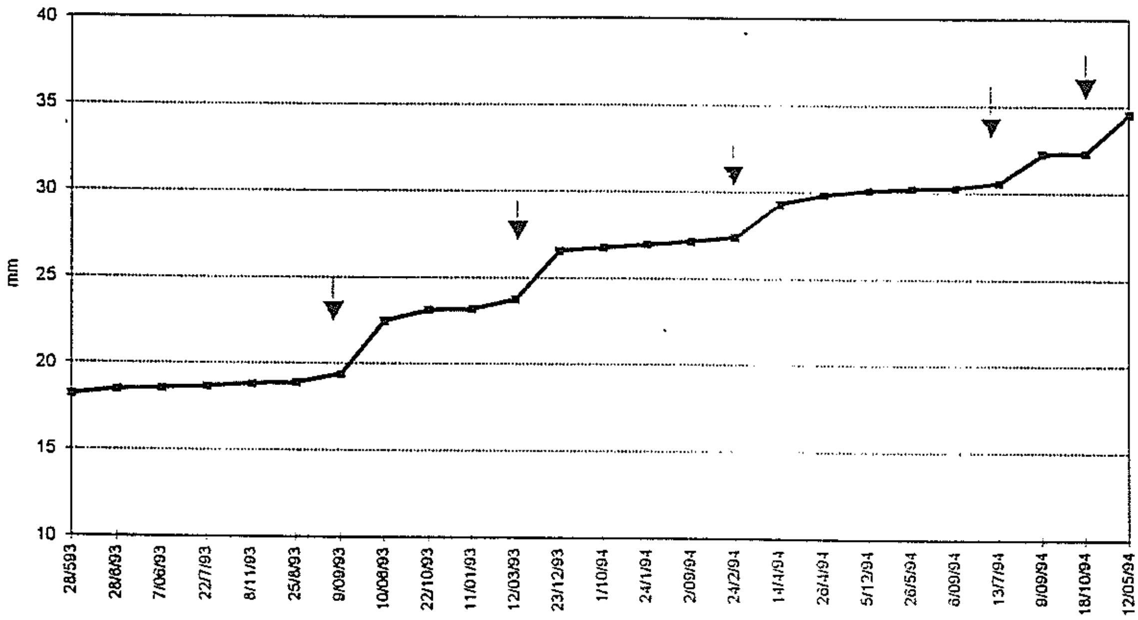


Figure 9. Mean growth extension of durian shoots.

Flowering phenology and floral biology

Our 4-year monitoring studies showed that several cool nights below 15°C could cause the appearance of floral protuberances on branches 1-2 weeks after, followed by flowering 4-6 weeks later. With the onset of 2-3 cool nights in May or June, floral initials appeared 2-3 weeks later usually in June /July and stretched through to August followed by flowering in July to September (Fig. 8). and thence to flower anthesis (Plate 1c & d). During the first 10 days, the protuberance increased in size with a slow extension of the rachis. From day 10-14 primary branching of the protuberance occurred. From day 14-20 secondary and tertiary branching could be seen. From day 20-30 bud differentiation and pedicel development occurred. From day 30-42 there was quite rapid extension of the rachis, pedicel and flower bud especially the longitudinal diameter. From day 42-50 there was very rapid expansion of the flower bud till anthesis but a slowing down in rachis and pedicel development (Fig. 10).

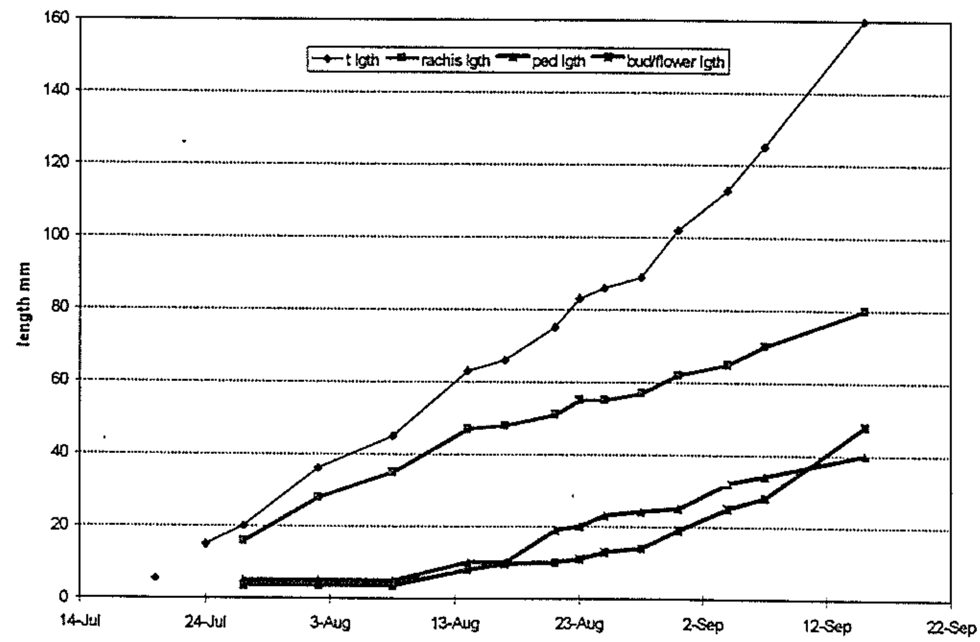


Figure 10. Development of a durian flower bud to anthesis.

Anthesis usually occurred from late afternoon 1530 to early evening 1800 hour and is characterised by splitting of the epicalyx and then the petals to reveal the protruding style that becomes moist, sticky and glistening. Stigma exudate can have three functions: lodging of pollen, pollen germination, and nectar reward to visiting insects and bats. At this stage the stigma is mature and receptive. The stigma is above the stamens during the bud stage but a few hours post-anthesis both style and stamens elongate to almost similar levels often with stamens above the stigma. The durian flower has many stamens some of which develop later and are thus shorter than the stigma but most will eventually reach the same level as the stigma. Thus, the durian flowers are homomorphic and not heteromorphic and do not exhibit heterostyly as reported (Sedgley and Griffin, 1989) unlike carambola that is strictly heterostylous. The durian flower is protogynous ie. the stigma matures before the anther dehisces but the flowering phenology provides ample opportunity for autogamous and geitonomous pollination. Autogamy and geitonomy are common in monoecious and hermaphroditic fruit like the durian. The former refers to the transfer of pollens from the stamen to the stigma of the same flower. The latter to the transfer of pollens from one flower to the stigma of another flower on the same tree. Anther dehiscence followed stigma maturation by a lag time of 1-3 hours but the stigma still remained receptive for 12-18 hours after anthesis coinciding with the maturation and transfer of the pollens, ie. it is also homogamous thus still facilitating self-pollination. Both male and female parts were viable till 1000 hour the next day. Save for the style and ovary, all the floral parts were shed 16- 48 hours after anthesis regardless of successful pollination. Unsuccessfully pollinated or fertilised flowers shrivelled and aborted 1-2 days later. Thus the initial temporal separation is annulled facilitating the occurrence of autogamous and geitonomous pollination.

Flowering was found to occur in consecutive overlapping cycles in tandem with alternating cycles of cool, dry nights below 25°C and above 15°C. This flowering cycle gave rise to an extended flowering period for 2-3 months and it took 110 to 130 days from anthesis to fruit ripening. Fruit development in durian is sigmoidal - slow during 1-3 weeks after anthesis, but increasing considerably after the 4th week. Growth rate declined again from the 13th week till 16-18th week when the fruits dropped off when ripened on their own accord. Fruit set generally occurred from August through

October and fruit development stretched from September through to fruit harvest in December to early February. In some years fruit harvest may occur in late October and November if the flowers successfully set fruit in July such as when the cool Dry is not as severe and protracted.

More specifically (Fig. 11) in 1992, flowering started in mid June and early July which coincided with the onset of cool and dry nights and resulted in very poor fruit set. In contrast the flowering which occurred in late July/August led to good fruit set and development in September/October producing the bulk of the season crop in December and January. In 1993, flowering started in June through September with fruit set and development from July through October. In 1994, flowering occurred in early May as a consequence of two fairly cool nights (<18°C) in mid March. This led to fruit harvest at the end of September/early October, the earliest ever in the Northern Territory. However the two main flower flushes occurred in June and September. No fruits were formed from the June flowering because of the prolonged cool and dry which caused extreme flower, fruit and leaf drop. A poor crop resulted from the September flowering because of excessive fruit abortion resulting from the competition with profuse new leaf flushes in late September/October after the abnormal leaf fall. This effect was more drastic in the Siah's orchard with excessive leaf flushing and no fruit at all. Many of the flowers shrivelled and aborted because of the failure of pollination and fertilisation due to the low night temperatures and humidity which affected pollen release, viability and transfer as well as pollinating activities. In 1995, a minor spurt of flowering occurred in mid June with little fruit set. Major flowering were observed in July and late August/September resulting in record fruit harvest in December to early February

The durian floral biology and phenology play a vital role in its mode of pollination. The white creamy coloured, large, odoriferous durian flowers are borne in corymbose fascicles of 5-30 flowers on branches ie. the durian is ramiflorous. The pollens are large, sticky and are released in clumps or singly. They are produced in stamens in five free phalanges, each filament has 12 reniform anthers which dehisces by a slit. The ovary is ovoid to ellipsoid, five-ribbed and covered with fimbriate scales. The style is pubescent near the apex and the stigma is papillose and capitellate. Being a mast flowering plant ie. one that produces many flowers over a period of several days,

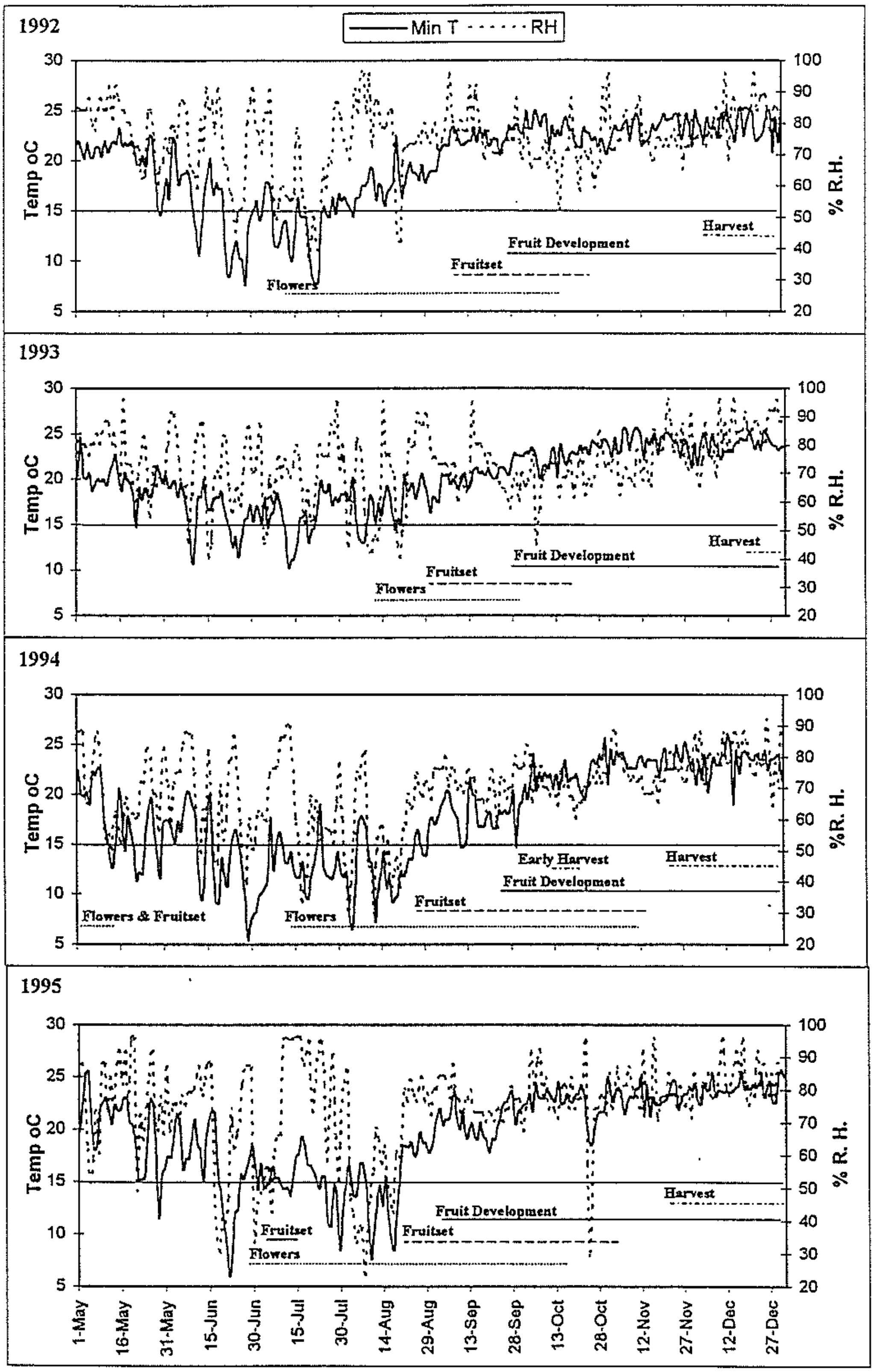


Figure 11. Minimum temperature and relative humidity from May to December 1992-1995 at Middlepoint.

In our studies we attempted to enhance fruit yield and fruit quality in durian by carrying out assisted pollination and also sought to increase our understanding on self-incompatibility in durian. Also the influence of weather conditions on the flowering phenology and reproductive biology of durian was also investigated.

Materials and methods

Flower clusters were thinned to 4-5 clusters so that they were evenly spaced on a branch (Plate 4b) and the remaining flowers were tagged and emasculated before pollination and bagged. Subsequent pollinations were emasculated without bagging which was found unnecessary. Flowers were pollinated at anthesis and after from 1630 - 2230, the late night pollinations were done with the help of growers. Pollens were collected at the time of anther dehiscence 1-2 hours after anthesis and used fresh or kept in glass vials in the refrigerator or room temperature (25°C) for pollination the next day. Flowers selected for pollination were marked and tagged with the pollen source, time and day of pollination. The crosses and selfings made are as shown in Tables. Pollination was effected manually using a fine-hair brush. Deposition of pollen on the stigma was checked with a hand lens. Pollen viability was also determined using Alexander's stain (Lim and Luders, 1996). Successful fruit set was recorded at 2, 4, and 6 weeks after pollination and at harvest. Fruits were evaluated for all fruit and seed characteristics including:- fruit weight, shape, colour, size; peduncle length and thickness; spine shape and length; rind thickness and weight; aril number; flesh colour, thickness, weight, texture, Brix, firmness, taste, and flavour; seed shape, size, weight and number.

Aborted flowers and fruits were collected to examine the frequency of fertilisation of ovules. The aborted fruits were also divided into normal shape, slightly deformed and badly deformed, curved fruits. Also, freshly fallen flowers collected post anthesis were sectioned and stained with lactophenol cotton blue to examine the pollen tube growth in the stylar tissues.

Results and discussion

Assisted Pollination and Incompatibility Studies.

In a preliminary study in 1991, after assisted pollination, a large fruit drop was observed from the 3rd to 6th week. By the sixth week all self-pollinated fruit aborted, but the final fruit set at harvest for assisted cross-pollination was low ranging from 4-16% (Table 14).

Table 14. Effect of assisted self and reciprocal crosses on durian fruit retention in 1991.

Female	Male	Flowers pollinated	Percent fruit at weeks after pollination 3	6	Harvest
Chanee	Chanee	5	20.00	0.00	0.00
Chanee	Monthong	12	33.33	16.67	16.67
Chanee	Luang	10	30.00	20.00	10.00
Monthong	Monthong	40	12.50	0.00	0.00
Monthong	Chanee	67	25.37	7.46	4.48
Monthong	Luang	66	34.85	15.15	4.55
Luang	Luang	43	13.95	9.30	0.00
Luang	Monthong	44	18.18	11.36	6.82
Luang	Chanee	69	26.09	15.94	4.35

In 1994, 700 self- and cross-pollinations were made at the Lemcke and Siah's orchard from late July through September. A large flower drop occurred especially during the 2 weeks after anthesis. There was massive flower, young fruit and leaf drop in both orchards because of the unusual prolonged cool and dry conditions during this period. Despite assisted pollination no fruit set occurred in the Siah's trees and both defoliation and flower abortions were extremely severe on the cultivar D 24. At the Lemcke's orchards the seedling trees and the Thai clones were more tolerant, 47 fruits mature and were harvested, 35 fruit from open pollination of a seedling tree and 12 fruits from cross-pollination.

Several possibilities are suggested for the poor fruit set during the prolonged cool in the Dry season of 1994: a) poor or failure of pollen release from anthers, b) drying up of stigma and pollens because of the very low humidity, c) weak or no production of musky odour, d) low production of nectar by the flowers e) no pollinating activity because of the low temperature, humidity and lack of musky odour and nectar stimulus and f) non-germination of pollens or aborted growth of pollen tube on stigma surface or in the stylar tissues due to the low humidity and temperature. In associated studies, Lim and Luders (1996) found that an alternating temperature of 15-30 °C was inhibitory to durian pollen germination.

Table 15. Effect of assisted self and cross pollination on durian fruit retention in 1995.

Female parent	Male parent	Flowers pollinated	Percent fruit at weeks after pollination			
			2	6	8	Harvest
Gumpun	Gumpun	100	41.00	37.00	17.00	9.00
Gumpun	D 24	30	66.67	56.67	26.67	16.67*
Gumpun	Luang	30	63.33	60.00	26.67	16.67
Gumpun	Monthong	23	56.52	47.83	39.13	30.43
Gumpun	R3 Seedling	22	72.73	54.55	45.45	31.82
Gob	Gob	27	44.44	25.93	14.81	7.41
Gob	R3 Seedling	25	68.00	48.00	40.00	24.00
Gob	Monthong	25	80.00	64.00	32.00	16.00
Gaan Yaow	Gaan Yaow	30	40.00	23.33	10.00	0.00
Gaan Yaow	Gumpun	30	66.67	56.67	33.33	13.33
Gaan Yaow	R1 Seedling	25	72.00	48.00	36.00	20.00*
Gaan Yaow	L Seedling	20	85.00	50.00	30.00	15.00*

* 1-2 fruits split and rotted on the ground and were not used for comparison of fruit traits

In 1995 at the Berrimah Farm, assisted cross-pollination had more fruit at 2, 4 and 6 weeks after pollination then self-pollination (Table 15). Selfing resulted in greater flower and fruit drop. At harvest greater fruit numbers were harvested from crossing, 13-31.82% compared with <10% for selfing. Premature fruit drop was also common in avocado where large numbers of fruit were shed a month after anthesis when the embryo was at the globular stage but had not started cotyledon differentiation (Sedgley, 1980). In *Eucalyptus* and *Camellia*, reduced seed set occurred following self pollination but pollen tube growth in the pistil did not appear to be inhibited. In Malaysia, assisted cross pollination studies on D 24 resulted in 54-60% final fruit set compared to <5% for self-pollination. (George et al., 1993). Valmayor et al. (1965) obtained fruit set of 87.3-90% only when the self-incompatible clones were cross-pollinated. Soepadmo and Eow (1976) reiterated that the high rates of 87.3 - 90% fruit set obtained by the Philippine workers represented a very high rate by any standard. They stated that a fruit set of 20- 25% in Peninsular Malaysia was generally considered as a very good crop. Their study showed that up to 65% successful pollination could be obtained if the flowers were cross-pollinated with pollen from other flowers of the same tree indicating that the tree was self-compatible. In *Ziziphus* self-pollination resulted in smaller fruits than those produced by cross-pollination and these selfed fruits had a tendency to drop prematurely. The cultivar, Gumpun, had more fruits as it had the most abundant flowering followed by the Gob and Gaan Yaow tree. Generally, selfing resulted in lower yields and poorer fruit quality. The selfed fruits were misshapened and distorted (Plate 2c), with a fresh weight decrease of 33-50% and a lower flesh recovery of 20% compared to >30% with assisted cross-pollinated fruits (Plate 2d). They produced heavier rind that is of uneven thickness. They had lower number of arils, 2 (1-4 range) per fruit, lower seed number, lower total seed weight, more shrunken, dysfunctional seeds and comparatively poorer flesh quality (Table 16). There was variability in the magnitude of self-incompatibility among the three clones. More fruit set success was obtained with selfing in Gumpun than in Gob or Gaan Yaow (Table 15). Gaan Yaow had no fruit set at all with selfing. This indicates that durian clones can be totally self-incompatible with no fruit at all, or partially self-incompatible, or self-compatible as was the case observed with some seedling trees.

Our data on post anthesis aborted fruits (>200) also confirmed that selfing resulted in more fruit drop, formation of deformed fruit and the occurrence of partial self-incompatibility in durian. Aborted floral structure smaller than 11 x 9 mm comprised unfertilised flowers which consisted of the ovoid to ellipsoid five-ribbed, fimbriate scale covered ovary, the style and stigma which dried up rapidly with deterioration starting at the stigma down the style. The high frequency of abortion of unfertilised flowers at this stage (Fig. 12) could be attributed to the failure of pollination and or fertilisation. Examination of stained sections of freshly aborted flowers post anthesis suggested that failure of fertilisation could also be due to the inhibition of pollen tube growth in the stylar tissues. This could be due to total self-incompatibility factors in addition to the onset of adverse environmental conditions. Although the rate of abortion of developing fruits

decreased with increase in fruit size (Fig. 12), fruit abortion still occurred until the 13th week after anthesis. Additionally we found that at least 1 ovule of the potential

Table 16. Differences in mean fruit characteristics affected by assisted self and cross pollination.

Female	Male	Fruit weight kg	Length cm	Mid width cm	Spine length mm	Rind thickness mm	No. filled locules	Husk weight kg	No. arils	No well formed arils	Flesh recovery %	Brix %	Total no. seed	Total seed weight
GP	Gp	2.094±0.519 b	23.2±3.46 ab	17.4±4.28 bc	14.41±1.41 a	12.22±2.72 ns	2.33±0.87 c	1.398±0.609 ab	3.44±1.42 b	2.33±0.71 c	21.4±4.94 b	25.48±2.47 a	2.33±0.71 c	99±38.45 b
GP	Mtg	2.447±0.99 ab	22.5±2.12 ab	18.4±3.04 abc	14.06±1.78 a	9.86±1.94 ns	4±0.58 bc	1.451±0.586 ab	12.29±5.22 ab	6.57±1.9 bc	30.9±3.58 ab	26.61±1.66 a	7.29±3.25 bc	241.2±78 ab
GP	Lg	4.190±1.244 ab	32.5±3.54 a	25.5±6.36 ab	13.19±2.10 ab	8.7±0.42 ns	5±0 b	2.436±0.836 a	17.5±2.12 a	16.5±0.71 a	29.7±2.21 ab	25.88±2.24 a	17.5±2.12 a	521.1±128.4 a
GP	D 24	5.300±4.030 a	28.5±10.61 ab	20.5±4.95 abc	14.5±0.71 a	8±0 ns	4±1.41 bc	2.717±1.939 a	18±4.24 a	15.5±7.78 a	34.8±5.61 ab	28.85±4 a	18.5±3.54 a	623.1±390 a
GP	R3Sdg	2.097±0.597 b	21.1±3.24 ab	18.6±1.9 abc	13.91±1.18 a	8.14±2.9 ns	4.29±0.76 b	0.950±0.478 ab	12.43±4.86 ab	10.86±4.74 abc	32.8±2.95 ab	26.98±1.06 a	10.71±4.72 ab	319.4±111.4 ab
Gob	Gob	0.956±0.317 b	18±1.41 bc	13.5±0.71 c	13.84±0.23 a	12±1.88 ns	1±0 d	0.674±0.207 b	1±0 b	1±0 c	21.3±1.12 b	27.2±2.55 a	1±0 c	41.9±1.29 b
Gob	Mtg	2.689±0.708 ab	22.5±2.12 ab	18.5±0.71 abc	14.34±0.47 a	7.5±0.24 ns	4.5±0.71 b	1.343±0.311 ab	11.5±2.12 ab	10.5±0.71 abc	37.9±3.2 a	25.3+3.58 a	10.5±0.71 abc	322.2±43 ab
Gob	R3Sdg	2.581±0.993 ab	24±2.94 ab	19.4±4.31 abc	1405±1.23 a	9.42±2.47 ns	4.75±0.5 b	1.409±0.453 ab	14±5.6 a	9.75±5.19 abc	32.2±6.86 ab	25.63±3.26 a	9.75±5.19 abc	307.2±134.3 ab
Gy	GP	2.098±0.167 ab	31±1.41 a	28.5±2.12 a	8.05±4.03 b	9.95±3.89 ns	5±0 a	1.198±0.169 ab	10±0 ab	10±0 abc	29.8±2.62 ab	17.35±1.77 b	10±0 abc	277.7±3.32 ab
Gy	R1Sdg	1.184±0.404 b	14±1.41 c	15.3±1.77 bc	9.84±0.23 ab	10±1.41 ns	5±0 b	0.687±0.222 b	12.5±0.71 ab	12.5±0. ab	25.4±2 ab	29.55±2.85 a	8.5±6.36 abc	150.9±113 b
Gy	SLSdg	2.354±0.3 ab	20±1.5 ab	18±0.5 abc	8.33±0.5 ab	12.67±0.8 ns	4± bc	1.371±0.52 ab	10±0 ab	9±0 abc	32.3±0 ab	29.22±3.42 a	9.0±0 abc	221±10 ab

* Means in each column with similar letters denote no significant differences at $P \leq 0.05$ as determined by a one way ANOVA.

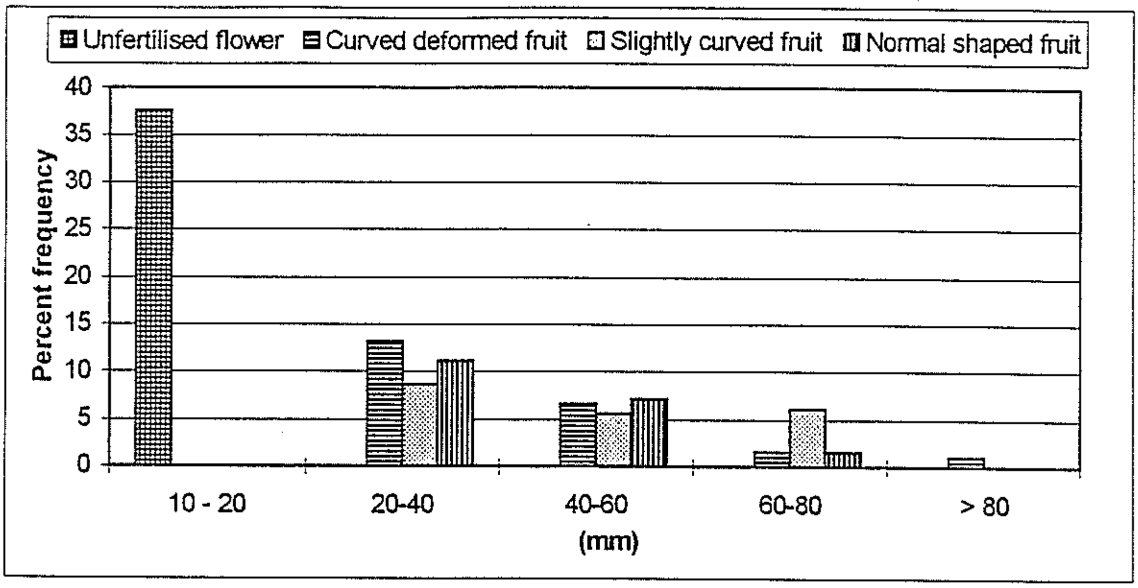


Figure 12. Frequency distribution of aborted durian flower/fruit according to various length groups.

25-30 ovules in the five locules had to be fertilised before the fruit was formed. Generally 12- 20 arils could be found in durian. The best stage to observe incipient stages of aril development was in developing fruit greater than 20 mm x 12 mm (Plate 2a & b). Spines which developed as fine protuberances from the ovary fimbriate scales became discernible 2-3 weeks after pollination ie. at the 16 mm x 10 mm stage. Many flowers and fruits aborted also because of damage from insect (Plate 4c & d)or chewing injury from rodents as evidenced from obvious marks or symptoms. Other causes include competition of nutrients, carbohydrates and water and self-incompatibility factors. It is difficult to separate the last two causes without proper experimentation.

Badly distorted, misshapened fruit had 2.75$\pm$ 0.89 fertilised ovules that developed into arils per fruit with a range of 1-4 arils; 0.55$\pm$0.18 arils/locule (range 0.2-0.8) and 2.25$\pm$0.75 locules with fertilised ovules/fruit (range 1-3) (Figs. 13 & 14). Potentially there are 25-30 ovules or 4-6 ovules per locule in the fruit. Also, the ovules at the peduncle end of the locule were found to be seldom fertilised. In contrast in both slightly deformed and normal shaped fruit ovules in all three positions in the locule

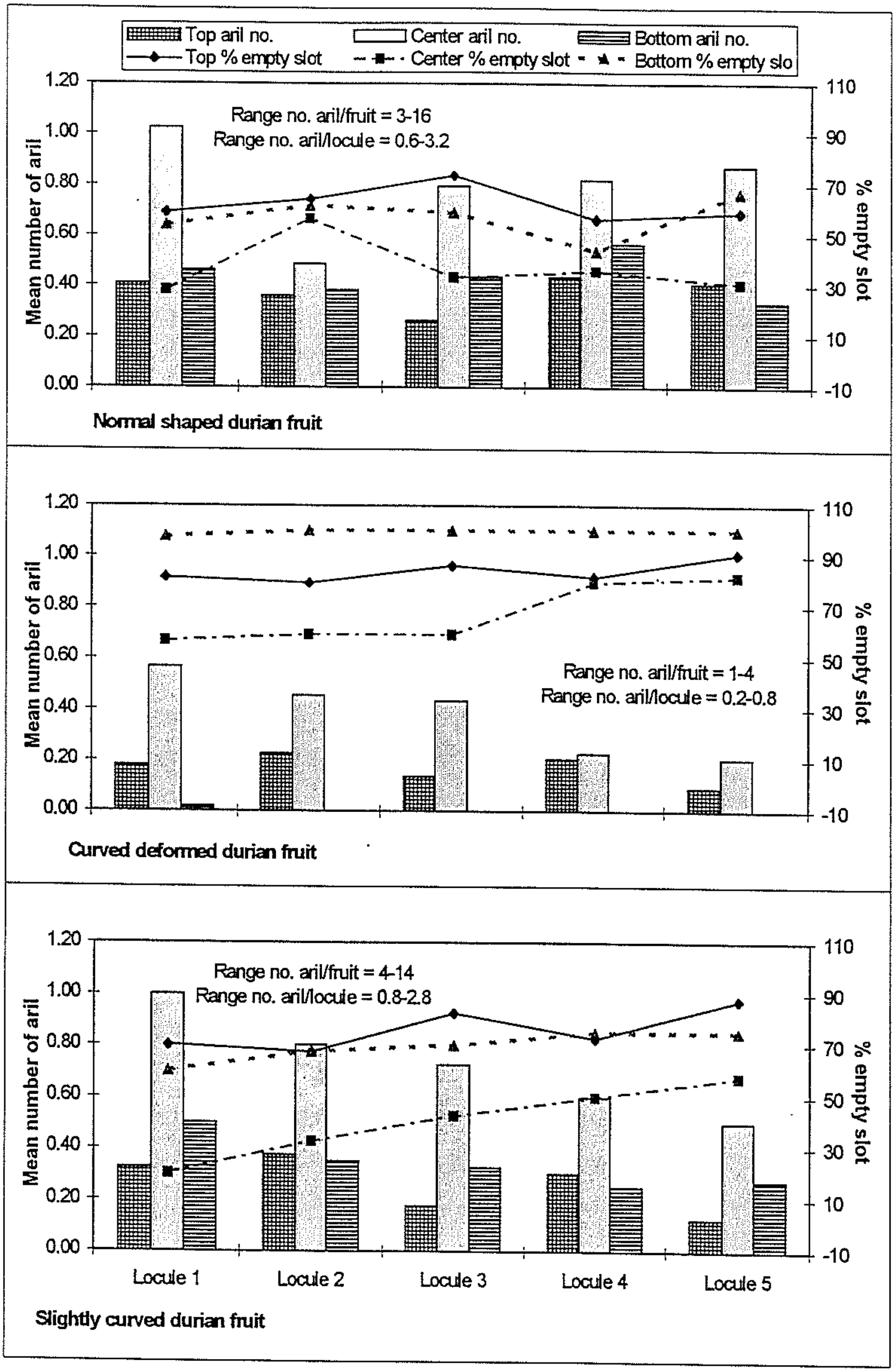


Figure 13. Mean number of arils developed in various positions and percent empty slots in the locule of normal and deformed durian fruit.

were fertilised, though more frequently in the central position. Slightly distorted or curved fruit had means of 6.63±2.41 arils per fruit (range 4 -14), 1.33±0.48 aril/locule (range 0.8- 2.8), 3.83±0.81 fertilised locule/fruit (range 2-5) (Fig. 14). Normal shaped fruit had means of 8.05±2.72 aril/fruit (range 3-16), 1.61±0.54 aril/locule(range 0.6-3.2), 4.26±0.68 fertilised locule/fruit (range 3-5) (Fig. 14). If ovules in one end of the locules were fertilised we get a bottle-shaped fruit. Ovule shrinkage or abortion after fertilisation but with well-developed aril was common in both well formed and deformed fruit but with a higher incidence in deformed fruit. This indicates post-zygotic self-incompatibility is also operative in durian. Thus, in durian there are both arguments for the occurrence of both pre- and post-zygotic self-incompatibility systems. Post-zygotic self-incompatibility mechanisms were also suspected to occur in pecan (Romberg and Smith, 1946), *Eucalyptus regnans* (Griffin et al., 1987), *Camellia sinensis* (Tilquin et al., 1985) and in *Ziziphus* (Ackerman, 1961).

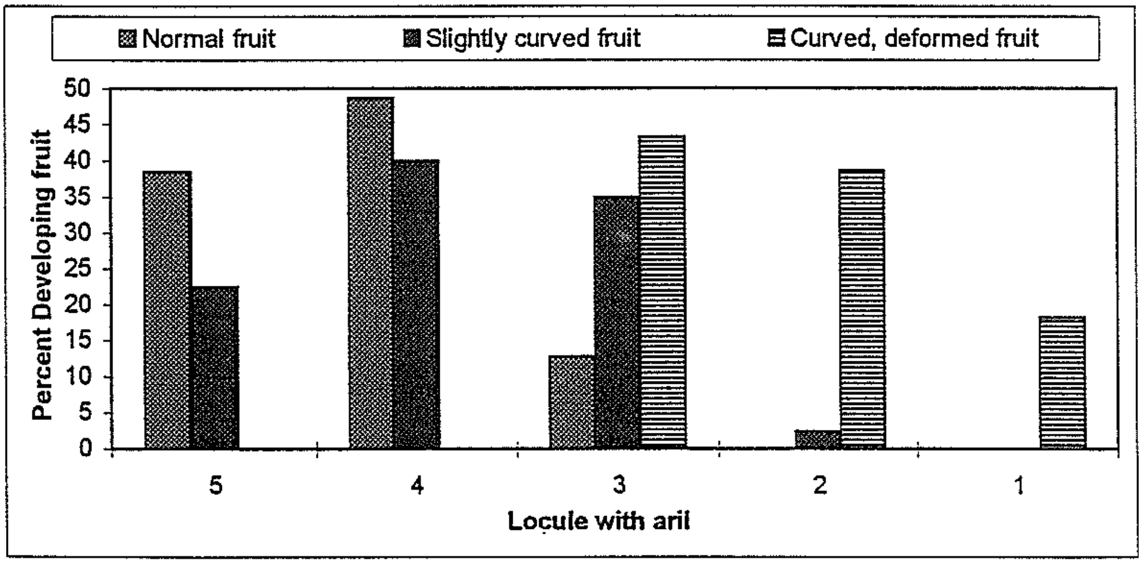


Figure 14. Difference in number of locule with aril between normal shaped and curved, deformed durian fruit.

The data also indicate that the self-incompatibility (SI) system operating in durian is gametophytically controlled. This was evident from the aborted, poor growth of pollen tubes in the stylar tissues, the moist, and sticky durian stigma at anthesis, the binucleate pollen grains which germinated readily and retained its viability in storage

(Lim and Luders, 1996). As according to Crane and Brown, (1937); Ton and Kredzorn, (1967) in gametophytic SI pollen tube growth was inhibited in the style. In species showing gametophytic control the pollen tended to be binucleate on release from the anther, retained its viability in storage and germinated readily invitro. (Sedgley and Griffin, 1989). In contrast species showing sporophytic control, the pollen tended to be trinucleate on release from the anther, rapidly loses viability in storage and germinated poorly invitro (Brewbaker, 1967). Also the stigmas of gametophytic control plants are wet at anthesis in contrast to the dry stigma in sporophytic control plants (Heslop-Harrison and Shivanna, 1977). We postulate that gametophytic SI in durian is controlled by a single gene S that is characterised by the large number of allelic forms in which it exists. According to Lewis (1954) in gametophytic SI pollen tube is usually slow in a style that contains the same allele of S, consequently plants are always heterozygous at this locus. Thus in durian the gametophytic SI give rise to three main types of pollination (Lewis 1954):- (1) fully incompatible (S1S2 x S1S2) in which both alleles are common,(2) partially incompatible ie, half pollen is compatible in which one allele is different (S1S2 x S1S3) and (3) all pollen are compatible (S1S2 x S3S4) in which all alleles are different. Despite the occurrence of total self-incompatibility, partial self-incompatibility and self compatibility, the data here and by other workers indicate the predominance of self-incompatibility in durian that favours outcrossing. The preponderance of so many cultivars and the variability in fruit characteristics among fruit of the same tree indicate that outcrossing appeared to be more predominant in durian than selfing. Scientists in Malaysia (Shaari *et al.*, 1985, Zainal Abidin, 1990) had shown that fruiting in many durian clones required cross-pollination between compatible clones and recommend establishment of polyclonal plantings to enhance fruit yield.

The assisted pollination studies also showed that there was variability in fruit harvest maturity period ie. from anthesis to harvest drop among the female parent and pollenizer source (Table 17). Very slight differences among the female parent were discerned, Gumpun had a mean of 123±5.6 days, Gob 123±4.6 days and Gaan Yaow 121±3.6 days. Among the pollenizer source, the Luang and Gumpun pollens had the longest maturity period viz: Gumpun 128±3.9 days, Gob 122±0 days, Monthong 117±10.8 days, Luang 126±4.95 days, D24 123±4.6 days, Siah Large Seedling

Table 17. Effect of male/female parent on mean fruit harvest maturity period from anthesis.

Parent	Days
Female	
Gumpun	123±5.4
Gob	123±4.6
Gaan Yaow	121±3.6
Male	
Gumpun	128±3.9
Gob	122±0
Monthong	117±10.8
D 24	123±5
Luang	126±5
R1 Seedling	124±2.1
R3 Seedling	122±7.9
Siah Large Seedling	117±0.2

(SLSdg) 117±0.2 days, Row 3 Seedling (R3Sdg) 122±7.9 days, Row 1 Seedling (R1Sdg) 124±2.1 days.

The maternal parent was found to influence the following fruit traits of flesh colour, taste, flavour, basic fruit shape and spine length (Table 18). All three female parents in this study produced creamy, sweet fruits with Brix reading ranging from 21-31.8% and a mean of 25.5%. No difference in fruit characteristic between female parents Gumpun and Gob was detected.

The data (Table 19) indicate that the pollenizer source had a greater influence on the fruit traits and exerted differing influence over the maternal fruit tissues. The pollen had a metaxenia effect on fruit weight, size (length), rind weight, number of locules with fertilised ovules, number of well-formed arils per locule, number of arils per fruit, percent flesh recovery and sweetness (Brix). The pollen also exhibited xenia effects on seed shape, total seed weight and number of seed formed. There was a higher success rate with pollen from seedling trees in crossing with Gumpun, Gob and Gaan Yaow but the metaxenia effects from seedling tree pollens were lower. Pollens from seedling trees and Monthong gave the highest fruit set. Overall, pollens from the cultivars Luang and D 24 were the best pollen source for Gumpun, and there was no detectable difference between pollens from Monthong and R3Sdg. On Gaan Yaow, no difference was found between Gumpun or seedling pollens but more crossings are needed with other pollen sources. On the cultivar Gob, no difference was detected

Table 18. Effect of female parent on mean fruit characteristics in durian.

Female parent	Fruit weight kg	Length cm	Mid width cm	Spine length mm	Rind thickness mm	No. filled locules	Husk weight kg	No. arils	No. well formed arils	Flesh recovery %	Brix %	Total No. seed	Total seed weight g
Gumpun B	2.58±1.41 ns	23.77±4.95 ns	18.80±3.93 ns	14.09±1.37 a	9.98±2.83 ns	3.59±1.19 ns	1.47±0.83 ns	10.19±6.4 ns	7.67±5.67 ns	28.41±6.42 ns	26.44±2.12 ns	8.1±6.0 ns	263.1±191 ns
Gaan Yaow B	1.78±0.60 ns	22.0±8.63 ns	21.1±6.99 ns	8.82±2.22 b	10.51±2.39 ns	4.8±0.45 ns	1.03±0.35 ns	11.0±1.4 ns	10.8±1.64 ns	28.52±3.46 ns	25.09±7.31 ns	9.2±3.3 ns	215.6±85 ns
Gob B	2.20±0.983 ns	22.13±3.18 ns	17.69±3.61 ns	14.29±0.82 a	9.58±2.3 ns	3.75±1.64 ns	1.21±0.44 ns	10.13±6.4 ns	7.75±5.04 ns	30.87±7.42 ns	25.94±2.82 ns	7.8±5.0 ns	244.6±144 ns

* Means in each column with similar letters denote no significant differences at $P \leq 0.05$ as determined by a one way ANOVA.

Table 19. Effect of male parent (pollen) on mean fruit characteristics in durian.

Male parent	Fruit weight kg	Length cm	Mid width cm	Spine length mm	Rind thickness mm	No. filled locules	Husk weight kg	No. arils	No well formed arils	Flesh recovery %	Brix %	Total No. seed	Total seed weight g
GP	2.09±0.47 b	24.6±4.45 bc	19.5±5.92 ns	13.25±3.14 ns	11.81±2.88 ns	2.82±1.33 ab	1.36±0.55 bc	4.6±3 c	3.7±3.2 d	22.9±5.6 b	24±4 b	3.7±3.2 cd	131.5±80.1 cd
Gob B	0.96±0.32. b	18±1.41 c	13.5±0.71 ns	13.84±0.24 ns	12±1.88 ns	1±0 b	0.67±0.21 c	1±0 c	1±0 d	21.3±1.1 b	27.2±2.55 ab	1±0 cd	41.9±1.3 cd
R1Sdg	1.18±0.40 b	14±1.41 c	15.3±1.77 ns	9.84±0.23 ns	10±1.41 ns	5±0 a	0.69±0.22 c	12.5±0.71 bc	12.5±0.7 bc	25.4±2 ab	29.55±2.85 a	8.5±6.4 bc	150.9±113 c
Siah lsdg	2.35±0.3 ab	20±1.5 ab	18±0.5 ns	8.33±0.5 ab	12.67±0.8 ns	4±0 a	1.37±0.52 ab	10±0 ab	9±0 abc	32.3±0 ab	29.22 ±3.41 a	9.0±0 abc	221±10 ab
D24	5.30±0.40 ab	28.5±10.6 ab	20.5±4.95 ns	14.5±0.71 ns	8±0 ns	4±1.41 a	2.72±1.94 ab	18±4.2 ab	15.5± 7.8 ab	34.8±5.6 a	28.85±4 ab	18.5±3.5 ab	623±390 ab
Luang	4.19±1.24 a	32.5±3.54 ab	25.5±6.36 ns	13.19±2.10 ns	8.7±0.42 ns	5±0 a	2.44±0.836 bc	17.5±2.1 ab	16.5±0.7 ab	29.7±2.2 ab	25.88±2.24 ab	17.5±2.2 ab	521±128 ab
Mtg	2.50+0.9 ab	23.22±3.67 ab	18.4±2.64 ns	14.13±1.52 ns	9.27±1.97 ns	4.14±0.65 a	1.43±0.52 bc	12.1±4.59 bc	7.44±2.4 bc	32.4±4.5 a	26.32±2 ab	8±3.16 c	259.2±77.9 bc
R3Sdg	2.27±075 b	22.2±3.31 bc	18.9±2.81 ns	14.12±1.18 ns	8.61±2.7 ns	4.45±0.55 a	1.12±0.50 c	13±4.9 b	10.5±4.7 bc	32.6±4.4 a	26.49±2.08 ab	10.4±47 b	315±113.6 bc

* Means in each column with similar letters denote no significant differences at $P \leq 0.05$ as determined by a one way ANOVA.

between pollens from Monthong and RLSdg. The more uniform-shaped, heavier fruit with higher flesh recovery of cross-pollinated fruits over self-pollinated fruits showed significantly greater heterosis and metaxenia effects of the pollen in cross pollination than in self pollination. From the data it was also evident that heterosis effect on weight and metaxenia effects on size of fruits could both be associated with increase in the degree of heterozygosis in the embryo.

In conclusion, it was found that cross-pollination resulted in higher fruit set, producing higher yields and better quality fruit. Manually assisted cross-pollination gave significantly higher fruit set of 31% in contrast to <10% for selfing. Self-pollination produced fruits that were misshapened, curved with lower number of arils/locule, arils/fruit and lower number of seeds which were usually shrunken and dysfunctional. Evidence from these studies also confirmed that the self-incompatibility system in durian is gametophytically controlled and that cultivars could be totally self-incompatible, partially self-incompatible or totally compatible. The durian pollen was found to exert metaxenia effects that influenced the development of the fruit characteristics and also xenia effect on the seed. The flowering and fruiting phenology in durian is also closely influenced by yearly fluctuations in weather conditions.

3.3 Pollen Germination And Viability Studies

Pollination and fertilisation are important prerequisites to fruit set in durian. Both processes are dependant on the viability or germination capacity of the pollen grains besides other factors. Studies in Thailand (Salakpetch *et al.*, 1992), Malaysia (Shaari *et al.*, 1985, Zainal Abidin, 1990) and recently in Darwin (cf 3.2; Lim and Luders, 1996b) had shown that manually assisted cross pollination can increase durian productivity by increasing fruit set (Shaari *et al.*, 1985; Zainal Abidin, 1990; Salakpetch *et al.*, 1992; cf 3.2; Lim and Luders, 1996), and production of better quality fruits (cf 3.2; Lim and Luders, 1996b). An understanding of the viability, germinability and storage life of durian pollens can assist in the development of a practical and sound assisted cross-pollination procedure that can be used by commercial growers to boost durian productivity.

Materials and methods

Pollen morphology and viability

Pollen grains collected 1-2 hours after anthesis were stained in Alexander's pollen stain (1969) or lactophenol cotton blue. Morphometric measurements were made of fifty pollen grains of the cultivar Monthong , Chanee and a seedling tree obtained from a grower's orchard in Lambells Lagoon.

To test for pollen viability, a preliminary investigation was done to screen the best stain for durian pollens. Four stains were compared:- Alexander's pollen stain (1969), 2,3,5- triphenyl tetrazolium chloride (Oberle, 1953), lactophenol cotton blue and acid fuchsin. Alexander's stain was used for subsequent studies as it was found to be the best. Its ingredients were as follows: 95% alcohol 95 ml, Malachite green 10 mg, distilled water 50 ml, glycerol 25 ml, phenol 5 g, chloral hydrate 5g, acid fucshin 50 mg, orange G 5 mg (0.5 ml of 0.1% solution in water) and glacial acetic acid 2 ml. The viability of pollens was determined immediately after collection 1-2 hours after anthesis and after various storage time in glass vials at 10°C.

Pollen germination

Pollen germination were compared using a liquid medium of Kwack (1965), semi-solid agar medium and Murashige and Skoog (1962) MS basal medium fortified with vitamins. Kwack's formula consisted of 10 % sucrose, 100 ug/g boric acid, 300 ug/g $CaC0_3$, 200 ug/g $MgSO_4$ and 100 ug/g KNO_3 and was maintained at pH 6. To vary the pH 0.1 N NaOH or 0.1N H_2SO_4 was used. Kwack's solution was pipetted in small drops onto a cavity slide and pollen deposited by taping a pollen-laden fine hair bush onto the solution and a fine needle was used to mix the pollens in the solution. The cavity slides were then placed in a humid chamber which consisted of a moist petri-dish with moistened paper and cover. The semi-solid media consisted of 100 of ug/g boric acid, 1% agar and three varying levels of sucrose 5%, 10%, and 20 %. On solid agar, pollen was deposited in sterile distilled water pollen suspension with Tween 80 and spread onto the agar surface by swirling motion. The excess liquid was drained off after 1 hour.

Fresh pollens of the cultivars Luang, Gumpun and a seedling collected 1-2 hours after anthesis were used for germination. A pollen was deemed germinated when the germ-tube exceeded half the pollen diameter. Germination was recorded at 24 and 36 hours and germ-tube growth at 24, 36 and 48 hours.

To determine the effect of temperature on pollen germination the semi-solid medium comprising 10 % sucrose, and 100 ug/g boron was used. The temperature treatments comprised 15-30°C and 20-30°C alternating temperatures (8 hr lower range alternating 16 hr higher range), 25°C, 30°C and 35°C.

Results and discussion

Pollen morphology and viability

Durian pollen grains are binucleate, almost spheroid with 3-5 pores ie. tricolporate(90%)- quadricolporate(8%) and pentacolporate(2%). The pore diameter measures 9.75 μm wide and 19.8 μm deep and the exine 2.25-3.75 μm thick. The pollens are sticky and released in clumps or singly. Pollens ranged from 94-141 μm in diameter. Pollen grains of the cultivar Monthong were larger than Chanee and those from the seedling trees were the smallest in diameter (Table 20). Our morphometric measurements of durian pollen grains agreed closely with the measurements of

Soepadmo and Eow (1976) and differed from those reported by Salakpetch *et al.*, (1992). We found the measurements reported by Salakpetch *et al,* (1992) to be erroneous and too low. They reported mean diameter of durian pollen grains to be 14.8-15 µm the size of some fungal spores.

Table 20. Durian pollen grain diameter (µm)

	Chanee	Monthong	Seedling
Mean µm	116.75	126.09	105.62
Standard Error	1.51	1.57	1.26
Median	116.80	126.74	101.89
Mode	111.83	126.74	96.92
Standard Deviation µm	10.70	11.09	8.89
Range µm	42.25	42.25	34.79
Minimum µm	94.43	99.40	94.43
Maximum µm	136.68	141.65	129.22

The viability of durian pollens can be rapidly and conveniently determined using an appropriate stain. The Alexander's pollen stain was found to far superior over the other stains tested (Table 21).

Table 21. Comparison of stains for determination of durian pollen viability

Stains	Rank	Comments
Alexander's	1	Clear differentiation viable red , non-viable green
Lactophenol cotton blue	3	Poor differentiation
Acid fuchsin	2	Dark red pink
Tetrazolium chloride	4	Need to warm up 2 hr at 30 °C and need refrigeration storage

Viability of durian pollen was high immediately post-anthesis but decreased gradually with storage period. After 5 days storage at 10°C the viability decreased to 50% (Fig. 15). Pollen grains from seedling trees were more resistant to loss in viability with storage and the percent viability were higher than those from known cultivars. Salakpetch *et al.*, (1992) reported that pollen viability was highest at anthesis, 83-96%, and gradually decreased to 79, 77, 92 and 93% in Monthong, Kradumtong, Chanee and Gaan Yaow respectively within 2 days after anthesis.

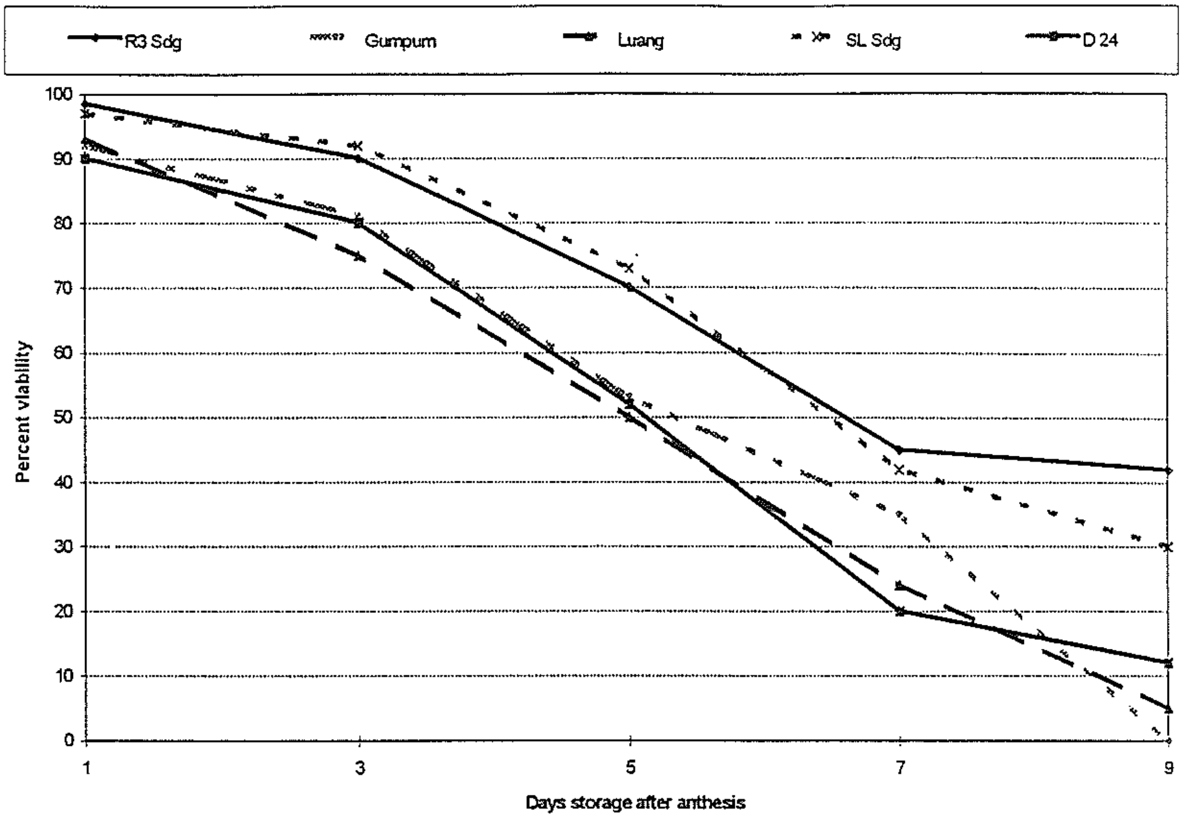
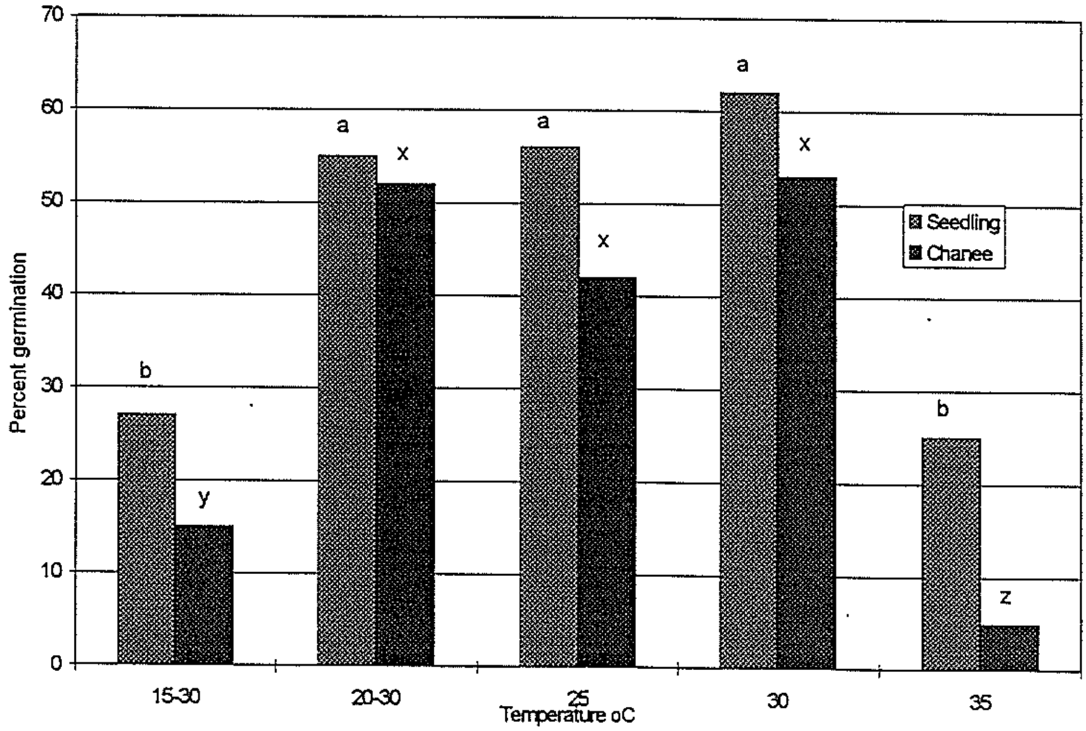


Figure 15. Viability of durian pollens and days of storage after anthesis.

Pollen germination studies

Kwack's solution and the 10% sucrose/ boron semi-solid medium were found to be the best for determination of durian pollen germination with germination ranging from 60-75 percent. However the liquid medium in the cavity slide tended to dry up within 36-48 hours and was not conducive for the observation of germ tube growth. The high (20%) and low sucrose (5%) semi-solid media and the MS basal agar medium supported the lowest germination. Soepadmo and Eow (1976) reported that pollen grains collected at the beginning of anthesis did not show any sign of germination but those collected from the phalanges on the following morning germinated under room temperature and after 40 hours showed 23.5-80% germination. They obtained optimal germination of 77% in 6% sucrose solution and found that the higher the sucrose concentration the longer the germ tube. Salakpetch *et al.*, (1992) found that optimal germination of durian pollens in solutions of 20-35% sucrose with 30-60 µg/g boron, 50-90 µg/g calcium and 15-30 µg/g potassium and magnesium. They obtained 3.4 % germination at 5% sucrose and 8% germination at 50 % sucrose concentration. Germ tube length was found to increase with increasing sucrose concentration up to 30% and decreased with increasing sucrose concentration up to 50% sucrose. However their measurement of germ tube length was erroneous as was the case with the pollen dimension. The disparity in results among various workers could be attributed to the manner in which the germination tests were carried out, differences in cultivars and local climatic conditions.

Our results showed that low and high temperature of alternating 15-30° C and 35°C was inhibitory to durian pollen germination and germ tube growth. Good germination and germ tube growth was obtained at alternating temperatures of 20-30°C, and at 25° C and 30°C (Fig. 16 and Table 22). Again the seedling pollen gave higher germination and longer germ-tube growth. Durian pollen usually exhibits monosiphinous germination although we saw some with three short germ tube protuberances ie. trisiphinous (Fig. 17a & b, Plate 3).



*Columns with the same letters denote no significant difference at P=0.05

Figure 16. Effect of temperature on durian pollen germination on sucrose and boron agar.

Table 22. Effect of temperature on durian pollen germination and germ-tube development.

Temperature ° C	15-30		20-30		25		30		35	
	Seedling	Chanee	Seedling	Chanee	Seedling	Chanee	Seedling	Chanee	Seedling	Chanee
Mean % germination	27	15	55	52	56	42	62	53	25	5
Mean germ tube length um	120	80	375	150	300	110	410	180	240	50
Max germ tube length um	150	150	520	270	500	200	540	250	350	110

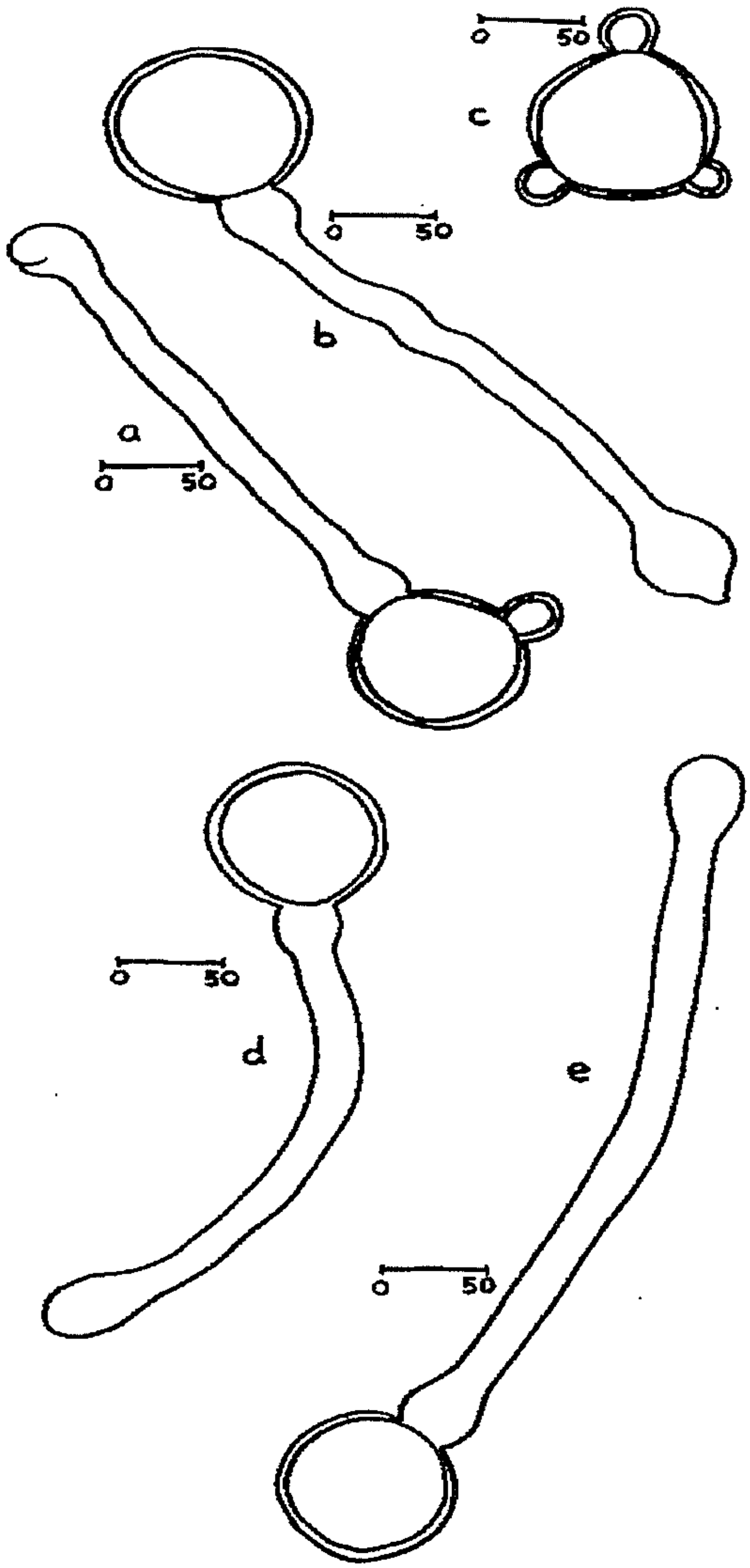


Figure 17. Germinating durian pollen (all measurements in micrometres): a) Gob, b) seedling, c) Gob, d) Gob and e) Luang in various germinating media.

CHAPTER 4

4.1 Seasonal Changes In Durian Leaf And Soil Mineral Nutrient Content.

The durian (*Durio zibethinus* Murr.) is the most lucrative fruit crop in southeast Asia but in northern Australia around Cairns and Darwin the industry is at its infancy stage. In the Northern Territory of the six growers, only two have over 100 trees, and around Cairns out of thirty growers, only three are deemed major growers (Lim, 1995). Despite its golden fruit image in southeast Asia very little published information is available on the durian tree nutrient requirement. Earlier papers on nutrient uptake provided information on the primary macronutrients removed by the harvested fruit as a basis for the crop fertiliser recommendation (Ng and Thamboo, 1967; Yaacob, 1983). Also, there are no published literature on traditional experiments to measure crop nutrient responses in durian as it can be costly and difficult for perennial tree crops (Smith, 1962.). An alternative approach is to conduct surveys of nutrient concentration in orchards varying in vigour and productivity to establish standard nutrient concentrations (Reuter and Robinson, 1986). A more common approach is to use soil and plant analyses to make fertiliser recommendations. The latter is an important tool to diagnose nutrient imbalances, deficiencies and toxicities in plant tissues. In this study we report on the seasonal changes in durian leaf and soil nutrient concentrations in response to changes in crop phenology and also on the best sampling time for durian leaf nutrient estimation.

Materials and methods

Site

Two durian orchards with varying tree vigour in Lambells Lagoon were selected. In Lambells Lagoon the soils in both orchards are the same and can be described as moderately deep to deep massive yellow earths 3b1, sandy/loamy, 20% gravel throughout increasing to 40% at depth and gradational, moderately well-drained to well-drained (Lucas and Czachorowski, 1980) corresponding to yellow, magnesic, ferric Kandosols (Isbell, 1992) or to the ultisol (U.S. Soil Taxonomy Classification).

Monitoring and sampling

The orchards were sampled for plant analysis and soil analysis every two months for more than three years, Lemcke's orchard with seven year old trees from March 1992 to May 1996 and Siah's orchard with 5 year old trees from March 1993 to May 1996. Four trees of mixed clones were selected and tagged for nutrient sampling in each orchard. The sampling procedure was standardised by randomly taking the 5th and 6th leaf from the fully expanded tip leaf of the latest mature flush from 4 quadrats of the tree. For soil analysis four soil cores, 15-20 cm deep were taken from around the tree close to the canopy drip line and bulked. More than 180 leaf and soil samples were taken and analysed for nutrient levels.

Leaf analysis

All leaf samples were washed in tap water and detergent, rinsed and dried at 65°C for 48 hr in a forced ventilation oven, then ground to pass through a 1 mm mesh sieve. Nitrogen was analysed using the sulfuric acid/ hydrogen peroxide digestion method followed by a Lachat Flow Injection Autoanalyser (FIA) procedure using a salicylate spectrophotometric method. The nutrients phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), copper (Cu), zinc (Zn), iron (Fe), manganese (Mn), and boron (B) were analysed by nitric acid digestion (Halvin and Soltanpour, 1980) followed by Inductively coupled plasma atomic emission spectroscopy (ICP-AES). Chloride was extracted with 2% nitric aid followed by potentiometric titration with silver nitrate.

Soil analysis

Soil samples were air-dried and sieved to the < 2 mm fraction. The pH and electrical conductivity were measured using 1:5 soil to distilled water supernatant solution. Soil nitrogen was determined by Kjedahl digestion and FIA measurement using a salicylate spectrophotometric method (Bremner 1965). Oxidisable carbon was determined by concentrated sulfuric /dichromate digestion with spectrophotometric measurements. P was determined by Colwell (1965) extraction in sodium bicarbonate and measurements using FIA utilising a molybdenum blue procedure. Na, K, Ca, and Mg were analysed by extraction with ammonium chloride and ICP-AES. S was analysed by calcium dihydrogen phosphate extraction (Hoeft *et al.*, 1973) and ICP-AES. Mn, Cu, Zn, Fe were analysed by diethylenetriaminepentaacetic acid extraction (Lindsay and Novell,

1978) and ICP-AES measurements. Nitrate-N was determined by potassium chloride extraction and measurement by FIA procedure using cadmium reduction and spectrophotometric method. Bicarbonate was analysed by extraction with carbon dioxide free distilled water and then titrated, the alkalinity was then expressed as $CaCO_3$. Chloride was analysed by extraction with aluminium nitrate and measured by FIA using a mercuric thiocyanate spectrophotometric method.

Data analysis

Seasonal fluctuations in leaf and soil nutrients were analysed using two way ANOVA (site and sampling months which corresponded to the different crop phenological stages). The normal or standard leaf nutrient range was set up by selecting values that fell between the lower and upper confidence limits (95%).

Results and discussion

Seasonal fluctuations in durian leaf and soil nutrient status

Nutrient concentrations for all the micro and macroelements changed in accordance with seasonal fluctuations in durian crop phenology which in turn appeared to be governed by the prevailing meteorological patterns as described above. This emphasised the need to consider the most appropriate time for leaf sampling to estimate the nutrient status of the durian tree.

Sampling time

The best sampling period would be when the nutrient levels were most stable and did not vary widely. From Table 23, this period fell in November. Except for the microelements Cl, Cu and Fe which appeared to fluctuate widely, the other microelements and macroelements were comparatively more stable with coefficient of variability close to or < 20. Thus leaf sampling taking the 5th and 6th leaf from the shoot tip should be done in November coinciding with fruit development. Tentative Australian standards for the NT are set up as shown in Table 24 based on the new range computed by taking the 95% confidence interval about the mean for mean percent concentration at this sampling time and compared with the standards in Malaysia reported by Zakaria (1994).

Table 23. Mean leaf nutrient levels for two durian orchards around Darwin over 3-4 years. Data are the means of four representative samples taken from each orchard at each sampling period.

Month	Crop Phenology	Parameter	N %	P %	K %	Ca %	Mg %	S %	Cl %	Cu mg/kg	Zn mg/kg	Mn mg/kg	Fe mg/kg	B mg/kg
Mar	Vegetative flush	Mean	1.87	0.18	1.49	1.66	1.09	0.17	0.07	22.41	18.54	13.97	39.28	38.05
		S.D.	0.19	0.01	0.27	0.33	0.15	0.02	0.02	26.66	9.54	3.79	16.1	5.51
		Range	1.65-	0.17-	1.06-	1.35-	0.94-	0.15-	0.06-	6.38-	10.75-	9.70-	14.75-	34.13-
			2.18	0.19	1.72	2.05	1.35	0.19	0.10	69.50	32.48	18.88	56.75	47.13
		CV	10.31	5.74	18.07	19.63	13.83	8.95	26.9	118.98	51.46	27.12	40.99	14.49
May	End Veg. flush	Mean	1.86	0.2	1.43	1.69	1.05	0.17	0.07	19.96	16.84	14.73	81.26	40.83
		S.D.	0.23	0.02	0.28	0.26	0.12	0.02	0.06	24.09	3.56	3.04	49.29	2.96
		Range	1.46-	0.18-	0.95-	1.50-	0.90-	0.14-	0.02-	6.04-	11.80-	11.29-	44.50-	36.38-
			2.05	0.22	1.63	2.14	1.23	0.19	0.16	62.18	21.38	19.13	164.14	43.50
		CV	12.56	8.81	19.23	15.26	11.41	12.34	84.75	120.68	21.13	20.66	60.66	7.25
Jul	Flowering	Mean	1.84	0.2	1.44	1.86	0.82	0.16	0.05	17.96	17.58	17.67	113.88	45.16
		S.D.	0.19	0.02	0.29	0.31	0.27	0.03	0.03	12.44	5.37	5.46	58.47	7.51
		Range	1.57-	0.17-	1.03-	1.57-	0.44-	0.12-	0.03-	6.30-	10.75-	12.50-	26.50-	37.13-
			2.00	0.22	1.65	2.14	1.01	0.18	0.09	35.40	23.66	25.14	148.00	54.13
		CV	10.5	11.26	20.1	16.7	32.66	17.35	49.55	69.27	30.57	30.92	51.35	16.62
Sep	Flowering/ Fruit set	Mean	1.87	0.22	1.75	1.46	0.98	0.2	0.06	13.24	15.54	23.43	59.66	36.5
		S.D.	0.16	0.03	0.3	0.48	0.21	0.04	0.05	9.44	3.61	16.47	42.98	8.04
		Range	1.64-	0.20-	1.35-	1.18-	0.74-	0.16-	0.01-	7.88-	10.25-	9.25-	24.25-	30.00-
			2.02	0.27	2.08	2.18	1.21	0.25	0.12	27.38	18.18	45.63	116.63	48.13
		CV	8.79	13.44	17.28	33.06	21.52	20.55	88.18	71.53	23.94	70.31	72.04	22.03
Nov	Fruit Development	Mean	1.78	0.2	1.72	1.49	0.98	0.19	0.06	9.14	13.28	16.95	22.94	35.91
		S.D.	0.2	0.02	0.25	0.39	0.15	0.03	0.01	3.4	1.39	10.92	8.08	2.67
		Range	1.60-	0.18-	1.49-	1.15-	0.80-	0.17-	0.05-	6.66-	11.25-	6.55-	13.25-	32.75-
			2.07	0.22	1.95	2.01	1.13	0.22	0.07	14.16	14.36	26.88	31.25	39.25
		CV	11.39	7.52	14.5	26.4	15.6	12.7	15.57	37.14	10.44	64.42	35.23	7.43
Jan	Harvest	Mean	1.87	0.18	1.53	1.41	0.99	0.19	0.06	10.6	12.19	14.08	40.85	37.03
		S.D.	0.22	0.01	0.34	0.63	0.1	0.02	0.02	8.63	2.76	8.41	21.93	4.09
		Range	1.63-	0.17-	1.02-	0.90-	0.84-	0.15-	0.04-	5.54-	9.39-	8.79-	14.25-	34.25-
			2.17	0.19	1.77	2.34	1.06	.0.20	0.08	23.50	15.88	26.63	66.43	43.00
		CV	11.9	5.3	22.42	44.9	10.28	12.18	29.15	81.4	22.81	59.71	53.7	11.05

Table 24. Tentative Australian leaf nutrient standards for durian compared with leaf nutrient standards in Malaysia.

Element	Malaysian Standard	Tentative Australian Standard*
N %	1.80-2.30	1.58-1.98
P %	0.12-0.25	0.18-0.22
K %	1.60-2.20	1.48-1.96
Ca %	0.90-1.80	1.11-1.88
Mg %	0.25-0.50	0.83-1.13
Na %	n.a.	0.01-0.09
Cl %	n.a.	0.05-0.07
S %	0.16-0.25	0.17-0.22
Cu mg/kg	6-10	5.82-12.47
Zn mg/kg	15-40	11.92-14.64
Mn mg/kg	25-50	6.25-27.65
Fe mg/kg	50-150	15.02-30.86
B mg/kg	15-80	33.29-38.52

* Range set by taking the 95% confidence interval about the mean for nutrient concentration data in November

Leaf macronutrients

There were significant differences only in mean leaf nitrogen and potassium between the two orchards studied (Table 23, Fig. 18). N varied from 1.4 to 2.4 % DW and K from 1.0 to 2.7 % DW. Leaf N and K levels were higher in the Siah's orchard where the trees were younger and more vigorous than at Lemcke's orchard but the older trees in the latter orchard gave higher yields. In 1992 at Lemcke's orchard, the decline of leaf N and K coincided with fruit development in September and remained low through November to harvest in December/January. In 1993, the reduction of N and K again coincided with fruit set and development from July through October in both orchards. In 1994, the trends for N and K were abnormal. The increase in leaf K levels in October coincided with the reduction of the developing fruit sink. A similar explanation accounted for the higher leaf N level in Lemcke's orchard. In Siah's orchard, the decline in N could be traced to the competition for N and dilution effect among the profuse new leaf flushes as a result of the preceding heavy leaf fall caused by the prolonged, prevalent cool weather; and the increase in leaf K could be attributed to the absence of competition from developing fruits as most of the meagre fruit formed aborted. In 1995, the decline of leaf N and K coincided with

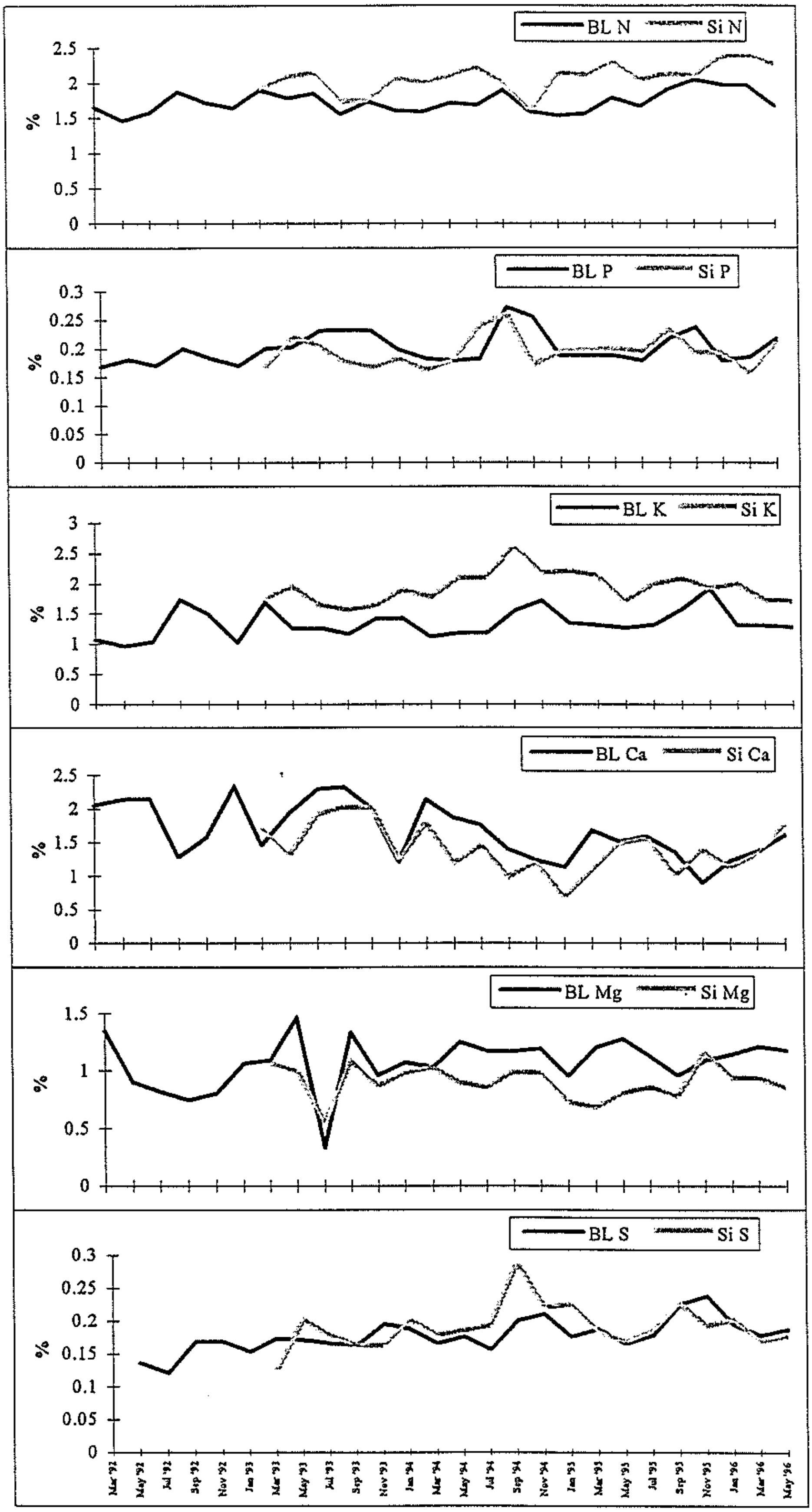


Figure 18. Durian leaf macroelement status in two durian orchards from March 1992 to May 1996.

the main fruit development phase in late October/November for both the orchards. Durian removed lots of K and N through their fruit (Ng and Thamboo, 1967). Ng and Thamboo, (1967) reported that the macroelements removed by the durian fruit followed the sequence K>N>Mg>P>Ca equivalent to 27.9>16.1>3.26>2.72>1.99 kg/ha respectively. They also reported that the highest concentration of K, Ca and Mg was found in the fruit skin.

Leaf P levels fluctuated marginally throughout the year ranging from 0.2% DW to 0.3% DW. Generally P tended to decline or is lower from July to November except in October 1994 in both the orchards. In October 1994, leaf P levels increased because of the absence of the sink effect from developing fruits. Mg was lower during the cool dry months from May to September coinciding with flowering, fruit set and development and this also corresponded to the period of lower metabolic activity in the leaf. Leaf Ca levels ranged from 0.7 to 2.3 % DW., and was lower in the younger trees in the Siah's orchard. Except in 1993 in the Siah's orchard, leaf Ca generally declined after July to marginally lower levels in August through November. One explanation could be the competition for calcium from the developing fruits as calcium is translocated in the xylem and is rather phloem immobile. Also during this period the leaf levels were not replenish because of the environmental stress imposed by the prevailing high temperature and greater evaporation loss which could have slowed down the transpirational stream to the leaf to minimise water loss.

The trend exhibited by leaf S closely followed that of leaf N in both orchards ie. declining during the main fruit development phase around October/November. Due to the unreliability of plant tissue sulphur as an indicator of sulphur deficiency several workers (Rasmussen *et al.* 1977, Saalbach 1973) regarded the N:S ratio to be a more reliable indicator. This ratio would changes greatly in favour of nitrogen in the event of a sulphur deficiency and in favour of sulphur in the event of a nitrogen deficiency. The N:S ratio in durian leaf varied from 8.67 to 12.89. Generally, the ratio decreased from 11.24 to 9.0-9.5 during the fruit development months from September through to fruit harvest in January. The lower leaf N:S ratios during this period could be attributed to the higher accumulation of sulphur in the leaf and decline of nitrogen due to greater mobilisation of nitrogen to the developing fruits. This further indicated little sulphur translocation from leaves to flowers and fruits and that sulphur supply to the developing durian fruits was mainly through increased root uptake during this period.

Leaf micronutrients

Leaf Zn and B levels declined during fruit development (Table 23, Fig. 19). B declined after flowering in July exhibiting the same trend as Ca and Mg as all three elements are phloem immobile. Mn and Fe fluctuated erratically and varied the most, being very high in late 1994 and early 1995 because of the abnormal vegetative flush in October 1994 as a result of preceding massive leaf drop. Leaf Mn levels varied between 12-50 mg/kg but we did not observe any Mn deficiency in the form of interveinal chlorosis as reported by Zakaria (1994) when leaf Mn levels hovered below or between 10-16 mg/kg. Copper showed no distinct trend with crop phenology; high leaf levels especially in March and May could be explained by the sprays of copper during the leaf flushing period.

Soil properties and macronutrients

In both orchards the levels of soil nutrients showed a gradual yearly increment because of better fertilisation and higher rates used by the growers. The Siah's orchard exhibited higher levels for all soil chemical properties due to more generous fertiliser application and the frequent use of chicken manure. This was evidenced from the higher variability in soil conductivity (CV 106%) and soil chloride levels (CV 225%) in Siah's orchard compared to the soil conductivity (CV 59%) and soil chloride (CV 81.29%) in Lemcke's orchard. In general soil conductivity fluctuated greatly from 0.016 to 0.8 mS/cm, soil pH varied from 5.3 to 7.7, soil organic matter ranged from 1 to 4.21 % and soil bicarbonate levels from 40 to 610 mg/kg (Table 24). The mean C:N ratio in the Siah's orchard was 15 and there was significant correlation R^2= 0.83 between soil total N and the C:N ratio. In Lemcke's orchard, the mean C:N ratio was 16 and the coefficient of correlation was marginally lower R^2 = 0.775. However, both were within the ideal range of 10-20 reported for most soils. The soil CEC in both orchards were low, 8.55 cmol{+}/kg in Siah's orchard and 6.21 cmol{+}/kg in Lemcke's orchard and this placed them in the low CEC (± 5 cmol{+}/kg) texture class of Cottenie (1980).

Both orchards have low soil Ca:Mg ratio: viz. 3.95 in the Siah's' orchard and 2.9 in the Lemcke's. Since the ideal ratio between the exchangeable cations should be

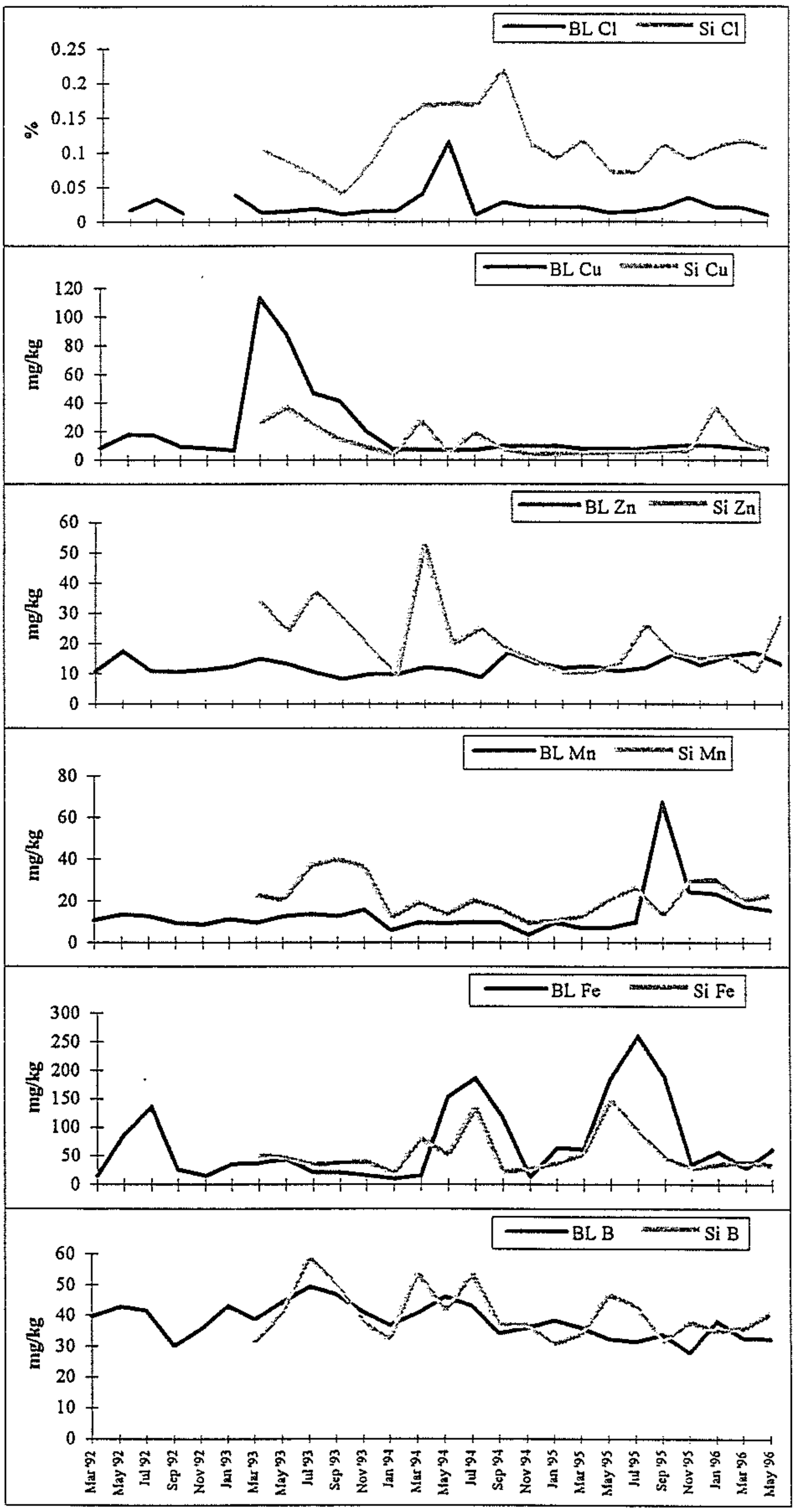


Figure 19. Durian leaf microelement status in two durian orchards from March 1992 to May 1996.

around 6 (Jokinen, 1981) both orchards should increase their soil Ca status. However, the K: Mg of 0.52 in the Siah' s orchard was within the ideal ratio of 0.5 (Jokinen, 1981) but in the Lemcke's orchard the ratio was low, 0.27, indicating that more K should be applied to increase the ratio to 0.5. Soil P levels in both orchards ie. 89 mg/kg in Lemcke's and 205 mg/kg in Siah's placed them in very high category of Cottenie (1980) where the limit set was > 25 mg/kg.

Generally levels of total N, available P and total bases (K, Ca, Mg). were higher in the soil in July and declined in September or October-November (for N) and was lower in March to May. The higher soil levels could be attributed to lower uptake by the tree and less losses from leaching and or volatilisation during the Dry (May to September) (Table 25 Fig. 20). The decline in October-November could be attributed to their increased uptake for fruit development and minor vegetative flush and to higher evaporative losses

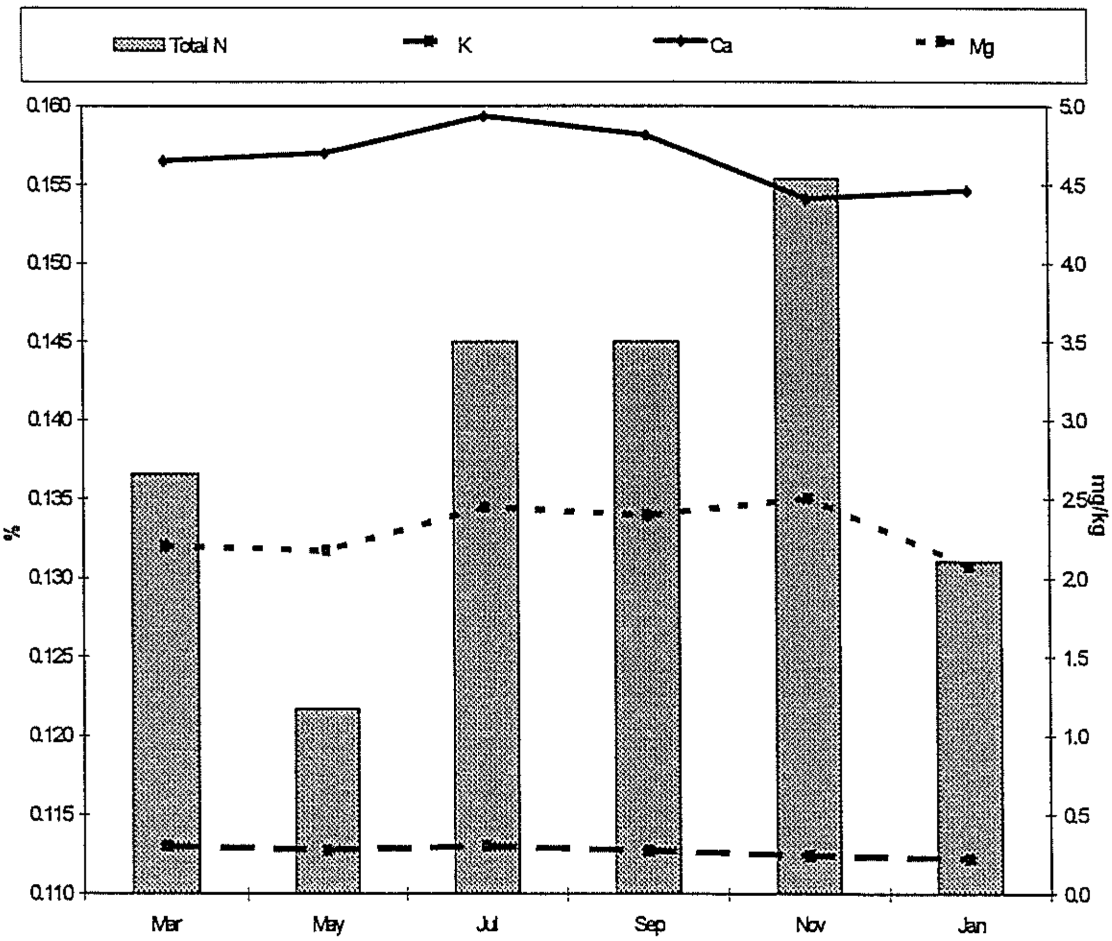


Figure 20. Available total nitrogen, potassium, calcium and magnesium in durian orchard soil.

Table 25. Mean soil nutrient status for two durian orchards around Darwin over 3-4 years. Data are the means of four representative samples taken from each orchard at each sampling period.

			pH	Total N %	P mg/kg	S mg/kg	Zn mg/kg	Fe mg/kg	HCO^{3-} mg/kg	Cl- mg/kg	K cmol[+] /kg	Ca cmol[+] /kg	Mg cmol[+] /kg	CEC cmol[+] /kg	OM %	EC dS/m	C/N	K:Mg	Ca:Mg
Mar	Veg flush	Mean	6.350	0.137	134.917	9.092	6.044	37.917	159.969	13.438	0.302	4.650	2.200	7.152	2.199	0.073	17.279	0.139	2.110
		SD	0.341	0.062	74.879	8.280	5.369	17.050	72.531	22.291	0.247	1.240	0.480	1.726	0.460	0.062	6.141	0.116	0.378
May	End veg flush	Mean	6.333	0.122	139.000	11.900	4.225	135.563	192.500	4.272	0.277	4.699	2.173	7.149	2.266	0.052	20.982	0.140	2.167
		SD	0.355	0.037	118.545	16.231	2.707	380.200	76.457	2.555	0.190	1.728	0.622	2.262	0.431	0.026	9.595	0.114	0.607
Jul	Fl	Mean	6.475	0.145	149.679	11.657	5.446	39.179	221.208	6.438	0.303	4.934	2.446	7.683	2.190	0.070	15.198	0.126	1.998
		SD	0.402	0.034	97.577	9.161	4.542	27.580	75.627	6.399	0.162	1.791	0.517	2.252	0.553	0.036	5.889	0.069	0.539
Sep	Fl/fruit set	Mean	6.682	0.145	200.250	10.904	13.950	41.786	212.125	5.250	0.275	4.813	2.397	7.485	2.040	0.072	14.754	0.123	2.078
		SD	0.316	0.030	134.869	7.952	32.461	19.401	78.888	3.032	0.149	1.300	0.607	1.618	0.281	0.026	4.356	0.077	0.640
Nov	Fruit devt	Mean	6.586	0.155	122.857	9.886	4.068	60.071	209.287	15.693	0.244	4.410	2.504	7.158	2.234	0.068	14.872	0.101	1.747
		SD	0.357	0.033	79.944	8.539	3.824	53.599	130.728	40.186	0.154	1.635	0.545	2.101	0.582	0.043	4.328	0.068	0.460
Jan	Harvest	Mean	6.450	0.131	125.786	12.018	3.311	67.857	180.296	6.125	0.224	4.464	2.074	6.762	2.040	0.055	16.439	0.118	2.160
		SD	0.233	0.043	99.475	17.514	3.248	43.620	47.980	6.036	0.176	1.167	0.424	1.517	0.333	0.039	3.529	0.109	0.431

during this period and the low soil levels in March to May was because of active leaf flushing. The sulphur levels in the soil generally began to decline from July and remained low through to December indicating greater uptake of sulphur during this period because of the sink effect from flowers and fruit development. Sulphur is a very important macroelement in durian as it a constituent of the volatile flavouring compound of durian which is responsible for its distinctive taste, flavour and odour. These compounds were found to be mainly esters, thiols and thioesters such as hydrogen sulphide, methanethiol, ethanethiol, propanethiol, dimethylthioether, diethylthioether and diethyldisulphide (Baldry *et al.*, 1972). They reported that propanethiol and ethyl α-methylbutyrate were predominantly responsible for the odour. Also, sulphur is an important constituent of thiamine (Vitamin B1) in durian fruit (Anon., 1989.)

Conclusion

The 3-4 year monitoring study showed that fluctuations in durian leaf and soil nutrient levels were closely related to seasonal changes in the crop phenology which are governed by fluctuations in weather conditions. All the leaf macroelements and the microelements Zn and B declined or were lower during fruit set and development. Leaf N was also lower during periods of active vegetative flushing. Soil N, P and the bases - K, Ca and Mg also exhibited similar trends - lower during fruit development in October-November and during active leaf flushing from March to May. A comparison of tentative Australian standards with published Malaysian standards revealed that our standards have narrower ranges and are higher for Ca and Mg but marginally lower for K and Zn and lower for Mn.

4.2 Preliminary M-DRIS Norms And Indices For Selected Macronutrients For Durian In The Northern Territory, Australia

The traditional method of leaf nutrient interpretations using critical nutrient concentrations (critical values) or sufficiency range do not account for the dynamic nature of foliar nutrient composition influenced by the physiological stage of crop growth (Angeles *et al.*, 1990), nutrient interactions and interactions between nutrients, dry matter accumulation and metabolic activities. To overcome such limitations the Diagnosis and Recommendation Integrated System (m-DRIS) method was evolved (Beaufils, 1973) and has since undergone considerable modifications. The m-DRIS method in its various modified versions has been successfully developed as a reliable diagnostic tool and applied to many annuals (Beverly 1987, Sumner 1979, Hallmark *et al.*, 1987, 1989, 1991, 1994, Sanchez *et al.*, 1991) and perennial crops (Sumner, 1977, Walworth *et al.*, 1986) including fruit trees. Examples on citrus (Beverly *et al.*, 1984, Beverly 1987); on apples (Beverly and Worley, 1992, Parent and Granger, 1989, and Goh and Malakouti, 1992); on mango (Schaffer *et al.*, 1988); on pineapples (Angeles *et al.*, 1990) and on sweet cherry (Davee *et al*, 1986). The m-DRIS approach minimises the effect of physiological age of tissue enabling. sampling of wider tissue age than is permissible under the critical value method, and it considers nutrient interactions and other factors and computes nutrient balance indices in order of limitations as being negative (deficient), positive as excess and zero as balance (Angeles *et al.*, 1990). Generally it can be applied wherever the crop is grown once established for a particular crop (Beaufils, 1973). The objectives of this study are to derive m-DRIS norms and indices for durian based on a three-four year orchard survey, to determine its seasonal and year to year variation, and to ascertain its diagnostic accuracy in predicting crop nutrient requirement by comparing it with similar m-DRIS norms derived from mean sufficiency levels standards in Malaysia and recently established tentative Australian standards (cf. 4.1; Lim *et al*, 1996c).

Materials and methods:

Two durian orchards in Lambells Lagoon were selected for crop phenology studies and monitoring of crop nutrient demand. The orchards were sampled every two months for more than three years, B. Lemcke's orchard with seven year old trees from March 1992 to

May 1996 and Siah's orchard with 5 year old tree from March 1993 to May 1996. The trees were established on yellow brown earths 26C with flat relief acidic sandy loam soil. Four trees of mixed clones were selected and tagged for sampling in each orchard. The standardised leaf sampling procedure employed together with plant and soil analyses were as previously described (cf 4.1; Lim, *et al.* 1996c).

Modified m-DRIS norms and ratios were computed from the nutrient data collected from the durian orchards using the procedures of Beaufils (1973) and Hallmark *et al.*, (1987) for the m-DRIS. The nutrient imbalance index was also computed to summarise deviations of diagnosed tissues from m-DRIS norms. This was computed by summing up the m-DRIS indices irrespective of signs. (Davee *et al.*, 1986). Mean sufficiency levels for durian in Australia and Malaysia were also used to compute derived m-DRIS norms which were then compared with the survey m-DRIS norms. A constant coefficient of variability of 20 was assigned following Angeles *et al.*, (1990) and Goh and Malakouti, (1992). Also the m-DRIS procedures were than compared for diagnostic accuracy with sufficiency ranges and the derived m-DRIS norms.

Results and discussion

Mean values for nutrient concentration (%) for N, P, K, Ca and Mg for durian leaf and the calculated preliminary m-DRIS norms and ratios based on data from March 1992- May 1996 were compared with standards and similar m-DRIS norms derived from published Malaysian sufficiency range and tentative Australian norms (cf 4.1; Lim *et al.*, 1996c) (Table 26). A comparison of the diagnostic accuracy for the two orchards using the m-DRIS indices from the survey data and standards derived from the Malaysian and tentative Australian sufficiency ranges are shown in Tables 27 and 28 and summarised in Table 29 The nutrient imbalance index at various sampling times for the two orchards is also shown in Tables 27 and 28. A comparison of the diagnostic accuracy based on m-DRIS norms and indices between the survey data and the Malaysian and tentative Australian standards both calculated on a basis of 20% coefficient of variability are shown in Tables 30 and summarised in Table 31. On the whole, the Malaysian standards were marginally higher for N, higher for K and lower for Ca and very much lower for Mg (Table 26).

Table 26. M-DRIS norms calculated from survey data and mean sufficiency levels in Malaysia and Australia based on a cv = 20%.

Forms of expression	Norms from survey data m-DRIS	Norms calculated from Mean Sufficiency Range Malaysia	Mean Sufficiency Range Australia (Nov)
N	1.88	2.05	1.79
P	0.2	0.19	0.2
K	1.6	1.9	1.72
Ca	1.56	1.35	1.5
Mg	1	0.38	0.98
N/P	9.74	10.79	8.95
N/K	1.25	1.08	1.04
N/Ca	1.38	1.52	1.19
N/Mg	2.32	5.39	1.83
P/K	0.13	0.10	0.12
P/Ca	0.15	0.14	0.13
P/Mg	0.25	0.50	0.20
K/Ca	1.23	1.41	1.15
K/Mg	1.95	5.00	1.76
Ca/Mg	2.01	3.55	1.53

The N, P, K leaf levels were comparatively higher in the younger trees in Siah's orchard than in B. Lemcke's orchard (Tables 27 and 28). One possible reason was that the older and higher yielding trees in B. Lemcke's orchard removed more N, P and K. Another reason could be attributed to the more generous and frequent basal application of fertiliser and chicken manure in the Siah's orchard. The leaf Ca and Mg levels are lower in Siah's than in the B. Lemcke's orchard. This again could be attributed to differences in orchard management as both are neighbouring orchards with the same soil type, yellow brown earths.

Generally, N, P and Ca were more limiting during fruit development after September till harvest in January. K became limiting during the latter part of fruit development through harvest and remained limiting till May. Durian removed lots of K and N through their fruit (Ng and Thamboo, 1967). Ng and Thamboo, (1967) reported that the macroelements removed by the durian fruit followed the sequence K>N>Mg>P>Ca equivalent to 27.9>16.1>3.26>2.72>1.99 kg/ha respectively. They also reported that the highest concentration of K, Ca and Mg was found in the fruit skin. The low K levels after harvest to May could be due to dilution effect from leaf flushing. Mg leaf levels were lowest during July ie. during flowering and this coincided with the peak of the cool dry

Table 27. Comparison in diagnostic precision between the m-DRIS indices calculated from the survey data in BL's durian orchard and the sufficiency range standards of Malaysia and Australia.

Month	Phenological Stage	Leaf Composition					DRIS Indices					Nutrient	DRIS order of	Diagnosis by Suff range :	
		N	P	K	Ca	Mg	N	P	K	Ca	Mg	Imbalance Index	requirement	Malaysia	Australia
Mar '92	Vegetative Flush	1.65	0.17	1.06	2.05	1.35	-5.71	-2.03	-17.15	13.93	6.06	-4.90	K>N>P>Mg>Ca	N-, K-, Ca+, Mg+	K-,P-,Ca+,Mg+
May '92	End Vegetative Flush	1.46	0.18	0.95	2.14	0.90	-10.36	1.33	-18.06	16.33	1.56	-9.20	K>N>P>Mg>Ca	N-, K-,Ca+,Mg+	N-, K-,Ca+
Jul '92	Flowering	1.57	0.17	1.03	2.14	0.82	-7.01	-2.32	-13.22	15.24	-0.39	-7.70	K>N>P>Mg>Ca	N-, K-,Ca+,Mg+	N-,K-,P-,Mg-Ca+
Sep '92	Fl. and Fruit Development	1.88	0.20	1.73	1.28	0.74	-0.13	-1.60	3.37	-3.75	-2.22	-4.33	Ca>Mg>P>N>K	Mg+	Mg-,
Nov '92	Fruit Development	1.71	0.18	1.49	1.58	0.80	-5.67	-2.09	0.05	5.07	-1.30	-3.94	N>P>Mg>K>Ca	N-,K-,Mg+	Mg-
Jan '93	Harvest	1.63	0.17	1.02	2.34	1.06	-6.46	-1.98	-16.22	17.06	2.83	-4.77	K>N>P>Mg>Ca	N-, K-, Mg+,Ca+	K-,P-,Ca+
Mar '93	Vegetative Flush	1.89	0.20	1.68	1.46	1.09	-2.56	-0.19	1.02	-1.11	1.87	-0.97	N>Ca>P>K>Mg	Mg+	
May '93	End Vegetative Flush	1.78	0.20	1.24	1.94	1.47	-5.92	2.23	-10.48	8.18	6.29	0.30	K>N>P>Mg>Ca	N-,K-,Mg+, Ca+	K-,Ca+,Mg+
Jul '93	Flowering	1.85	0.23	1.25	2.29	0.33	1.42	-3.46	-3.91	19.23	-48.92	-35.64	Mg>K>P>N>Ca	K-,Ca+	K-,Mg-,Ca+,P+
Sep '93	Fl./Fruit Devt.	1.55	0.23	1.15	2.32	1.33	-14.14	7.35	-16.69	15.32	6.40	-1.76	K>N>Mg>P>Ca	N-, K-,Mg+,Ca+	N-,K-,P+,Ca+,Mg+
Nov '93	Fruit Development	1.73	0.23	1.41	2.01	0.96	-8.62	3.72	-5.74	9.42	1.12	-0.10	N>K>Mg>P>Ca	N-,K-,Ca+,Mg+	K-,P+,Ca+
Jan '94	Harvest	1.61	0.20	1.42	1.21	1.07	-6.31	2.78	-1.32	-2.84	3.12	-4.57	N>Ca>K>P>Mg	N-, K-,Mg+	K-,
Mar '94	Vegetative Flush	1.58	0.18	1.11	2.14	1.03	-8.13	-0.04	-14.23	14.62	2.61	-5.17	K>N>P>Mg>Ca	N-, K-,Ca+,Mg+	K-,Ca+
May '94	End Vegetative Flush	1.70	0.18	1.17	1.86	1.25	-4.72	-0.58	-9.80	8.33	4.36	-2.41	K>N>P>Mg>Ca	N-, K-,Ca+,Mg+	K-,Mg+
Jul '94	Flowering	1.68	0.18	1.17	1.75	1.17	-5.85	0.47	-9.24	7.89	3.75	-2.98	K>N>P>Mg>Ca	N-, K-,Mg+	K-,Mg+
Sep '94	Fl./Fruit Devt	1.90	0.27	1.54	1.40	1.17	-3.95	9.31	-3.83	-6.68	4.24	-0.91	Ca>N>K>Mg>P	K-,Mg+,P+	Mg+,P+
Nov '94	Fruit Development	1.59	0.26	1.72	1.23	1.19	-11.93	8.69	2.12	-5.24	4.38	-1.98	N>Ca>K>Mg>P	N-,P+,Mg+	Mg+,P+
Jan '95	Harvest	1.52	0.19	1.34	1.12	0.95	-6.75	2.30	-1.52	-4.33	1.93	-8.37	N>Ca>K>Mg>P	N-, K-,Mg+	N-,K-
Mar '95	Vegetative Flush	1.56	0.19	1.31	1.67	1.20	-10.05	1.00	-4.59	6.55	3.97	-3.12	N>K>P>Mg>Ca	N-, K-,Mg+	N-,K-,Mg+
May '95	End Vegetative Flush	1.78	0.19	1.26	1.51	1.28	-1.75	0.91	-8.87	1.57	4.71	-3.43	K>N>P>Ca>Mg	N-, K-,Mg+	K-,Mg+
Jul '95	Flowering	1.66	0.18	1.31	1.59	1.13	-5.49	-0.84	-4.41	3.89	3.14	-3.71	N>K>P>Mg>Ca	N-, K-,Mg+	K-
Sep '95	Fl./ Fruit Devt	1.90	0.22	1.57	1.35	0.96	-1.98	1.96	-0.34	-1.96	1.09	-1.23	N>Ca>K>Mg>P	K-,Mg+	
Nov '95	Fruit Development	2.04	0.24	1.92	0.91	1.09	2.62	5.01	5.37	-17.63	3.22	-1.41	Ca>N>Mg>P>K	Mg+	Ca-,N+,P+,K+
Jan '96	Harvest	1.96	0.18	1.31	1.23	1.14	5.04	-1.39	-5.03	-5.04	3.07	-3.35	Ca>K>P>Mg>N	K-,Mg+	K-,Mg+
Mar '96	Vegetative Flush	1.96	0.19	1.30	1.36	1.21	2.17	-0.90	-6.79	-1.70	3.83	-3.39	K>Ca>P>N>Mg	K-,Mg+	K-,Mg+
May '96	End Vegetative Flush	1.67	0.22	1.27	1.62	1.18	-7.53	5.48	-8.01	3.79	4.03	-2.24	K>N>Ca>Mg>P	N-,K-Mg+	K-,Mg+

Overall means N=1.88, P=0.20, K=1.60, Ca=1.56, Mg=1.00. Malaysian published norms (Zakaria, 1994) N=1.8-2.3, P=0.12-0.25, K=1.6-2.2, Ca=0.9-1.8, Mg=0.25-0.5. Australian sufficiency range (Lim et al., 1996) N=1.58-2.0, P=0.18-0.22, K=1.48-1.96, Ca=1.11-1.89, Mg=0.83-1.13. *

Table 28. Comparison in diagnostic precision between the m-DRIS indices calculated from the survey data in Siah's durian orchard and the sufficiency range standards of Malaysia and Australia.

Month	Phenological Stage	Leaf Composition					DRIS Indices					Nutrient	DRIS order of	Diagnosis by Suff range :	
		N	P	K	Ca	Mg	N	P	K	Ca	Mg	Imbalance Index	requirement	Mal	Aus
Mar '93	Vegetative Flush	1.92	0.17	1.74	1.71	1.07	-0.46	-7.26	2.98	3.15	0.75	-0.84	P>N>Mg>K>Ca	Mg+	P-
May '93	End Vegetative Flush	2.09	0.22	1.95	1.31	1.00	1.72	0.72	4.65	-6.19	1.06	1.96	Ca>P>Mg>N>K	Mg+	N+
Jul '93	Flowering	2.15	0.21	1.64	1.92	0.55	5.86	-7.14	4.07	9.94	-33.62	-20.89	Mg>P>K>N>Ca	Ca+,Mg+	Mg-,N+Ca+
Sep '93	Fl. and Fruit Development	1.73	0.18	1.56	2.04	1.09	-7.18	-4.16	-0.58	9.95	1.62	-0.35	N>P>K>Mg>Ca	N-, K-,Mg+,Ca+	Ca+
Nov '93	Fruit Development	1.76	0.17	1.64	2.02	0.87	-6.04	-6.78	1.26	10.37	-1.05	-2.24	P>N>Mg>K>Ca	N-, Ca+,Mg+	P-,Ca+
Jan '94	Harvest	2.07	0.18	1.89	1.23	0.99	3.73	-4.80	5.93	-6.37	0.79	-0.72	Ca>P>Mg>N>K	Mg+	N+
Mar '94	Vegetative Flush	2.01	0.16	1.77	1.79	1.03	-0.66	-8.93	3.50	6.51	0.36	0.78	P>N>Mg>K>Ca	Mg+	P-,N+
May '94	End Vegetative Flush	2.10	0.18	2.09	1.19	0.90	4.15	-6.45	9.05	-6.95	-0.63	-0.83	Ca>P>Mg>N>K	Mg+	N+,K+
Jul '94	Flowering	2.23	0.24	2.10	1.46	0.86	2.37	0.43	5.35	-3.51	-1.13	3.51	Ca>Mg>P>N>K	Mg+	N+,K+
Sep '94	Fl. and Fruit Development	2.01	0.26	2.62	0.99	1.00	-2.68	4.54	14.28	-16.37	1.31	1.08	Ca>N>Mg>P>K	K+,P+,Mg+	Ca-,N+,P+K+
Nov '94	Fruit Development	1.61	0.17	2.18	1.21	0.98	-8.21	-5.43	13.61	-4.70	0.76	-3.97	N>P>Ca>Mg>K	N-,Mg+	P-,K+
Jan '95	Harvest	2.15	0.20	2.21	0.68	0.73	8.39	-2.53	14.28	-26.33	-2.18	-8.37	Ca>P>Mg>N>K	Ca-,Mg+	Ca-, N+,Mg-,K+
Mar '95	Vegetative Flush	2.12	0.20	2.13	1.08	0.69	4.67	-3.60	10.15	-10.61	-4.06	-3.45	Ca>Mg>P>N>K	Mg+	Ca-, N+,Mg-,K+
May '95	End Vegetative Flush	2.32	0.20	1.71	1.49	0.81	6.88	-3.64	0.37	-1.08	-1.91	0.62	P>Mg>Ca>K>N	N+,Mg+	Mg-,N+,K+
Jul '95	Flowering	2.05	0.20	1.99	1.56	0.86	0.91	-4.52	6.11	-0.35	-1.49	0.66	P>Mg>Ca>N>K	Mg+	N+,K+
Sep '95	Fl. and Fruit Development	2.14	0.24	2.09	1.01	0.78	3.37	1.68	7.70	-12.55	-1.58	-1.38	Ca>Mg>P>N>K	Mg+	Ca-, Mg-,P+,K+,Mg+
Nov '95	Fruit Development	2.09	0.19	1.93	1.40	1.17	2.90	-3.30	3.78	-3.93	2.49	1.94	Ca>P>Mg>N>K	Mg+	N+,Mg+
Jan '96	Harvest	2.38	0.19	2.01	1.14	0.95	9.27	-5.12	5.94	-10.03	0.31	0.37	Ca>P>Mg>K>N	N+,Mg+	N+,K+
Mar '96	Vegetative Flush	2.39	0.16	1.73	1.33	0.93	12.20	-11.22	2.90	-4.47	-0.56	-1.15	P>Ca>Mg>K>N	N+,Mg+	P-,N+
May '96	End Vegetative Flush	2.27	0.21	1.71	1.76	0.86	3.14	-2.09	0.11	2.99	-1.25	2.90	P>Mg>K>Ca>N	N+,Mg+	N+

*Overall means N=1.88, P=0.20, K=1.60, Ca=1.56, Mg=1.00. Malaysian published norms (Zakaria, 1994) N=1.8-2.3, P=0.12-0.25, K=1.6-2.2, Ca=0.9-1.8, Mg=0.25-0.5. Australian sufficiency range (Lim et al., 1996) N=1.58-2.0, P=0.18-0.22, K=1.48-1.96, Ca=1.11-1.89, Mg=0.83-1.13.

season where leaf metabolic activities were low.

For durian m-DRIS norms defined seasonally or yearly is more preferable because of seasonal and yearly variations. Highest nutrient imbalance periods were observed during flowering especially in July 1993 in both orchards as indicated by the higher Nutrient Imbalance Index (NII) values (Tables 27 & 28) There were closer agreement with the m-DRIS from survey and from the Australian mean sufficiency norm levels than the m-DRIS derived from the mean sufficiency levels from Malaysia (Tables 27 & 28). The m-DRIS approach was able to detect more cases of limiting nutrient requirement than the sufficiency range approach. There was good agreement between the m-DRIS values from the survey and that calculated from the Australian mean sufficiency range but poor agreements between the Malaysian mean sufficiency range and the calculated m-DRIS. The N and K Malaysian norms were comparatively higher and the Ca and Mg norms were too low.. From Table 29 it can be seen that there was closer agreement between the m-DRIS survey data and the Australian sufficiency norms than between the Malaysian standards. There were higher number of mismatches with the Malaysian norms both for limiting nutrients and nutrients in excess. The lower discordance between the m-DRIS survey diagnosis and the Malaysian norms could be due to the wider range in the latter, the higher values for the N and K , the lower value for Ca and extremely low level for Mg. Also, the Malaysian norms were not able to diagnose limiting requirement for Ca and Mg because of their lower range values for these two elements and the range for P was too wide.

Table 29. Matching diagnoses between the m-DRIS survey data and the Malaysian and Australian sufficiency range standards.

Orchard	Mean No. diagnoses	Mean cases of m-DRIS diagnoses as		Percent cases of Malaysian sufficiency range diagnoses as			Percent cases of Australian sufficiency range diagnoses as		
		deficient (-ve index)	excess (+ve index)	deficient	excess	mismatch	deficient	excess	mismatch
Siah	100	49	51	8.16	33.33	11.00	22.40	50.98	2.00
BL	130	71	59	49.30	28.81	6.15	45.07	47.46	0.77

Comparing the Malaysian and tentative Australian standards with the survey data using the m-DRIS approach (Tables 30 & 31) it can be seen that the trend was similar. There was closer agreement between the survey m-DRIS standards and the Australian standards than with the Malaysian norms. The Malaysian m-DRIS norms gave poorer

Table 30. Comparative m-DRIS indices and m-DRIS order of requirement of the survey norms with the Malaysian and Australian sufficiency norms, both of which are computed on a cv = 20% basis.

Orchard	Month	Phenological stage	m-DRIS indices (survey norms)					m-DRIS indices (Malaysian sufficiency norms)					m-DRIS indices (Australian sufficiency norms)					m-DRIS order of requirement survey norms	m-DRIS order of requirement Malaysian sufficiency norms	m-DRIS order of requirement Australian sufficiency norms
			N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg			
BL	Mar	Vegetative Flush	-4.86	-0.27	-8.35	6.46	3.67	-42.48	25.57	-68.23	16.46	67.89	-11.36	-1.60	-30.77	29.49	8.71	K>N>P>Mg>Ca	K>N>Ca>P>Mg	K>N>P>Mg>Ca
	May	End Vegetative Flush	-6.06	1.88	-11.04	7.64	4.19	-45.88	28.53	-78.12	20.24	74.20	-13.90	1.32	-37.42	33.33	11.10	K>N>P>Mg>Ca	K>N>Ca>P>Mg	K>N>P>Mg>Ca
	Jul	Flowering	-4.24	-1.54	-7.69	11.56	-10.61	-33.91	13.96	-57.31	38.63	33.17	-0.39	-16.74	-22.73	61.84	-41.15	Mg>K>N>P>Ca	K>N>P>Mg>Ca	Mg>K>P>N>Ca
	Sep	Fl./ Fruit Devt	-5.05	4.25	-4.37	0.73	2.38	-37.40	27.30	-49.96	1.37	60.48	-8.19	3.60	-19.08	13.57	6.16	N>K>Ca>Mg>P	K>N>Ca>P>Mg	K>N>P>Mg>Ca
	Nov	Fruit Devt	-5.90	3.83	0.45	-2.10	1.85	-35.78	25.37	-31.45	-10.31	54.88	-9.24	3.36	-6.87	5.25	4.18	N>Ca>K>Mg>P	N>K>Ca>P>Mg	N>K>P>Mg>Ca
	Jan	Harvest	-3.62	0.43	-6.02	1.21	2.74	-35.55	24.42	-55.34	1.02	62.95	-6.82	-0.31	-23.04	15.37	6.79	K>N>P>Ca>Mg	K>N>Ca>P>Mg	K>N>P>Mg>Ca
Siah	Mar	Vegetative Flush	3.94	-7.75	4.88	-1.36	-0.88	-16.87	12.37	-19.26	-4.08	31.78	5.48	-11.87	2.54	8.10	-7.52	P>Ca>Mg>N>K	K>N>Ca>P>Mg	P>Mg>K>N>Ca
	May	End Vegetative Flush	3.97	-2.87	3.54	-2.81	-0.68	-14.40	14.09	-18.37	-7.82	33.08	7.89	-5.78	1.24	2.57	-6.44	P>Ca>Mg>K>N	K>N>Ca>P>Mg	Mg>P>K>Ca>N
	Jul	Flowering	3.05	-3.74	5.18	2.03	-12.08	-16.29	7.14	-13.10	12.77	13.32	14.80	-18.71	10.23	28.91	-45.71	Mg>P>Ca>N>K	N>K>P>Ca>Mg	Mg>P>K>N>Ca
	Sep	Fl. and Fruit Devel.	-2.16	0.69	7.14	-6.32	0.45	-24.50	20.36	-12.29	-21.16	42.85	-0.78	-0.97	8.18	-6.34	-1.58	Ca>N>Mg>P>K	N>Ca>K>P>Mg	Ca>Mg>P>N>K
	Nov	Fruit Development	-3.78	-5.17	6.22	0.58	0.73	-34.93	15.47	-19.24	1.83	40.72	-8.26	-8.46	2.72	13.95	-2.23	P>N>Ca>Mg>K	N>K>Ca>P>Mg	P>N>Mg>K>Ca
	Jan	Harvest	7.13	-4.15	8.72	-14.24	-0.36	-5.67	17.06	-6.41	-42.51	39.22	15.40	-4.71	13.11	-25.81	-4.11	Ca>P>Mg>N>K	Ca>K>N>P>Mg	Ca>P>Mg>K>N
Both	Mar	Vegetative Flush	-0.95	-3.60	-2.47	2.99	1.65	-31.10	19.70	-46.47	7.33	51.84	-3.88	-6.17	-15.97	19.99	1.50	P>K>N>Mg>Ca	K>N>Ca>P>Mg	K>P>N>Mg>Ca
	May	End Vegetative Flush	-1.60	-0.23	-4.56	3.00	2.03	-31.89	22.11	-51.56	7.77	55.92	-4.22	-1.83	-20.24	19.66	3.30	K>N>P>Mg>Ca	K>N>Ca>P>Mg	K>N>P>Mg>Ca
	Jul	Flowering	-1.11	-2.48	-2.18	7.48	-11.24	-26.35	11.03	-38.36	27.54	24.66	6.12	-17.59	-8.61	47.73	-43.11	Mg>P>K>N>Ca	K>N>P>Mg>Ca	Mg>P>K>N>Ca
	Sep	Fl. and Fruit Devel.	-3.81	2.73	0.56	-2.29	1.55	-31.87	24.32	-33.82	-8.29	52.92	-5.01	1.64	-7.40	5.04	2.84	N>Ca>K>Mg>P	K>N>Ca>P>Mg	K>N>P>Mg>Ca
	Nov	Fruit Development	-4.99	-0.03	2.92	-0.95	1.37	-35.41	21.13	-26.22	-5.11	48.81	-8.82	-1.71	-2.76	8.98	1.43	N>Ca>P>Mg>K	N>K>Ca>P>Mg	N>K>P>Mg>Ca
	Jan	Harvest	0.99	-1.53	0.30	-5.41	1.41	-22.75	21.27	-34.37	-17.64	52.78	2.70	-2.20	-7.55	-2.28	2.12	Ca>P>K>N>Mg	K>N>Ca>P>Mg	K>Ca>P>Mg>N

Table 31. Percent matching diagnoses of limiting nutrients and nutrients in excess between the m-DRIS indices calculated from the 1992-96 leaf nutrientsurvey data and the tentative Australian norms and published Malaysian norms, both based on a cv = 20%.

	Australian norms				Malaysian norms			
	Limiting		Excess		Limiting		Excess	
	In accord	Disaccord	In accord	Disaccord	In accord	Disaccord	In accord	Disaccord
BL	73.33	26.67	60.00	40.00	46.67	53.33	13.33	86.67
Siah	60.00	40.00	26.67	73.33	6.67	93.33	0.00	100.00
Both	58.82	41.18	53.85	46.15	17.65	76.47	13.33	86.67

diagnoses of both nutrients in excess and those which were limiting.

M-DRIS and its modified approaches have more advantages over the critical value or sufficiency approaches for nutrient diagnosis. A critical value is the concentration of nutrient in a particular plant part sampled at a particular growth stage at which a 5-10% reduction in yield is observed. The requirement that plant tissues be sampled at a particular stage is not always convenient to meet (Sumner, 1978). Sufficiency ranges have been proposed such that the lower limit represents roughly the critical level and the upper limit is set at a value corresponding to unusually high concentration. Contrary to giving flexibility to diagnoses they lead to decrease diagnostic precision because the limits are far too wide (Sumner, 1978). Beaufil (1973) originally recommended the use of medium yielding sub population for deriving diagnostic norms but Beverly (1987) found collecting yield data to be unnecessary which is another big advantage with the m-DRIS approach.

In conclusion, the m-DRIS norms were able to detect more limiting nutrients than the sufficiency range approach. m-DRIS norms should take into account seasonal or yearly variations between trees There was closer agreement with the Australian than with Malaysian sufficiency range norms. There is a need to develop more m-DRIS norms for the other elements as well.

4.3 Nutrient Interaction In Durian Leaf, Soil And Between Soil And Leaf Nutrients.

Nutrient relationships in plant tissues and soil involves complex reciprocative effects of pairs of cations, anions or between cation and anion. Such interactive effects are manifested in the form of antagonism and synergism (Prevot and Ollagnier, 1961). Antagonism occurs when the uptake of one element depresses the supply of another. One effect commonly reported is the decrease of leaf P resulting from an increase in leaf N (Burr, 1961, Reitz and Koo, 1960). Another example occurs commonly among the base elements K, Ca and Mg (Embleton *et al.*, 1958). Synergism is the opposite effect wherein the increase of one element results in the simultaneous increase in another. Examples are the simultaneous increase in tissues of Na and K from applied K (Prevot and Ollagnier, 1961); increases in Ca and Mg from applied Ca (Embleton *et al.*, 1958) and increases in N and Mg from applied N (Nerf *et al.*, 1958).

The study of such relationships can enhance our understanding of crop nutrient requirement and nutrient application. In this study an attempt is made to study such interactions and to determine how accurately can soil test results predict leaf nutrient status in durian.

Materials and methods

Two durian orchards in Lambells Lagoon were selected for crop nutrient requirement monitoring. The orchards were sampled every two months for more than three years, B. Lemcke's orchard with seven year old trees from March 1992 to May 1996 and Siah's orchard with five year old trees from March 1993 to May 1996. The trees were established on yellow brown earths 26C with flat relief acidic sandy loam soil. Four trees of mixed clones were selected and tagged for sampling in each orchard. The standardised leaf sampling procedure employed together with plant and soil analyses were as previously described (cf. 4.1; Lim, *et al.*, 1996b).

Pearson Product Moment Correlation Coefficients determinations and regression analyses were performed on the data of leaf and soil nutrient levels collected. A search for the best prediction model was conducted using Sigmastat statistical software for

Windows [(R)]. Regression models were processed on individual subsets of leaf nutrients, soil nutrients and leaf:soil nutrients. All regressions models were evaluated on the basis of the coefficient of determination (R^2) and F values.

Results and discussion

Leaf N

From Table 32 it can be seen that there was highly significant moderate positive correlation between leaf N and leaf K, and Leaf N and soil K in durian. This indicated that durian leaf N increased with an increase in leaf K. The regression of leaf K on leaf N and vice-versa were highly significant with R^2= 0.44 and could be expressed by the equations $N=2.32- 1.98e^{-K}$ and $K=2.68-6.76e^{-N}$ (Table 33).

The negative correlation between leaf N and leaf Ca was highly significant indicating that leaf N was depressed by an increase in leaf Ca and vice-versa (Table 32). The regression of leaf N on leaf Ca and vice-versa were also highly significant but with lower R^2 values of 0.254 and 0.245. These regressions (Table 33) could be expressed by the equations $N=2.04-0.2\ Ca \ln Ca$ and $Ca=0.68+5.5e^{-N}$.

The correlations between leaf N and leaf P, leaf Mg, leaf S, soil P and soil Ca were also significant but weaker (Table 32). The regression of soil K on leaf N was also significant with a regression coefficient of 0.231 and could be characterised by the expression leaf N= 2.18-5.26 ln soil K (Table 33). The impact of soil P and soil Ca on leaf N were lower with $R^2 < 0.2$ although significant (Table 34).

Leaf P

The correlations between leaf P and leaf K, leaf P and leaf S were moderate but highly significant R=+0.4 and +0.5 respectively (Table 32) indicating leaf P increased with increasing leaf K and leaf S levels. However, the regression of leaf S on leaf P was higher as indicated by the higher R^2 value and F value (Table 33) and could be defined by the expression $P= 0.15+1.43S^2$. Leaf P was depressed by high levels of leaf Ca as indicated by the highly significant negative correlation R= -0.356. The influence of leaf K and leaf Ca on leaf P was weaker. The data in Table 32 also indicated that leaf P was not affected by soil macronutrient status.

Table 32. Pearson product moment correlation coefficients of durian leaf and soil macronutrients

	Leaf N	Leaf P	Leaf K	Leaf Ca	Leaf Mg	Leaf S	Soil TN	Soil P	Soil K	Soil Ca	Soil Mg	Soil S
Leaf N	-	+0.294***	+0.664***	-0.526 ***	-0.338 ***	+0.305***	+0.085ns	+0.301***	+0.395***	+0.391***	+0.049 ns	+0.0694 ns
Leaf P		-	+0.405***	-0.354 ***	-0.205 **	+0.479 ***	-0.074 ns	+0.078ns	-0.095 ns	-0.09 ns	-0.0047 ns	-0.0248 ns
Leaf K			-	-0.733 ***	-0.368 ***	+0.625 ***	+0.147ns	+0.340***	+0.397***	+0.378***	+0.130 ns	0.120 ns
Leaf Ca				-	+0.261**	-0.572 ***	-0.0008 ns	-0.094 ns	-0.161 *	-0.159 *	+0.0005 ns	-0.1499 *
Leaf Mg					-	-0.014ns	-0.0067 ns	-0.205 **	-0.177 *	-0.228 **	+0.027 ns	-0.002 ns
Leaf S						-	-0.100 ns	+0.144 ns	+0.114 ns	+0.0156 ns	+0.024 ns	+0.062 ns
Soil TN							-	+0.247 **	+0.147 ns	+0.378 ***	+0.365 ***	+0.038 ns
Soil P								-	+0.411 ***	+0.582 ***	+0.0745 ns	+0.191 *
Soil K									-	+0.364 ***	+0.0566 ns	0.396 ***
Soil Ca										-	0.6 ***	+0.0584 ns
Soil Mg											-	-0.0696 ns
Soil S												-

n > 150 P > 0.05 = ns p < 0.05 = * p < 0.01 = ** p < 0.001 = ***

Table 33. Regression analyses of durian leaf nutrient interactions.

Interaction	Variables	Mean	SD	R^2	F value	Regression Equation	Regression Equation
N & K	N(x)	1.882	0.3	0.443	141.63**	$y=a+be^{-x}$	$K=2.68-6.76e^{-N}$
	K(y)	1.607	0.465				
K & N	K(x)	1.607	0.465	0.44	139.97**	$y=a+be^{-x}$	$N=2.32-1.98e^{-K}$
	N(y)	1.862	0.3				
N & P	N(x)	1.882	0.3	0.09	17.42 NS		
	P(y)	0.199	0.042				
P & N	P(x)	0.199	0.042	0.08	16.02 NS		
	N(y)	1.882	0.3				
N & Ca	N(x)	1.882	0.3	0.254	60.74	$y=a+be^{-x}$	$Ca=0.675+5.5e^{-N}$
	Ca(y)	1.55	0.499				
Ca & N	Ca(x)	1.549	0.450	0.245	57.77*	$y=a+bx\ln x$	$N=2.035-0.202Ca\ln Ca$
	N(y)	1.882	0.3				
N & Mg	N(x)	1.882	0.3	0.121	25.46*	$y=a+b/x\ x^{1/2}$	$Mg=0.59+1.0/N\ N^{1/2}$
	Mg(y)	0.991	0.28				
Mg & N	Mg(x)	0.991	0.28	0.152	31.83*	$y=a+bx\ln x$	$N=1.9-0.44Mg\ln Mg$
	N(y)	1.882	0.3				
N & S	N(x)	1.882	0.3	0.099.	19.63 NS		
	S(y)	0.183	0.0373				
S & N	S(x)	0.183	0.037	0.084	16.31 NS		
	N(y)	1.882	0.3				
K & P	K(x)	1.607	0.465	0.147	30.69*	$y=a+b/x^{1/2}$	$P=0.3-0.123/K^{1/2}$
	P(y)	0.199	0.042				
P & K	P(x)	0.199	0.042	0.149	31.2*	$y=a+b/x^{1/2}$	$K=3.55-0.856/P^{1/2}$
	K(y)	1.607	0.465				
Mg & P	Mg(x)	0.9909	0.28	0.031	5.712NS		
	P(y)	0.1989	0.042				
P & Mg	P(x)	0.1989	0.042	0.037	6.813 NS		
	Mg(y)	0.9909	0.28				
S & P	S(x)	0.183	0.037	0.234	54.245*	$y=a+bx^2$	$P=0.15+1.427S^2$
	P(y)	0.199	0.042				
P & S	P(x)	0.199	0.042	0.245	57.77*	$y=a+b(\ln x)$	$S=0.267-0.031\ (\ln P)^2$
	S(y)	0.183	0.037				
Ca & P	Ca(x)	1.5942	0.499	0.141	29.092*	$y=a+b/x\ x^{1/2}$	$P=0.171+0.043/Ca\ Ca^{1/2}$
	P(y)	0.199	0.042				
P & Ca	P(x)	0.199	0.042	0.114	22.94*	$y=a+b/x(x)^{1/2}$	$Ca=0.91+0.054/P\ (P)^{1/2}$
	Ca(y)	1.549	0.499				
K & Ca	K(x)	1.607	0.465	0.544	212.03**	$y=a+b/x^{1/2}$	$Ca=-0.743+2.81/K^{1/2}$
	Ca((y)	1.549	0.499				
Ca & K	Ca(x)	1.549	0.499	0.513	187.54**	$y=a+bx^{1/2}\ln x$	$K=1.977-0.688Ca^{1/2}\ln Ca$
	K(y)	1.607	0.465				
K & S	K(x)	1.607	0.465	0.379	108.788**	$y=a+bx/x^{1/2}$	$S=0.129+0.0257K/K^{1/2}$
	S(y)	0.183	0.037				
S & K	S(x)	0.183	0.037	0.385	111.59**	$y=a+bx^2\ln x$	$K=0.576-18S^2\ln S$
	K(y)	1.607	0.465				
K & Mg	K(x)	1.607	0.465	0.136	28.044*	$y=a+be^{-x}$	$Mg=0.763+1.025\ e^{-K}$
	Mg(y)	0.991	0.280				
Mg & K	Mg(x)	0.991	0.280	0.202	45.16*	$y=a+bx^2\ln x$	$K=1.667-0.589\ Mg^2\ln Mg$
	K(y)	1.607	0.465				
Mg & Ca	Mg (x)	0.991	0.28	0.269	32.63	$y=a+b\ln x+c\exp^{-x}$	$Ca=5.89-3.27\ln Mg-11.82e^{-Mg}$
	Ca(y)	1.549	0.499				
Ca & Mg	Ca(x)	1.549	0.499	0.084	16.42 NS		
	Mg(y)	0.991	0.28				
S & Ca	S(x)	0.1834	0.037	0.32	83.86*	$y=a+bx^2\ln x$	$Ca=2.558+17.601S^2\ln S$
	Ca(y)	1.5493	0499				
Ca & S	Ca(x)	1.549	0.499	0.32	83.61*	$y=a+bx^{1/2}$	$S=0.312-0.105\ Ca^{1/2}$
	S(y)	0.183	0.037				
Mg & S	Mg(x)	0.991	0.28	0.034	3.127NS		
	S(y)	0.183	0.038				
S & Mg	S(x)	0.183	0.037	0.006	1.08 NS		
	Mg(y)	0.991	0.28				
N & Zn	N(x)	1.877	0.300	0.101	20.433*	$Y=a+b\ln x/x$	$Zn=-9.92+81.03\ln N/N$
	Zn(y)	16.291	9.306				
Ca & B	Ca(x)	1.56	0.504	0.286	66.673*	$Y=a+be^{-x}$	$B=48.34-39.57e^{-Ca}$
	B(y)	38.995	8.431				
Zn & B	Zn(x)	16.291	9.306	0.160	34.657*	$y=a+bx^2$	$B=36.64+0.007(Zn)^2$
	B(y)	38.995	8.431				

<u>Leaf K</u>

As discussed above there were moderate positive but highly significant correlation between leaf K with leaf N and leaf P, and also between leaf K and leaf S. The increase in leaf K with increase in leaf S could be governed by the expressions leaf K =0.58-18S^2 ln S and leaf S = 0.13+0.026 K/K $^{1/2}$ with regression coefficient values greater than 0.4 (Table 33). The negative correlation between leaf K and leaf Ca was highly significant and stronger than with leaf Mg.(Table 32). Leaf K declined with increasing leaf Ca and this relationship could be characterised by the highly significant $R^2 > 0.5$ and had the following equations: Leaf K = 1.98-0.69 Ca $^{1/2}$ ln Ca and leaf Ca = -0.743+2.81 K $^{1/2}$ (Table 33).

Leaf K appeared to be influenced synergistically in decreasing degree by soil K, soil P and soil Ca as indicated by the magnitudes of the R^2 and F values (Table 34). Increases in soil K increased leaf K levels. The effect of soil Kon leaf K could be expressed by the equation leaf K =0.104+0.34ln soil K. This agrees with the observation of Prevot and Ollagnier (1961);who reported simultaneous increases in tissues of Na and K from applied K.

Table 34. Regression analyses of durian leaf and soil nutrient interactions.

Interaction	Mean	SD	R^2	F value	Regression equation	Regression equation
Soil P & Leaf N	143.7 1.88	104.28 0.3	0.108	21.56	y=a+bx lnx	Leaf N=1.769+ 0.00015 Soil P ln Soil P
Soil K & Leaf N	107.37 1.88	72.94 0.30	0.231	53.31*	y=a+b lnx	Leaf N=2.18-5.26 ln Soil K
Soil Ca & Leaf N	936.59 1.88	298.37 0.3	0.177	38.34	y=a+bx^2 lnx	Leaf N=1.69+0.00002 SoilCa^2 ln Soil Ca
Soil P & Leaf K	143.7 1.61	104.28 0.465	0.137	28.434	y=a+bx lnx	Leaf K=1.41+0.0002 Soil P ln Soil P
Soil K & Leaf K	107.37 1.607	72.94 0.465	0.216	48.97*	y=a+b lnx	Leaf K= 0.104+0.336 ln Soil K
Soil Ca & Leaf K	936.59 1.607	298.37 0.465	0.121	24.593	y=a+bxsqrtx	Leaf K=10255+0.0001 Soil Ca ln Soil Ca

Leaf Ca

As seen above there were highly significant negative correlations between leaf Ca and leaf N, leaf P, leaf K and also leaf S (R=-0.57) (Table 32). Leaf Ca was depressed by high leaf S and was governed by the equations leaf Ca = 2.6+17.6 S^2 ln S and leaf S =0.31-0.1 Ca $^{1/2}$ (Table 33). Positive correlations were found between leaf Ca with leaf Mg ie. leaf Ca increased with leaf Mg. Soil Ca had a negative relationship with leaf Ca but the correlation was low although significant (Table 32). In contrast, Embleton *et al.*, (1958) reported increases in leaf Ca and Mg in Fuerte avocado from applied Ca.

Leaf Mg

As discussed above leaf Mg had a positive significant correlation with leaf Ca but significant negative correlations with leaf N, leaf P, and leaf K (Table 32). Additionally there were significant but very low negative correlations between leaf Mg and soil P and soil Ca status. High soil Ca tended to lower leaf Mg as indicated by the low but significant correlation of R=-0.228.

Leaf S

As discussed above there were highly significant moderate to low positive correlation with leaf N, leaf P leaf K but negative correlation with leaf Ca. There was no correlation between leaf S with any soil macronutrient (Table 32).

Nutrient interaction in durian soil

From Table 32 soil Ca status was highly significantly synergistic to soil Mg with R= +0.6 and their relationship could be defined by the expressions soil Ca = 3190+738.8 ln Mg with R^2 = 0.389** and soil Mg = 149+0.14 Ca with R^2 = 0.364** (Table 35). Thus liming can increase the availability of Mg in the soil to a certain extent.

There was also positive and highly significant correlation between soil Ca and soil P with R= 0.58. This relationship was characterised by the regression equation soil Ca = 456.5+4.27 soil $P^{1/2}$ with R^2= 0.3 (Table 35).

Another significant relationship was between soil P and soil K with a correlation coefficient of R=0.2 and the regression equations of soil K = 4501+11.1soil P $^{1/2}$ ln soil P and soil P=202.6+77.45 ln soil K (Table 35).

The significant low to moderate correlation and regression relationships among leaf nutrients, soil nutrients and between leaf and soil nutrients indicated that interaction

Table 35. Regression analyses of durian soil nutrient interactions.

Inter-action	Variable	Mean	SD	R^2	F value	Regression equation	Regression equation
N & P	N(x)	0.138	0.0426	0.358	32.763	y=a+b/(1+(x/c)^d)	P=18325248-18325077
	P(y)	143.7	104.28		*		/(1+(N/0.513)^47.93)
	P(x)	143.7	104.28	0.074	14.263		
	N(y)	0.138	0.0426		NS		
N & Ca	N(x)	0.138	0.042	0.152	31.81*	y=a+b/x	Ca=1252-39.28/N
	Ca(y)	936.59	293.37				
	Ca(x)	936.59	298.37	0.116	23.34*	y=a+b sqrt x ln x	N=0.071+0.00033 sqrt
	N(y)	0.138	0.042				Ca ln Ca
P & K	P(x)	143.7	104.28	0.190	41.62	y=a+b sqrt x ln x	K=45.13+1.11 sqrt P
	K(y)	107.37	72.94				ln P
	P(y)	143.7	104.28	0.228	52.59*	y=a+b ln x	P=202.6+77.45 ln K
	K(x)	107.37	72.94				
P & Ca	P(x)	143.7	104.28	0.352	96.70*	y=a+b sqrt x	Ca=456.52+42.67 sqrt
	Ca(y)	936.59	298.37				P
	P(y)	143.7	104.28	0.325	85.55*	y=a+bx sqrt x	P=14.69+0.004 Ca sqrt
	Ca(x)	936.59	298.37				Ca
K & Ca	K(x)	107.37	72.94	0.17	36.32*	y=a+b ln x	Ca=82.53+191 ln K
	Ca(y)	936.59	298.37				
	K(y)	107.37	72.94	0.12	24.14*	y=a+b sqrt x ln x	K=-9.65+0.57 sqrt Ca
	Ca(x)	936.59	298.37				ln Ca
K & S	K(x)	107.37	72.94	0.146	30.41*	y=a+bx	S=4.17+0.063K
	S(y)	10.95	12.06				
	K(y)	107.37	72.94	0.15	31.45*	y=a+b sqrt x ln x	K=75.39+4.43 sqrt S
	S(x)	10.95	12.06				ln S
Ca & Mg	Mg(x)	275.07	66.63	0.389	113.25	y=a+b ln x	Ca=3190.72+738.77 ln
	Ca(y)	936.59	298.37		**		Mg
	Mg(y)	275.07	66.63	0.364	101.68	y=a+bx	Mg=148.95+0.135Ca
	Ca(x)	936.59	298.37		**		

between nutrients was more complex and dynamic and involved more multiple interaction than two factor interactions. Also the significant but weak relationships (R= 0.2-0.4) between foliar and soil nutrients suggested that the utility of soil tests to predict leaf nutrient status in durian was rather limited.

CHAPTER 5

5.1 Precocity Studies

Durian has a long gestation period. For seedling trees a juvenile period of 10-12 years is not uncommon. Whilst for vegetatively propagated trees 6-8 years period is the norm. The long gestation period is a major deterrent to potential growers because of the lengthy lag time for realisation of returns to investment and the accompanying risk factors involved in production. There are many ways to obviate the long juvenile period and enhance precocity such as by using chemical growth hormones or by cultural manipulation using various forms of grafting onto precocious or dwarfing rootstocks, interstocks and multiple rootstocks. Albeit such studies are long term and results will come to bear only in 4- 6 years. It is crucial that a diverse gene-pool of *Durio* species be introduced and evaluated for imparting precocity of bearing. A scan of literature reveals that several *Durio* species are dwarf in stature and some have a tendency to bear early. For many tropical fruit species there is a close relationship between dwarfness and early bearing precocity. *D griffithii* had been reported to flower when they were only 3 metres high and *D. kutejensis* 4-5 metres high. *D. acutifolius* is a small tree that flowered almost year round (Kostermans, 1958). Other dwarfing or small tree species include *D. acutifolius, D. grandiflorus, D griffithii, D. kutejensis, D. pinangianus, D macrolepis, D. malaccensis, D testudinarum*, (Table 36) and *D. macrantha* (Kostermans, 1992).

To attain the objective of advancing precocity we adopted the approach of using multiple rootstock of precocious or dwarf *Durio* species and to top-work with mature scion from a good quality bearing durian tree. However, since we could not obtain seeds of any of the dwarf or precocious species we used multiple rootstocks of *D. zibethinus* instead in our study. We attempted to compare the precocious growth and yield performance of seedling trees, single grafted trees and double rootstock grafted trees.

Materials and methods

To prepare the seedlings we had to introduce seeds from Malaysia. To prepare double rootstock trees we planted two seeds in a polybag and allowed them to germinate. After two months the young seedlings were approach-grafted. Subsequently one seedling was cut off (two months later) and the remaining seedling with two rootstocks was top-worked by Fokert budding (Plate 4a) or by cleft grafting with a mature bud from a high

Table 36. *Durio* species categorised as small and medium-sized trees based on height when mature in their natural habitat.

Durio species	Small tree (< 25 metres)	Medium sized tree (25-33 metres)
D. acutifolius	12-28 (b)	up to 30 (a)
D affinis		up to 30 (a, b), 33 (d)
D. excelsus		up to 30(b)
D. grandiflorus	up to 20 (b)	
D. griffithii	small to medium (d)	up to 30 (b)
D. kutejensis	up to 24 (b)	
D. lissocarpus		28 (b)
D. macrantha	10 (c)	
D. macrolepis	small (b)	
D. macrophyllus	small to medium (d)	up to 30 (b)
D. malaccensis	15-20 (b), 24 (d)	
D. oblongus	up to 23 (b)	
D. pinangianus	small (b, d)	
D. purpureus		32 (b)
D. singaporensis		up to 30 (b)
D. testudinarum	10-25 (b), 20 (a)	
D. wyatt-smithii	20 (b)	36 (d)

a= Cockburn 1976, b= Kostermans 1958, c= Kostermans 1992, d= Whitmore 1972

yielding tree producing good quality fruit. Single rootstock grafted seedling was prepared by similarly grafting the mature bud wood immediately onto a young seedling by Fokert budding. Rootstocks were prepared during the first one and the half years of the project. The following treatments were investigated in a randomised complete block design in four replicates with four trees per replicate:

a) seedling to serve as control treatment
b) single rootstock with Gumpun bud wood
c) single rootstock with D 24 bud wood
d) double rootstock with Gumpun budwood
e) double rootstock with D 24 bud wood.

Windbreaks of Bana grass and permanent Inga bean shade trees were planted out in the experiment block during the first two years prior to planting out of the durian seedlings in 1994. In early 1995, after field preparation and establishment of the irrigation lines, the test seedlings were planted on mounds and under 30% netted shade.

Results and discussion

As this is a long term project, final results could only be realised in 4-5 years from planting out. Nevertheless interim results on the preparation and success of the rootstocks are discussed. Approach grafting of seedlings gave 100% success. However top-working the single and double rootstocked seedlings gave only 40% success in 1993 and this was attributed to the time of the year top-working was carried out ie. in the " Dry" from July to September 1993. Top-working the rootstocks during the wet in 1994 with scion-wood from bearing Gumpun and D 24 trees gave 95% success. Also we found no difference in success rate between Fokert budding and cleft grafting. The trees were planted out in February 1995 and are doing well under 30% artificial shade.

Multiple rootstock can produce faster growth and advance maturity by its more extensive, and better root system which facilitates greater uptake of nutrients and water. Voon (1994) reported dwarfing effect of *D. testudinarum* (identified as synonymous as *D. macrophyllus*) as a rootstock for *D. zibethinus*. Using multiple rootstocks have other advantages too besides imparting precocity. The better and stronger root system can result in better anchorage and support making the tree less prone to wind-throw by strong winds. Also multiple rootstocks can be used as an important component in an integrated disease management strategy if all or one of the rootstock is tolerant or resistant to the soil borne disease such as that caused by *Phytophthora palmivora* the most devastating pathogen of durian (Lim, 1990). This fungus causes destructive diseases at all stages of the crop growth from the seedling to the adult stages, attacking roots, trunk, branches, leaves and fruits (Lim, 1990).Besides, even if none of the rootstocks are tolerant, the double root system will increase the chances of the tree survival to some extent. There are several *Durio* species with potential for resistance against *Phytophthora.* This include those species whose natural habitat are found in wet or marshy areas and those species which can withstand water-logging for some period. Examples include *D. carinatus* with knee roots inhabiting peat swamps, *D. lissocarpus* and *D. graveolens* in marshy areas (Kostermans, 1958). *D. acutifolius* (Kostermans, 1958), *D. oxleyanus* and *D testudinarum* could tolerate water-logged conditions(Voon, 1994). Conversely, *D. kutejensis* although precocious was very susceptible to water logged conditions (Voon, 1994). *D. lowianus* and *D. mansonii* had also been reported to be resistant to *Phytophthora*, however no details on procedures and results were provided (Subhadrabandhu *et al.*, 1992). They also reported *that D. mansonii* might had a dwarfing effect as rootstock since it did not thicken at the same rate as the scion. Unfortunately trials with these stocks in Thailand had been discontinued because of the low percentage take of grafts and also the scion overgrowth was considered as sign of incompatibility. Besides *Durio* species, tolerant durian cultivars can also be used as multiple rootstocks. Tai (1971), through artificial inoculation found the cultivars D 2, D 10, D 30 and D 63 to be tolerant to *Phytophthora* compared to cultivars D 4, D 24 and D 66. Lee (1994) reported the following hybrids cultivars MDUR 79, 23-6 (D 10 x D 24), 22-5 (D 24 x D 10) to be more field tolerant compared with D 24, F 6 (D 8 x D 24), E 33 (D 8 x D 100).

Thus it is essential that those *Durio* species as well as the cultivars mentioned above should be introduced in the near future so that their potential for precocity enhancement and disease resistance to *Phytophthora* be harnessed when used as single or multiple rootstock combinations or for breeding purposes.

CHAPTER 6

6.1 Conclusion And Summary

The primary objective of this study is to boost durian productivity in northern Australia. The study will help to create a broad-based, diversified horticultural industry in northern Australia. More specifically, this project has four parts with the following aims: i) to increase durian productivity by introducing more adaptable, high-yielding and compatible clones; ii) to improve our understanding of the crop phenology and reproductive biology of durian with regards to pollination and to rationalise cultural practices such as assisted pollination and fertilisation; iii) to improve fruit yield, size, quality and uniformity by practical cultural measures and proper fertilisation based on soil and foliar nutrient monitoring; and iv) to reduce the juvenile period using various precocious rootstock-scion combinations and propagation techniques with introduced *Durio* species and clones.

Part 1

From the overseas trips to Sarawak and Peninsular Malaysia a total of 440 plants and seeds of 45 plant species were brought back besides durian cultivars and *Durio* species. On the whole the plant collection trip to Sarawak was extremely fruitful. Besides achieving our objectives, the trip served as the catalyst and springboard for the establishment of collaborative research and exchange of germplasm with the Department of Agriculture, Sarawak. Another spin-off from our efforts was that we helped establish contacts between growers and the Sarawak Department of Agriculture officials and private growers in Sarawak.

We found that a much higher success level was obtained by bringing in scionwood and budding them onto rootstocks in the quarantine screen-house than by introducing bare-rooted grafted durian seedlings. Many of the cultivars already introduced into Australia have different characteristics to their namesakes in their sources of origin. The misidentification and erroneous labelling of cultivars and individual durian trees are not only rampant here in Australia but also in other countries in southeast Asia. The confusion created by the wrong identification of cultivars can have a serious impact on the durian industry. Imagine the frustration and tremendous waste on the time, money and effort spent on research and development as well as the cultivation of wrong clones with low market acceptance. Marketing the wrong clones will damage the industry and cause its premature demise.

As a prelude to correct identification, detailed information was collated on recognised cultivars from south east Asian countries gleaned from various sources and the principal investigator's personal notes and a novel method called polygonal graph analysis developed to correctly characterise and identify cultivars based on leaf parameters. Polygonal graph analysis of leaf characters can be used to differentiate among durian cultivars instead of using reproductive characters which entails a long waiting period of 10-12 years for seedling trees and 6-8 years for grafted trees. This technique rectified 11 cases of misidentification and confirmed similarities in identity between samples from different localities, regions and countries. Fifty samples from 32 designated durian cultivars were reduced to 21 cultivars. Similar polygonal graph profiles can be done for fruit characteristics or a combination of leaf and fruit characteristics as identification aids that can be conveniently and accurately developed and used by growers without the employment of sophisticated expensive instrumentation. This technique offers a good alternative to differentiate among cultivars in the absence of a determinative DNA finger printing test for durian and other tropical fruits. Additionally a multiple linear regression model was developed to estimate leaf area in durian based on non-destructive measurements of leaf length and mid width. The model $A = -52.1 + 2.67\ L + 13.3\ Wm$ had a high coefficient of determination $R^2 = 0.967$ and lowest error mean square. The model was found to be highly predictable, precise and rapid. Leaf area, leaf length, width and dry weight are common leaf parameters employed as indices of growth and development in crop physiological studies and in horticulture.

Part 2 & 3

A crop phenology model encompassing flowering and vegetative phenology was developed for durian in the Darwin area after 3-4 years of phenological studies. Such fundamental information is an important prerequisite to boosting the crop's productivity. It provides a holistic approach to optimising crop management inputs and cultural practices in particular with respect to the development of assisted pollination methods, sound fertilisation and irrigation scheduling programs. Additionally, the study of the crop's reproductive biology is a fundamental prerequisite for the development of a sound selection and breeding program.

Durian crop phenology in the Darwin area was found to be governed closely by changes in the local weather conditions. Generally, vegetative flushing is extensive and more pronounced in February to late April and less so in September/October which coincides with fruit development, and in December. Vegetative growth is slow during the dry, cool months from June to August. Floral initials appear as small, pimple, grape-like protuberances on the branches in May to July. It takes about 6-8 week for the floral protuberances to develop into flower buds and thence to flower anthesis. Anthesis usually occurs from late afternoon 1530 to early evening 1800 hour. At this stage the stigma is mature and receptive . The durian flower is protogynous ie. the stigma matures before the anther dehisces but the flowering phenology provides ample opportunity for autogamous and geitonomous pollination. Autogamy and geitonomy are common in monoecious and hermaphroditic fruit like the durian. The former refers to the transfer of pollens from the stamen to the stigma of the same flower. The latter to the transfer of pollens from one flower to the stigma of another flower on the same tree. Anther dehiscence follows stigma maturation by a lag time of 1-3 hours but the stigma still remains receptive for 12-18 hours after anthesis coinciding with the maturation and transfer of the pollens, ie. it is also homogamous thus still facilitating self-pollination. Flowering usually occurs in consecutive overlapping cycles, giving rise to an extended flowering period for 2-3 months and it takes 110 to 130 days from anthesis to fruit ripening. Fruit set generally occurs from August through October. Fruit development stretches from September through to fruit harvest in December/January or in some years as early as late October or as late as early February depending on the extent of the cool "Dry" which affects flower opening and fruit set..

The durian floral biology and phenology play a vital role in its mode of pollination. The durian flower nectar was found to be very rich in fructose (6.4%), sucrose (5.4%) and lower in glucose (3.4%) in the ratio of 2:2:1. In Darwin, we found that both bats and the stingless *Trigona* bees (beeflies) are the major pollinators of durian although the flower possesses characteristics for bat-pollination, ie. it is chiropterous:

In the pollination and incompatibility studies, it was found that selfing resulted in lower yields and poorer fruit quality. The selfed fruits were mis-shapened and distorted with a fresh weight reduction of 33-50% and a lower flesh recovery of 20% compared to >30% flesh recovery with assisted cross-pollinated fruits. Selfed fruits had heavier rind that is of uneven thickness, lower number of arils 2 (1-4 range) per fruit, lower seed number, lower total seed weight, more shrunken, dysfunctional seeds and comparatively poorer flesh quality. Selfing also resulted in more fruit drop. Assisted cross-pollination resulted in higher fruit set, producing higher yields and better quality fruit. Manually assisted cross-pollination gave significantly higher fruit set of 31% in contrast to <10% for selfing.

The studies also revealed that there was variability in the magnitude of self-incompatibility among durian clones. Durian clones can be totally self-incompatible with no fruit at all, or partially self-incompatible, or self-compatible as was the case observed with some seedling trees. Ovule shrinkage or abortion after fertilisation but with well-developed aril was common in both well formed and deformed fruit but with a higher incidence in deformed fruit. This indicates that both pre- and post-zygotic self-incompatibility are operative in durian.

The data also indicate that the self-incompatibility (SI) system operating in durian is gametophytically controlled. This was evident from the aborted, poor growth of pollen tubes in the stylar tissues, the moist, and sticky durian stigma at anthesis, the binucleate pollen grains which germinated readily and retained its viability in storage. The assisted pollination studies also showed that there was variability in fruit harvest maturity period ie. from anthesis to harvest drop among the female parent and pollenizer source. The maternal parent was found to influence the following fruit traits:- flesh colour, taste, flavour, basic fruit shape and spine length. The data indicate that the pollenizer source had a greater influence on the fruit traits and exerted differing influence over the maternal fruit tissues. The pollen had a metaxenia effect on fruit weight, size (length), rind weight, number of locules with fertilised ovules, number of well-formed arils per locule, number of arils per fruit, percent flesh recovery and sweetness (Brix). The pollen also exhibited xenia effects on seed shape, total seed weight and number of seed formed.

An understanding of the viability, germinability and storage life of durian pollens can assist in the development of a practical and sound assisted cross-pollination procedure that can be used by commercial growers to boost durian productivity. The viability of durian pollens can be rapidly and conveniently determined using an Alexander's stain. Viability of durian pollen was high immediately post-anthesis but decreased gradually with storage period. Pollen grains from seedling trees were more resistant to loss in viability with storage and the percent viability were higher and gave better germination and germ-tube growth than those from known cultivars. Our results showed that low and high temperature of alternating 15-30° C and 35°C was inhibitory to durian pollen germination and germ tube growth. Good germination and germ tube growth was obtained at alternating temperatures of 20-30°C, and at 25° C and 30°C.

The practical implication from these studies are that to have uniform well shaped, high quality fruits, assisted cross-pollination should be carried out. Selfing resulted in more fruit abortion, lower yields and poor quality, deformed fruits. This can be done manually using brushes attached to long poles for flowers high in the canopy during the evening from 1800 hr to 2000 hr. Pollens should be freshly collected 1-2 hours after anthesis and should not be stored longer than 1-2 days after anthesis for good fruit set. The viability of the pollens should be periodically checked using Alexander's stain. It is also critical that growers should plant mixed clones of durian in a block eg. in different rows to ensure cross-pollination by natural biotic pollinating agents as many durian cultivars exhibit partial self-incompatibility. To maximise fruit productivity the maintenance and continuous presence of such pollinating agents is of vital importance. Thus it is imperative that indiscriminate and excessive use of pesticides during this period be drastically reduced or avoided. The findings also highlight the importance of having the right pollinizer (male pollens) for a particular cultivar to maximise fruit set and yield.

Nutrient concentrations for all the micro- and macro-elements changed in accordance with seasonal fluctuations in durian crop phenology which in turn appeared to be governed by the prevailing meteorological patterns as described above. This emphasised the need to consider the most appropriate time for leaf sampling to estimate the nutrient status of the durian tree. We developed a standardised sampling technique by taking the 5th and 6th leaf from the shoot tip. We suggest that leaf sampling should be done in November as the variability for the nutrients were comparatively the least. Also another advantage is that result could be obtained on the leaf nutrient status just before a large fertiliser application is carried out at the tail end of harvest in January or February. The 3-4 year monitoring study also allowed the setting up of tentative durian leaf nutrient sufficiency range norms for Australia based on nutrient status in the leaf in November. A comparison of tentative Australian standards with published Malaysian standards revealed that our standards have narrower ranges and are higher for Ca and Mg but marginally lower for K and Zn and lower for Mn. All the leaf macroelements and the microelements Zn and B declined or were lower during fruit set and development. Generally, N, P and Ca were more limiting during fruit development after September till harvest in January. K became limiting during the latter part of fruit development through harvest and remained limiting till July. Leaf N was also lower during periods of active vegetative flushing. Soil N, P and the bases - K, Ca and Mg also exhibited similar trends - lower during fruit development in October-November and during active leaf flushing from March to May.

The traditional method of leaf nutrient interpretations using critical nutrient concentrations (critical values) or sufficiency range (as described above) do not account for the dynamic nature of foliar nutrient composition influenced by the physiological stage of crop growth, nutrient interactions and interactions between nutrients, dry matter accumulation and metabolic activities. To overcome such limitations a modified Diagnosis and Recommendation Integrated System (m-DRIS) method was used to establish m-DRIS norms for durian. Our results showed that the m-DRIS norms were able to detect more limiting nutrients than the sufficiency range approach. There was closer agreement with the Australian than with Malaysian sufficiency range norms. For durian m-DRIS norms defined seasonally or yearly is more preferable because of seasonal and yearly variations. Highest nutrient imbalance periods were observed during flowering especially in July 1993 in both orchards as indicated by the higher Nutrient Imbalance Index (NII) values. There is a need to develop more m-DRIS norms for the other elements as well.

The study of plant, plant-soil, and soil nutrients relationships can enhance our understanding of crop nutrient requirement and nutrient application. The significant low to moderate correlation and regression relationships among leaf nutrients, soil nutrients and between leaf and soil nutrients indicate that interactions between nutrients are more complex and dynamic and involve multiple interactions rather than two factor interactions. Also the significant but weak relationships (R= 0.2-0.4) between foliar and soil nutrients suggest that the utility of soil tests to predict leaf nutrient status in durian was rather limited.

Fertiliser scheduling should be made in accordance to the crop phenology and the crop nutrient requirement fluctuations. Diagnosis of crop nutrient demand should be assessed from leaf and soil sampling done in November using the tentative standards drawn up for northern Australia. For instance from our studies, it is evident that most fertilisers should be applied in February/March after the crop harvest and at the incipient stages of major vegetative flushing, another smaller application just before the Dry during the time in late April/May and another round in late August/September to coincide with the early stages of fruit development. The quantity of fertilisers use should be adjusted yearly according to the results of leaf sampling as well as the crop load (yield) removed. Application of micronutrients as foliar spray should be done during flushing in March and another application in May.

Part 4

The long gestation period of 10-12 years for a seedling tree or 6-8 years for a grafted tree is a major deterrent to potential growers because of the lengthy lag time for realisation of returns to investment and the accompanying risk factors involved in production.. There are many ways to obviate the long juvenile period and enhance precocity such as by using chemical growth hormones or by cultural manipulation using various forms of grafting onto precocious or dwarfing rootstocks, interstocks and multiple rootstocks. In our study we compared double rootstocks and single rootstock topworked with mature scion-wood against seedling trees for growth and precocity performance.

Results from such studies are only achievable after several years. Top-working the rootstocks during the wet in 1994 with scion-wood from bearing Gumpun and D 24 trees gave 95% success. Also we found no difference in success rate between Fokert budding and cleft grafting. Multiple rootstock can produce faster growth and advance maturity by its more extensive, and better root system which facilitates greater uptake of nutrients and water. The better and stronger root system can result in better anchorage and support making the tree less prone to wind-throw by strong winds. Also multiple rootstocks can be used as an important component in an integrated disease management strategy if all or one of the rootstock is tolerant or resistant to the soil borne disease such as that caused by *Phytophthora palmivora* the most devastating pathogen of durian.

Future research areas

From the studies, future areas of research that need further emphasis include:

- More efforts need to be emphasised to introduce more correctly identified high yielding cultivars and precocious, dwarf *Durio* species from southeast Asian countries like Indonesia and Malaysia.
- The applicability of the polygonal graph analysis method need to be further tested to characterise more of the cultivars in southeast Asia that have not been introduced into Australia.
- A more precise, accurate determinative DNA finger printing test is needed for durian and other tropical fruits to solve the problems of misidentification of cultivars and *Durio* species.
- More manually assisted cross-pollination and pollen viability studies need to be carried out in Queensland to determine the most compatible pollinizer clones for the clones of commercial importance in order to boost productivity.
- Crop nutrient monitoring and phenological studies should be carried out in the various growing regions of northern Queensland to rationalise the implementation and scheduling of various cultural practices and management inputs.
- It is of vital importance that dwarf and precocious *Durio* species and durian cultivars as well as those that exhibit resistance to devastating diseases such as those caused by *Phytophthora* should be introduced as soon as possible for use as single or multiple rootstock combinations for enhancement of precocity, resistance to wind-throw, resistance to disease and also for breeding purposes.

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APPENDIX 1

Plants Introduced From Sarawak

Botanical Name	Variety / Local Name	Material	No.
I. FRUIT AND SPICES			
Ananas comosus	Sarawak	Crown suckers	3
Artocarpus anisophyllus	Entawa/Bintawa	Seedling	2
Artocarpus kemando	Pudu	Seedling	2
Artocarpus odoratissimus	Terap	Seedling	2
Artocarpus sarawakensis	Pingan	Seedling	2
Artocarpus sericicarpus	Pedalai	Seedling	2
Baccaurea motleyana	Rambai	Seedling	2
Baccaurea parviflora	Uchong	Seedling	2
Canaruim odontophyllum	Dabai	Seedling	4
Dacryodes rostrata	Kembayau	Seedling	2
Dialium indum	Keranji	Seedling	2
Dimocarpus longan ssp. malesianus	Isau	Seedling	2
Dimocarpus longan spp. malesianus	Mata kucing	Seedling	2
Dimocarpus longan spp. malenianus	Isau Seliong C	Grafted plant	2
Durio graveolens		Seedling	2
Durio graveolens	Entulang	Grafted plant	2
Durio kutejensis		Seedling	2
Durio zibethinus	D 99	Grafted plant	2
Durio zibethinus	D96	Grafted plant	2
Durio zibethinus	D24S	Grafted plant	2
Durio zibethinus	D2S	Grafted plant	2
Durio zibethinus	D24	Grafted plant	2
Durio zibethinus	DS60	Grafted plant	2
Flacourtia rukum		Seedling	2
Garcinia parvifolia		Seedling	2
Lepisanthes alata	Engkilili	Seedling	2
Mangifera indica	Chok Anan	Grafted plant	2
Mangifera laurina	Depih	Seedling	2
Mangifera odorata	Padol No. 1	Grafted plant	2
Mangifera pajang		Seedling	4
Mangifera similis (M. torquenda)		Seedling	2
Nephelium maingayi		Seedling	2
Nephelium sp. A	Sibau	Seedling	2
Nephelium sp. B	Melanjan	Seedling	2
Nephelium sp. C	Mao	Seedling	2
Piper nigrum	Kuching	Cutting	6
Pithecelobium dulce	Jering	Seedling	2
Sandoricum borneense	Kelampu	Seedling	2
Xanthophyllum amoenum		Seedling	2

Botanical Name	Variety / Local Name	Material	No.
II. ORNAMENTAL PLANTS			
Achasma sp.	Sg. Sebiew	Rhizome	1
Achasma sp.		Rhizome	4
Alocasia sp.	Variegated	Plant	6
Alpinia sp.	Various sp.	Rhizome	8
Bambusa sp.		Plant	7
Bambusa sp.	Epiphitic bamboo	Plant	1
Bambusa sp.	Small bamboo.	Plant	4
Begonia sp.		Plant	1
Cordyline sp.		Cutting	3
Curcuma sp.		Plant	3
Dracaena sp.		Plant	1
Etlingera sp.	Various sp.	Rhizome	39
Globa atrosanguinea		Rhizome	1
Globa sp.	Various sp.	Rhizome	4
Hedychium sp.	Various sp.	Rhizome	4
Hibiscus sp.		Plant	2
Ixora sp.	Various sp.	Plant	13
Kaempferia sp.	Various sp.	Rhizome	28
Kaempferia sp.	Stilt Ginger	Rhizome	5
Licuala sp.		Plant	2
Licuala sp.	Variegated	Plant	1
Lilium sp.	Various sp.	Plant	3
Lycopodium sp.	Rh. Akan		3
Orchids			15
Pandanus sp.		Plant	5
Paphiolidium sp.	Lundu orchid		7
Pellionea sp.		Plant	8
Pinanga vietchii		Plant	1
Pometia sp.		Plant	2
Pometia sp.		Cutting	7
Zingiber sp. (Hairy ginger)	Rh. Akan		1
Zingiber sp. (Short ginger)	Rh. Akan		1
Zingiber sp. (Miniature ginger)			1

Botanical Name	Variety / Local Name	Material	No.
	III. SEEDS (Fruit and Vegetables)		
Areca catechu	Betlenut		17
Artocarpus camansi	Kamansi		40
Artocarpus elasticus	Terkalong		50
Artocarpus odoratissimus	Terap		30
Artocarpus rigidus	Pala munsoh		10
Artocarpus sarawakensis	Pingan		20
Baccaurea lanceolata	Empaong		10
Baccaurea parivflora (B. angulata)	Uchong		5
Canarium odontophyllum	Dabai		20
Citrus sinensis	Honey mandarin		20
Cynometra cauliflora	Nam nam		4
Dacryodes rostrata	Kembayau		14
Dialium sp.	Keranji		20
Durio oxleyanus	Isu		25
Durio zibethinus	Durian		200
Eleiodoxa conferta	Asam paya kuning		10
Eleiodoxa conferta	Asam paya merah		8
Garcinia mangostana	Mangosteen		6
Litsea garciae	Engkala red		3
Litsea garciae	Engkala white		4
Mangifera foetida	Bacang		3
Mangifera laurina ?	Depih		3
Mangifera pajang	Mawang		1
Mangifera quadrifida	Asam Kumbang		5
Mangifera similis (M. torquenda)	Lamantan		5
Myristica fragrans	Nutmeg		10
Nephelium lappaceum	Meruntik		3
Nephelium lappaceum	Sibau		10
Nephelium rambutan-ake	Mak		3
Nephelium sp.	Kebuau		3
Nephelium sp.	Melanjau		30
Pangium edule	Kepayang		10
Salacca zalacca (S. edulis)	Gula-gula salak		20
Salacca zalacca (S. edulis)	Nangka salak		30
Solanum sp.	Terong Dayak		100
Willughbeia sp.	Kubal susu		10
Xanthophyllum amoenum	Langgir		20

Botanical Name	Variety / Local Name	Material	No.
	IV SEEDS (Ornamental)		
Achasma sp.			10
Arengga pinnata			13
Costus sp.			20
Cryostachys lakka	Non-clumping		20
Iguanura elegans			20
Kaempferia sp.	Stilt ginger		20
Licuala orbicularis			20
Pinanga sp.			7

Plants Introduced From Peninsular Malaysia

Botanical Name	Variety / Local Name	Material	No.
	I. FRUIT		
Durio zibethinus	Ang Bak	Grafted plant	3
Durio zibethinus	Ang Hea	Grafted plant	3
Durio zibethinus	D 24	Grafted plant	3
Durio zibethinus	D 96	Grafted plant	3
Durio zibethinus	D 98	Grafted plant	4
Durio zibethinus	D 99	Grafted plant	3
Durio zibethinus	D 123	Grafted plant	3
Durio zibethinus	D 139	Grafted plant	4
Durio zibethinus	Deka	Grafted plant	3
Durio zibethinus	Holor	Grafted plant	3
Durio zibethinus	Kan Yau	Grafted plant	4
Durio zibethinus	MD 78	Grafted plant	3
Durio zibethinus	MD 79	Grafted plant	3
Durio zibethinus	MD 88	Grafted plant	3
Durio zibethinus	Monthong	Grafted plant	4
Durio zibethinus	Tawa	Grafted plant	3
Garcinia prainiana	Cerapu	Seedling	1
Lansium domesticum	Duku Muar	Grafted plant	4
Lansium domesticum	Duku Trengganu	Grafted plant	4
Lansium domesticum	Langsat	Grafted plant	5
Lansium domesticum	Longkong	Grafted plant	4
Psidium guajava	Crystal Seedless #2	Grafted plant	4
	II ORNAMENTALS		
Alpinia javanica		Rhizome	9
Alpinia mutica		Rhizome	1
Alpinia sp.		Rhizome	3
Alpinia vitellinum		Rhizome	2
Amomum sp.		Rhizome	1
Bambusa sp.		Rhizome	22
Begonia sp.	Blue flower	Rhizome	13
Begonia sp.	Climbing	Cutting	5
Etlingera sp.	Various localities	Rhizome	18
Globba uniflora		Rhizome	1
Hedychium otensii		Rhizome	1
Kaempferia pulchra	Various localities	Rhizome	38
Kaempferia sp.		Rhizome	1
Scaphochlamys concinna		Rhizome	2
Scaphochlamys errecta		Rhizome	2
Scaphochlamys kenstleri		Rhizome	
Scaphochlamys sp.		Rhizome	2
Scaphochlamys subbilobba		Rhizome	1
Tapeinochilus sp.		Rhizome	4

APPENDIX 2

Fruit Characteristics of Edible *Durio* Species

Durio Species	Shape	Size cm	Colour	Spines		Aril				Seed			Mode of Ripening
				Shape	Size cm	Colour	Consist'y	Odour	Taste	Colour	Shape	Size cm	
graveolens	globose	10	orange-yellow	short, slender, wavy, split into 5 parts	2	dark red-pink (orange)	fleshy	odourless	sweet	brown	ellipsoid	2x4	stays attached to branches, open when ripe
dulcis	globose	15-20	red	long and stiff	1-2	dark yellow	soft, fleshy	very strong, offensive	very sweet	dark brown, glossy			drops unopen when ripe
kutejensis	ovoid-ellipsoid	20x 12	yellow	pyramidal, curved, flexible	1-1.5	orange-yellow	fleshy	fragrant	sweet		ellipsoid	4	drops unopen when ripe
oxleyanus	globose	15x 20	greyish green	long, curved, slightly hairy	4	yellow	fleshy, creamy	slightly fragrant	very sweet	red-brown	ellipsoid	3	drops open when ripe
grandiflorus	ellipsoid	18x 20	grey green	triangular, pointed	1.2	yellow	thin		edible	dark brown, glossy	ellipsoid		attached, open when ripe, 5 lobes
zibethinus	variable large	>20 x25	yellow	broad, conical	1-1.5	pale-strong yellow	thick, fleshy, creamy	fragrant-strong	sweet-very sweet	orange brown	ellipsoid	4	drops unopen when ripe
testudinarum	globose	7		pyramidal	0.9	yellow	watery	caramel	sweet		triangular cross section	2.5 x1	formed at base of trunk, drops unopen when ripe
lowianus	globose-ellipsoid	20x 25	green yellow	stout	<1	dark yellow	thin		edible				