RURAL INDUSTRIES RESEARCH
& DEVELOPMENT CORPORATION

# Durian Germplasm Evaluation

## for Tropical Australia

## *Phase 1*

**A report for the Rural Industries Research and Development Corporation**

by G. Zappala, A. Zappala and Y. Diczbalis

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# Foreword

ZTR-1A Durian Germplasm Evaluation for Tropical Australia, Phase 1 is a RIRDC Project supported under the New Plant Products program. The project's objectives were:

1. The introduction of the best durian clones of Asia from guaranteed budwood sources.
2. Propagation of these clones (single and multi-rootstocked) with the best nursery practices.
3. Development of an Industry Strategic Plan.
4. To compare growth rates and performances under different soil types and climatic regimes.
5. To evaluate and monitor nutrition requirements and in particular clonal tolerances to pests, diseases and strong winds.
6. To identify clones best suited for Phase 2 (Yield and Fruit Quality Assessment) for future Australian planting and export potential.

The project's results identify seven new clones, evaluated under north Queensland's wet tropical conditions, offering the best opportunities to existing and future durian growers, to further develop their industry. It is also worth noting that although this project's RIRDC funding ceased in July 2001, the researchers continued to collect data through to January 2002. This was undertaken to ensure the Australian industry had as much up to date information as possible, including initial yield data, to enable better decision making on the clonal evaluation.

Durian is usually regarded as a tree with a long juvenile period yet some of the new clones are already fruiting for the first time in Australia.

The Australian Durian Industry is a close knit group willing to share its information through newsletters and field days. This spirit of cooperation and coordination is actively contributing to the dissemination and adoption of new technical opportunities to improve productivity and competitiveness.

The research findings of this report will be presented to growers in August 2002 through an information field day when all interested parties will be able to inspect the two trial sites and witness first hand the clonal differences.

This project was funded from RIRDC Core Funds which are provided by the Federal Government.

This report, a new addition to RIRDC's diverse range of over 800 research publications, forms part of our New Plants Products R&D program, which aims to facilitate the development of new industries based on plants or plant products that have commercial potential for Australia.

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**Simon Hearn**
Managing Director,
Rural Industries Research and Development Corporation.

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# Contents

# List of Tables

# List of Figures

# Executive Summary

Durian *(Durio zibethinus* Murray) is one of the most remarkable tropical fruit in the world. What other single fruit can arouse the human senses and emotions of smell, taste, pleasure, passion or even hatred? Westerners often quickly retreat or decline any invitation to partake in the unique taste experience of the "*King of Fruits*".

Durian is indigenous to the hot equatorial rainforest of Malaysia and Indonesia where it thrives in the humid tropical environment with high rainfall spread evenly throughout the year. Durian provides one of the most lucrative financial returns for tropical fruit growers in southeast Asia.

While a relatively new crop for Australia, durian has been cultivated at the village or "kampong" status in southeast Asia for centuries. Commercial production commenced in Thailand in the mid 1900's when the superior cultivars: Mon Thong, Chanee, Kan Yao and Kradum Thong were identified and propagated. These clones now form the basis of their world leading export industry.

Watson (1988) reported that the Australian domestic market could absorb production from 100 hectares. Most consumers prefer fresh fruit, but frozen products are also acceptable. The export potential for Australian durian is also good, as northern Australian production can fill the "January to April" market window in Asia.

In Australia, the latest industry census (conducted at the request of the Economic Policy Branch of AFFA) in 1999 - 2000, identified that more than 12000 grafted trees were planted in the Northern Territory and north Queensland. There are currently no orchard plantings in the northern tropical region of Western Australia.

One of the major constraints in the establishment of a successful durian industry in Australia has been the importation of unreliable planting material, i.e. many varieties previously imported have been misidentified due to a lack of guaranteed budwood sources. There has been limited evaluation of these clones in replicated field conditions.

This five-year project evaluated the performance of 30 newly imported durian clones from Asia's major durian growing regions. The new clones were supplied as either grafted trees or budwood from guaranteed sources in Thailand, Malaysia and Indonesian. It tracks the results of 5 single plant replicates of each clone on two differing soil types and their response to the Australian climatic conditions. These results will establish the most suitable clones to move forward for industry expansion.

As task 3 of this project, RIRDC required the development of an industry strategic plan. The direction provided through this planning process has unified the 50 Australian growers, who are spread along coastal north Queensland (from Tully to Cooktown) and the 20 Northern Territory growers in the Darwin region (Lake Bennett in the south to Lambell's Lagoon in the east).

The researchers together with Phil Ross and Chris Horsburgh (both from DPI) identified the major issues as the first round of stakeholder consultation for the strategic planning process. These are listed in full in the *Australian Durian Industry Strategic Plan 2001-1006*. A sample of the some of the major issues are listed below:

- A gene-pool of world renowned cultivars has been introduced
- Scarce availability of quality planting material
- Durian is not a host of the papaya fruit fly
- Australia is free of the dreaded durian seed borer.
- The industry has a group of dedicated growers

- Lack of research information and grower management experiences regarding growing, harvesting and post harvest issues
- To supply a consistent product
- To replace frozen imports
- Sale of inferior fruit gives industry a bad name
- To accurately identify existing varieties
- There are strong market opportunities for this high-priced quality fruit in both domestic and international markets, particularly in the off-season for other growing regions.
- The introduction of new strains of pests and diseases into Australia
- Imports of fresh Asian fruit if the existing Australian quarantine restrictions are dropped

These issues were presented at three grower Strengths, Weaknesses, Opportunities and Threats (SWOT) meetings. Two stakeholder meetings were held in north Queensland and one in Darwin. Growers identified the issues into strengths, weaknesses, opportunities or threats and placed a value on their importance to the industry for each issue. Each attendant nominated their priorities on a scale of 1 (being most important) to 5 for every issue. Each meeting also added new issues to the preliminary list. A working group then progressed the issues to include the required actions to reach the preferred industry outcomes over a time period. The major issues had personnel allocated to deliver through a performance indicator or work plan. This process has proven extremely beneficial and our current plan, which is version 3, has achieved much when compared to version 1. The latest strategic plan is available as a separate publication.

Cyclones, extreme rainfall and cold winters have subjected the evaluation trees to one of the most extreme set of weather conditions imaginable over the 5 years of the project. Highlights of these weather conditions are listed below from data collected from the Campbell Scientific weather station located on site from January 1997 to December 2001.

**Table 1. Maximum Wind Speeds from 1997 to 2001.**

| Date | Cyclone | Wind Speed | Wind Direction |
|---|---|---|---|
| 22 March 1997 | Justin | 104.8 km/hr | N NE |
| 11 February 1999 | Rona | 78.1 km/hr | E |
| 27 February 2000 | Steve | 87.8 km/hr | N |

**Table 2. Annual Rainfall from 1997 to 2001.**

| Year | Rainfall |
|---|---|
| 1997 | 3968 mm |
| 1998 | 4335 mm |
| 1999 | 5850 mm (2 data sources) |
| 2000 | 6278 mm |
| 2001 | 4002 mm |

**Table 3. Minimum Temperatures from 1997 to 2001.**

| Date | Year | 0°C |
|---|---|---|
| 16 June | 1997 | 6.9 |
| 2 July | 1998 | 8.4 |
| 18 July | 1999 | 7.2 |
| 19 July | 2000 | 5.3 |
| 30 July | 2001 | 4.8 |

Propagation and nursery practices are discussed in Chapter 2. Besides coping with the extreme weather, clonal survival also depended on the size of the original planting material. Grafted trees with heights of one metre and trunk diameters of >12mm survived best. This is in line with the current Malaysian Agricultural Research and Development Institute (MARDI) research recommendations and discussed in Chapters 2 and 3.

Observations of pest and diseases that were recorded over the project are listed in Chapter 4 together with results from nutrition research and irrigation records. *Rhyparida sp* was identified as the major pest to young trees while fruit spotting bug (*Amblypelta lutescens lute* Distant) was the major pest for fruiting trees. The major diseases of *Phytophthora palmivora* and *Pythium sp* were detected from samples collected over the project. A program of mulching in conjunction with chicken manure has increased root growth (Figure 12).

Results of leaf nutrition levels for the project trees were compared to the Malaysian recommended leaf standards and the NT recommended leaf standards. These are listed in Table 30. Mean seasonal trends in leaf macro and micro elements from March 2000 to March 2001 are displayed in Figure 13.

Phenology studies are discussed in Chapter 5. Shoot activity was more prolific then imagined, with trees exhibiting the ability to remain vegetatively active during periods of relatively cool conditions. All clones were visually rated for tolerance to cold temperatures by the use of differing percentages of leaf abscission. Project yield data was also collected up to January 2002 and is presented in Chapter 5. The Hawaiian Mon Thong clone has performed well with one tree producing 140 kg of fruit at 10 years of age and another producing 45 kg at year 6 (Table 36).

The DNA classification and identification of 28 clones has verified many of the researchers' field observations in Australia and overseas. This work has significant benefits for a developing industry, which can now plan future expansion with confidence. The clones recommended in Group 1 have all been classified and identified as discussed in Chapters 6 and 7.

Although this project's RIRDC funding ceased in July 2001, the researchers continued to collect data through to January 2002 to ensure 5 complete years of weather data. Many of the new clones flowered for the first time in November 2001, fruit set and estimated yield observations were collected up to January 2002. This ensured that the Australian industry was supplied with the latest information on these new clonal selections.

Australia's current recommended durian variety planting list includes the Thai clones Luang, Gumpun, Kan Yao and the Malaysian clones Hew 3 and Hew 1 (Darwin).

32 clones (30 new introductions and 2 "standards") were evaluated. Two planting sites with differing soil types were used with 5 replicates of each clone planted at each site. An additional 20 clones, many of which were limited by the availability of planting material, were observed in an attempt to identify as many possible clones for our developing Australian industry.

The clones Luang and Kan Yao were included as "standards." Luang and Kan Yao are listed on the current recommended planting list and both performed well.

Clones were evaluated on a number of selection criteria. These included:

- the authenticity of the budwood source,
- classification and identification of 28 clones by DNA testing,
- planting survival rate,
- tree growth rate and structure,
- comparison of clonal survival between both sites,
- pest and disease observation,

- response to cold temperature and strong wind,
- early flowering and fruiting habit,
- fruit quality and yield data from project trees identified in Group 1.

One of the major influences on clonal selection was their superior survival performance in conditions that were less than optimum during the evaluation period. These observation results were a clear example of "*survival of the fittest*." No project trees were spoon-fed and all project trees were treated as commercial plantings. Evaluation criteria is described in Chapter 3. The evaluation results of the 32 clones are best grouped into 4 sections:

**Group 1. Highly recommended Top 9 clones (including 2 "standards")**

Seven new introductions are highly recommended. All of these clones achieved an 80% survival or greater, from the original plantings for the 5-year period i.e. a minimum of 8 plants survived from the original 10 planted (Table 12). These clones are listed in decreasing percentage of survival and are Hepe, *D. macrantha*, D 175 (Red Prawn), DPI Mon Thong, Hawaiian Mon Thong, D 190 and Kradum Thong. The results obtained from the clones, Kan Yao and Luang, included as "standards," demonstrate their suitability for Australian conditions and therefore justifies their inclusion in the current recommended Australian planting list.

**Group 2. Potential additions for grower plantings (13 clones) via ZTR-1A Phase 2**

D 178, P 21, KK11, Hew 7, D 179, D 99X, D 144, D 24, Chanee, D 168, D 99, D 118 and Sahom. All of these clones achieved a greater than 50% survival from the original plantings for the 5 year period. The results of the clones D 144, Chanee, D 168, D 118 and Sahom were disadvantaged when compared to the rest of this group as some of their original replicate trees were lost to cyclone damage (Table 12).

**Group 3. Deleted from future evaluation (6 clones)**

Ampung, D 16, D 120, Hew 6, Permasuri and Sukun.

**Group 4. Require further evaluation (4 clones) via ZTR-1A Phase 2**

Chin, D 163, D 164, and D 2.

A further 20 clones were also observed but unfortunately these clones were not replicated by 5 at both sites to ensure a thorough analysis. Their evaluation was restricted by the lack of planting material, as some of these were late introductions. These are listed in Group 5.

**Group 5. Insufficient replicates for evaluation. (20 clones)**

Capri, D 7, D 10, D 24 Serawak, D 96, D 123, D 140, D 143, D 145, D 160, D 188, D 197, Hew 1, Hew 2, NG Mon Thong, P 601, Petruk, Taiping 1, XA and Yeao. Gob Yaow, Gumpun and Sunan were also included as "standards" with this group.

The 37 clones identified in Groups 2, 4 and 5 clearly need further investigations before any final recommendations on their future are made. As many of these clones have excellent qualities, research should be undertaken through ZTR-1A Phase 2, or a similar project to achieve their full evaluation.

The industry is still recovering from the recent AQIS Import Risk Analysis (IRA) policy decision allowing fresh imports into Australia from the April to September period. Thai authorities are still to sign off on this IRA despite the decision being announced by AQIS on 3 August 2000, more than 18 months ago. Market access is already available to Australia, with approximately 500 tonnes of frozen durian already entering Australia annually. Unlike fresh imports, frozen durian poses only a minimal quarantine risk to our Australian industry.

The best way the Australian industry can compete with any future fresh imports is to move forward rapidly and expand plantings with quality clones identified by this research project. The adoption of this research will undoubtedly create interest in upgrading current plantings and stimulate industry development thereby contributing to the economy of Australia.

# 1. Introduction

From 1975, dedicated Australian durian grower/addicts introduced clonal durian material through quarantine stations in Cairns and Darwin.  Orchard plantings commenced in 1980 for north Queensland and in 1984 for the Northern Territory.  North Queensland plantings are found along the coastal strip from Tully 18$^{o}$S to Cooktown 15$^{o}$S.  In NQ, there are 50 growers with around 8500 trees, 10% of which are fruiting.  In the Northern Territory, 4000 trees are planted south of Darwin, latitude 12.5$^{o}$S, spread between 20 growers with approximately 400 trees bearing.  Tropical Primary Products (TPP) from the Lambell's Lagoon area has recently established a new orchard of more than 2000 trees and other NT growers are planning their orchard layouts after purchasing grafted trees.

The value of the durian industry worldwide is estimated at US$1.5 billion (Lim, 1998). Watson (1988) stated that a successful durian industry in Australia is dependent on a number of factors the first being "*Satisfactory production of quality fruit, preferably over at least 5 months*."  Watson (1988) identified areas of future research, the first being, *the further importation and screening of quality cultivars*.  Both of these issues are linked and where yield data is available, the quality clones to progress the industry are identified in this report.

The present Australian production is less than 50 tonnes, worth approximately $350,000 to $500,000 as most of the present plantings are yet to reach full production.  Prices range from $8-12/kg for fresh fruits and $15-20/kg for minimal processed arils.  Lim (1998) reported that the potential is bright and stated "*Assuming an orchard with 100 trees per hectare having an average yield of 50 fruit per tree at year 10, and a farm gate price of $10 per kg, annual return of an industry growing 5000 trees is $5 million* and that "*The export potential for durian is good, as the major production in northern Australia can fill the market window from December to April*."

In the Northern Territory, the fruiting period usually occurs from October to mid February.  Fruiting in north Queensland is usually from January to May. In 1999 and 2000 mature fruit in North Queensland was produced through to September, so as in other Asian countries, durian harvest can be produced off-season.  Volumes for out of season fruit are low as this usually occurs as a result of different weather conditions or lack of fruit set at the standard flowering time or from clones with very early or late flowering characteristics.

Clones more tolerant of cool temperatures could also enable the existing durian production regions to be expanded further south along the Queensland coast.  This would also extend the Australian fruiting season.

Major Asian production peaks usually occurs in Thailand from April to July, Malaysia from July to August and the Philippines from August to October within any year.

Recent developments in countries like the Philippines have highlighted the importance of durian in Asian markets.  From 1994 to 1999, the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) implemented a coordinated program entitled "Durian Agribusiness Development for Domestic and Export Markets."  This program increased the production area by 164%, from 6954 hectares in 1994 to 18347 hectares in 1999 (Anon, 2000).

This is a clear demonstration of how research, together with Government planning and grower commitment can rapidly develop an industry.  PCARRD has also recently released "*The Philippines Recommends for Durian*" (2000), which states: "*A key factor in the success of durian production is the use of superior cultivars.  The National Seed Industry Council of the Department of Agriculture recommends 10 cultivars.  These include two Thailand cultivars (Chanee and Mon Thong) and eight local cultivars."*(Anon, 2000)

While the Philippine experience would be extremely difficult to emulate in Australia, our growers and investors now have availability of the knowledge contained in this report and RIRDC publication *"The New Rural Industries Volume II  Financial Indicators"* by Hassell & Associates Pty Ltd, (September 2000) to plan their future plantings.  Hassall's and Associates Pty Ltd., (2000) includes detailed spreadsheets for orchard establishment, operating expenses and cash flows and is an important reference tool for current and future Australian growers.  It is the researchers hope that a similar rapid expansion will occur in Australia as has happened in the Philippines, as supplying the demand of the domestic market with an Australian clean green quality product, is our best defence against imported fresh fruit.

## 1.1 List of Clones introduced into Australia 1992 - 1998

Zappala Tropicals Pty Ltd developed a serious commitment to growing durian in 1992 following a visit to the farm by Dr. Mohamed Bin Osman, Director of Horticulture Malaysian Agriculture Research and Development Institute (MARDI) Serdang and Dr Chan Ying Kwok, the deputy director. MARDI invited us to a conference in Ipoh, West Malaysia, where their latest hybrid durian clone MDUR 88 (now called D 190) was to be released to the public.  MARDI, following more than a 20-year hybridisation and evaluation program, released this clone together with MDUR 78 and MDUR 79.  These clones are high yielding, of superior quality and have demonstrated early fruiting commencing in year 5 – 6, after planting.  These clones also demonstrate a moderate to good tolerance to *Phytophthora* patch canker disease (Zainal *et al*., 1992).

Previously durian budwood that had been introduced into Australia was proven to be non-genuine ie: not true to the label (Watson, 1988 and Watson, 1991).  The reliability of clonal material is critical for any industry to develop as this is the nucleus for industry production, research and marketing. Mistakes that usually lead to the introduction of inferior clones, impacts on every industry section.

Lim (1997) stated: "*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 of time, money and effort spent on research and development as well as the cultivation of wrong clones with low market acceptance."*

The researchers therefore accepted the MARDI invitation to contact sources in Malaysia that could provide the genuine article.  The trip was successful as the researchers formed close bonds with MARDI, Malaysian growers and other researchers at the University of Pertanian (UPM) located at Serdang.  Malaysian growers invited us to visit their orchards, to taste the fruit from their trees and cut budwood from these trees if we liked the particular clone.  This single action of sharing enabled Australia to now have the most diverse genepool of durian clones in the world.

Other valuable introductions were made by Brian Watson, DPI (OIC) Kamerunga, NT DPI&F staff, Colin and Dawn Gray from Cape Tribulation, Tropical Primary Products from Lambell's Lagoon, Bert Jaminon from Howard Springs, Barry Shah from Humpty Doo, Brian Dodds from Woopen Creek and John Marshall from Cairns.

In all, Zappala Tropicals Pty Ltd undertook 4 trips to ensure that as many introductions as possible from different regions of Malaysia, Thailand and Indonesia were brought into Australia through the AQIS Quarantine stations in Darwin and Kamerunga near Cairns.  The largest shipment was over 200 bare-rooted plants and budwood for grafting more than 100 seedling trees.  AQIS post entry quarantine staff took a personal interest in this project and without their commitment survival results would have been less.

Clones (42) imported from Malaysia from all sources (listed on page 2) include:
Ampung, Capri, Chin, D 2, D10, D 16, D 24, D 24 Serawak, D 96, D 99, D 99X, D 118 (Tembaga), D 120, (KK5, Manong), D 123, D140, D 143, D 144, D 145, D 160, D 163 (Hor Lor), D 164 (Red

Flesh), D 166, (Penang 604), D168, D 175 (Red Prawn), D 178 (Penang 88), D179 (Penang 99), D 188 (MDUR 78), D190 (MDUR 88), D 197 (Raja Kunyit), Hew 1, Hew 2, Hew 6, Hew 7, KK 11, P 21, P 601, Permasuri, Sahom, TLK/YEAO, Taiping 1, Tembaga and XA.

Clones (6) imported from Indonesia from all sources (listed on page 2) include: Hepe, Petruk, Sitokong, Sukun, Sunan and *Durio macrantha*;

Clones (4) imported from Thailand from all sources (listed on page 2) include: Chanee, DPI Mon Thong, Kradum Thong, NG/Mon Thong and one clone imported from Thailand via Hawaiian was Hawaiian Mon Thong (also called Pomoho Mon Thong.)

The successful introduction and evaluation of the above world class collection of durian germplasm and local seedling selections like Z1, which has produced quality fruit for three consecutive years, will greatly assist the Australian Durian Industry to further develop and claim its rightful economic place in the world durian market.

## 1.2 References


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# 2. Propagation and Nursery Practices

## 2.1 Introduction

All grafted introductions were required to remain a minimum of 9 months in quarantine and were subjected to inspection by qualified plant pathologists prior to release. Plants also had to achieve a certain growth size for these inspections to be carried out. This meant that often trees were in quarantine for at least 12 months. On release from quarantine, the aim was to multiply the clones as quickly as possible so that field planting could commence. Field planting was usually timed to coincide with the warmest period of the year (September to March) to assist plants to adjust from the greenhouse environment to the field environment.

Watson (1978) had reported that cleft grafting had been used at Kamerunga Research Station, Cairns, with moderate 40% success. Therefore cleft grafting was the method used for nursery propagation. This enabled smaller budwood to be used to ensure enough plants were available for the project.

## 2.2 Materials and Methods

Project results found that durian responded well to wedge or whip grafting onto healthy 6-month old seedlings. Scion material with active buds was selected for use. Where possible a section of leaf was left attached to the scion. Budwood was kept as fresh as possible with grafting batches of around 50 trees being the maximum attempted. Plastic clothes pegs were used to hold the grafts together till callus had occurred usually three weeks after grafting. Grafts were covered with clear plastic bags. The bags were turned inside out each week and any shoots below the graft union or dead leaves on the scion were removed.

## 2.3 Results and Discussion

Results as presented in Table 4 clearly demonstrate that grafting completed earlier in the year eg: February produced higher success rates. This is probably best demonstrated by Z1. Success rates were excellent in February 2000, yet results plummeted in the April to May period in 2000. There were clonal differences as well. The clone, Petruk had very thin budwood with little reserves and proved difficult to cleft graft. DPI Mon Thong also proving more difficult to graft than other clones.

## 2.4 Nursery Potting Mix

Under nursery conditions in north Queensland, Watson (1984) found that seedlings potted in light sandy rather than high clay content mediums sustained markedly more vigorous growth. Pine bark and sand at the ratio of 80% to 20% has been identified as the best potting mix for durian. This mix has been trialed over the last three years and gives excellent drainage and encourages fine root development. Macro and micronutrients are critical for plant growth and are added to the base potting mixture in the ratios indicated in Table 5. Zappala Tropicals Pty Ltd evaluated the performance of *Trichoderma sp.* of beneficial fungus as part of an IDM strategy to improve *Phytophthora palmivora* control methods in the nursery on a limited observation basis. Further research into beneficial fungi is required.

Since 2000 pelletised chicken manure was used to supplement the potting mix following research findings (Tan *et al.,* 2000) which indicate that chicken manure used in potting mixes can suppress *P. palmivora*.

For Phytophthora control, Nik Masdek and Lee (2000) states that *"Sanitation at the nursery level before planting materials are moved to the field is of primary importance."* This is achieved through pathogen-free potting mixes, storage on benches, good ventilation, restriction of entry to nurseries and testing for Phytophthora prior to planting (Nik Masdek and Lee, 2000).

**Table 4. Project Grafting Results 2000 – 2001.**

| Date | Clone | Wedges | W. Losses | Survival. W | % Success |
|---|---|---|---|---|---|
| 23/03/00 | Sukun | 17 | 7 | 10 | 58.8 |
| 23/03/00 | Hew 7 | 20 | 3 | 17 | 85 |
| 23/03/00 | D190 | 47 | 16 | 31 | 66 |
| 23/03/00 | D99X | 28 | 5 | 23 | 82.1 |
| 11/04/00 | D190 | 57 | 19 | 38 | 66.6 |
| 11/04/00 | Red Prawn | 40 | 24 | 16 | 40 |
| 17/04/00 | Kradum Thong | 12 | 3 | 9 | 75 |
| 17/04/00 | DPI Mon Thong | 23 | 11 | 12 | 52.2 |
| 17/04/00 | D159 | 28 | 10 | 18 | 64.3 |
| 19/04/00 | Red Prawn | 44 | 17 | 27 | 61.4 |
| 19/04/00 | P99 | 33 | 13 | 20 | 60.6 |
| 25/04/00 | Z1 | 49 | 43 | 6 | 12.2 |
| 28/04/00 | *D. macrantha* | 38 | 20 | 18 | 47.4 |
| 28/04/00 | D2 | 12 | 9 | 3 | 25 |
| 5/05/00 | P21 | 45 | 26 | 19 | 42.2 |
| 5/05/00 | P601 | 13 | 4 | 2 | 15.4 |
| 10/05/00 | DPI Mon Thong | 50 | 45 | 5 | 10 |
| 16/05/00 | P88 | 8 | 6 | 2 | 25 |
| 16/05/00 | D159 NG | 24 | 20 | 4 | 16.7 |
| 16/05/00 | Pertuk | 10 | 10 | | 0 |
| 23/05/00 | Z1 | 55 | 48 | 7 | 12.7 |
| 1/02/01 | Red Prawn | 49 | 11 | 38 | 77.5 |
| 8/02/01 | Red Prawn | 38 | 3 | 35 | 92.1 |
| 16/02/01 | Red Prawn | 26 | 12 | 14 | 53.8 |
| 20/02/01 | Z1 | 48 | 1 | 47 | 97.9 |
| 22/02/01 | Red Prawn | 23 | 6 | 17 | 73.9 |
| 6/03/01 | Red Prawn | 14 | 7 | 7 | 50 |
| 6/03/01 | *D. macrantha* | 18 | 3 | 15 | 83.3 |
| 14/03/01 | *D. macrantha* | 25 | 3 | 22 | 88 |
| 14/03/01 | DPI Mon Thong | 13 | 8 | 5 | 38.5 |
| 19/03/01 | Chanee | 9 | 3 | 6 | 33.3 |
| 19/03/01 | Kradum Thong | 10 | 8 | 2 | 20 |

**Table 5. Potting mix for durian now used by Zappala Tropicals Pty Ltd.**

| **Major Ingredient** | **Quantity** |
|---|---|
| Composted pine bark | 80% |
| Sand | 20% |
| **Fertiliser additions per cubic metre** | |
| Superphosphate | 800g |
| Gypsum | 500g |
| Lime | 1000g |
| Dolomite | 2000g |
| Potassium Nitrate | 750g |
| Sulphate of Iron | 1000g |
| Grit Lime | 4000g |
| Chelate micro nutrients | 100g |

## 2.5 Advanced Planting Material

At the MARDI Durian Seminar in Ipoh, June 1992, from a paper titled "*Nursery practices in durian propagation*," Lye Tuk Thye, University of Pertanian (UPM) spoke on the use of advanced planting material (APM) to promote precocity and reduce field mortality. This is simply using planting material grown on in a nursery situation for an additional 6 to 12 months to improve orchard survival.

Zainal *et al*., (1992) states that "*field survival of APM are generally 75% and above, compared with normal plants*" as they "*are able to withstand water stress better as their root: shoot ratio is much higher than normal-sized seedlings* (planting material)." *It is therefore recommended that APM should be widely used in durian cultivation to ensure high field survival, particularly in dry environments. Because APM have to be maintained in the nursery stage longer, their cost of production is inevitably more than normal-size plants. The high cost is justified as growers can be assured of a higher field survival."*

The project researchers have examined the growth measurements of the surviving project trees using the May 1998 data set (Table 6). Trunk diameter was always measured at a point 150 mm above the graft union. The average of the trunk diameter of the 367 surviving project trees was 44.57mm. Table 7 lists row 1 and 2 from the hall site (numbers 16 to 71). These two rows contained 55 project trees, which were the last ones to be planted and therefore the smallest in size. The mortality rate was so high that these trees were deleted from the final data. This was due to the combined effects of Cyclone Justin and the size of the planting material. An analysis of the May 1998 trunk measurements of 47 of these deleted plants indicates that the average trunk diameter was only 8.1mm (Table 7). As tree numbers 20, 26, 27, 32, 40, 41, 45 and 52 were already dead, these tree numbers are excluded from Table 7. 17 of the plants in these rows had a trunk diameter >10 mm while 30 plants were <10mm.

**Table 6. Trunk diameter (mm) of Surviving Project trees, May 1998.**

| **Date** | **Site** | **Number of trees** | **Mean Diameter (mm)** |
|---|---|---|---|
| May 1998 | Hall | 156 | 54.0 |
| May 1998 | House | 211 | 37.0 |
| **May 1998** | **Combined** | **367** | **44.6** |

Table 8 and 9 further demonstrate that weak trees followed by cyclone damage were the major cause of project tree mortality. These tables do not include tree numbers 16 to 71, from the Hall site, which were badly affected by Cyclone Justin. Total tree losses were 134 from the original plantings.

Many replacements also died, as the extreme weather conditions from 1998 to 2000 were unsuitable for newly planted trees. Observations indicate that once a durian tree dies in a planting site, it is difficult for the next replacement to successfully establish. New soil was even introduced into tree numbers 16 to 71 in an attempt to re-establish the replacement trees. This proved unsuccessful.

Therefore APM through improved nursery practices allows the grower the best option to minimise initial orchard establishment losses. APM must be stored on raised benches to avoid contact with the soil. This is standard practice coupled with sterile potting mixes is used within avocado propagation nurseries to combat *Phytophthora cinnamomi*.

In Thailand's durian nurseries, clonal seed selection is practiced to reduce *P. palmivora*. Seed from the clone Chanee is used as Thailand's preferred rootstock (Sangchote, 2000). Zappala Tropicals have used seed stock from the surviving fruiting trees and imported Chanee to provide the nursery plants with the best chance to tolerate *P. palmivora.*

**Table 7. Trunk Diameter (mm) of Tree No 16 to 71, May 1998.**

| No | Variety | Trunk Diameter (mm) |
|---|---|---|
| 16 | Chanee | 8 |
| 17 | Chanee | 10 |
| 18 | D 99TE | 7 |
| 19 | D 99TE | 6 |
| 21 | Chanee | 9 |
| 22 | D123MDI | 5 |
| 23 | D123MDI | 3 |
| 24 | D123MDI | 9 |
| 25 | D 163 | 6 |
| 28 | D 163 | 10 |
| 29 | D 178 | 5 |
| 30 | D 178 | 12 |
| 31 | D 144 | 3 |
| 33 | Sahom | 3 |
| 34 | D 118 | 4 |
| 35 | D 118 | 3 |
| 36 | Sukun | 6 |
| 37 | Sukun | 10 |
| 38 | D 120 | 14 |
| 39 | D 120 | 8 |
| 42 | Sukun | 8 |
| 43 | Sukun | 4 |
| 44 | KK 11 | 10 |
| 46 | Chin | 4 |
| 47 | Chin | 17 |
| 48 | D 164 | 6 |
| 49 | D 164 | 8 |
| 50 | D 164 | 17 |
| 51 | D 96 | 7 |
| 53 | D 16 | 4 |
| 54 | D 16 | 3 |
| 55 | D 16 | 3 |
| 56 | Permasuri | 9 |
| 57 | Permasuri | 11 |
| 58 | Hew 6 | 6 |
| 59 | Hew 6 | 12 |
| 60 | Hew 6 | 14 |
| 61 | Hew 7 | 10 |
| 62 | Hew 7 | 19 |
| 63 | D 96 | 6 |
| 64 | D 96 | 4 |
| 65 | Permasuri | 10 |
| 66 | Permasuri | 8 |
| 67 | D 164 | 3 |
| 69 | Chin | 14 |
| 70 | Chin | 11 |
| 71 | Chin | 11 |
| **Average Trunk Diameter (mm)** | | **8.1** |

**Table 8. Observations for Hall site from April 1997 to June 2001 for Field Mortality.**

| Date | Row | Tree No. | Variety | Planting Date | Comments |
|---|---|---|---|---|---|
| Sep-97 | 3 | 72 | Kradum Thong | 95/96 | died, weak tree, cyclone |
| Sep-97 | 3 | 73 | Kradum Thong | 95/96 | died, weak tree, cyclone |
| Sep-97 | 3 | 91 | D 24 | 95/96 | died, cane grub damage |
| Apr-97 | 3 | 98 | D 144 | 95/96 | died, weak tree, cyclone |
| Apr-97 | 3 | 101 | D 168 | 95/96 | died, weak tree, cyclone |
| Apr-97 | 3 | 108 | Sahom | 95/96 | died, weak tree, cyclone |
| Apr-97 | 3 | 109 | Sahom | 95/96 | died, weak tree, cyclone |
| Sep-97 | 3 | 110 | Ampung | 95/96 | died, weak tree, cyclone |
| Apr-97 | 4 | 112 | KK 11 | 95/96 | died, weak tree, cyclone |
| Apr-97 | 4 | 113 | DPI Mon Thong | 95/96 | died, weak tree, cyclone |
| Dec-99 | 4 | 114 | Capri | 95/96 | died, weak tree, cyclone |
| May-98 | 4 | 115 | D 160 | 95/96 | died, weak tree, cyclone |
| Dec-99 | 4 | 117 | D 10 | 95/96 | died, weak tree, cyclone |
| Apr-97 | 4 | 138 | D 24 | 95/96 | died, weak tree, cyclone |
| Dec-99 | 4 | 140 | D 24 | 95/96 | died, weak tree, cyclone |
| Dec-99 | 4 | 150 | D 24 | 95/96 | died, weak tree, cyclone |
| Sep-97 | 4 | 151 | Hepe | 95/96 | died, weak tree, cyclone |
| May-99 | 5 | 158 | D 99 | 96/97 | died, weak tree, cyclone |
| Sep-97 | 5 | 159 | D 163 | 96/97 | died, weak tree, cyclone |
| Sep-97 | 5 | 163 | D 175 | 96/97 | died in cyclone |
| May-98 | 5 | 167 | P 21 | 96/97 | died, weak tree, cyclone |
| Apr-97 | 5 | 170 | D 179 | 96/97 | died, weak tree, cyclone |
| Apr-97 | 5 | 172 | D 179 | 96/97 | died, weak tree, cyclone |
| Apr-97 | 5 | 173 | D 144 | 96/97 | died, weak tree, cyclone |
| May-98 | 5 | 174 | D 188 | 96/97 | died, weak tree, cyclone |
| Sep-97 | 5 | 175 | D 188 | 96/97 | died, weak tree, cyclone |
| Sep-97 | 5 | 177 | D 168 | 96/97 | died, weak tree, cyclone |
| May-99 | 5 | 178 | D 168 | 96/97 | died, weak tree, cyclone |
| May-99 | 5 | 179 | D 168 | 96/97 | died, weak tree, cyclone |
| May-98 | 5 | 182 | Sahom | 96/97 | died, weak tree, cyclone |
| May-99 | 6 | 190 | Gumpun | 92/93 | died, weak tree, cyclone |
| Jun-01 | 6 | 200 | Hepe | 94/95 | died, weak tree, cyclone |
| Apr-97 | 6 | 209 | D 24 | 94/95 | died, weak tree, cyclone |
| Apr-97 | 6 | 210 | Hew 1 | 94/95 | died, weak tree, cyclone |
| Apr-97 | 6 | 211 | Hew 1 | 94/95 | died, weak tree, cyclone |
| May-98 | 6 | 226 | D 24 | 94/95 | died in cyclone |
| May-98 | 6 | 227 | D 2 | 94/95 | died in cyclone |
| May-98 | 6 | 230 | D 24 | 94/95 | died, weak tree, cyclone |
| Apr-97 | 6 | 237 | D 98 | 94/95 | died, weak tree, cyclone |
| Dec-99 | 7 | 255 | D 24 | 94/95 | died, weak tree, cyclone |
| Jun-01 | 7 | 264 | D 24 | 94/95 | died, weak tree, cyclone |
| May-99 | 9 | 274 | Luang | 92/93 | died, weak tree, cyclone |
| Dec-99 | 9 | 299 | Luang | 92/93 | died, weak tree, cyclone |
| May-99 | 10 | 324 | H. Mon Thong | 92/93 | died, weak tree, cyclone |
| **Total Losses at the Hall site: 44 trees** | | | | | |

**Table 9. Observations for House site from April 1997 to June 2001 for Field Mortality.**

| Date | Row | Tree No. | Variety | Planting Date | Comments |
|---|---|---|---|---|---|
| Jun-01 | 1 | 332 | HEW 2 | 94/95 | died, weak tree, cyclone |
| May-99 | 1 | 341 | HEW 1 | 94/95 | died, weak tree, cyclone |
| Apr-97 | 1 | 342 | Sukun | 94/95 | died, weak tree, cyclone |
| Jun-01 | 2 | 361 | Sahom | 95/96 | died, weak tree, cyclone |
| May-99 | 3 | 370 | P 21 | 95/96 | died, weak tree, cyclone |
| Dec-99 | 3 | 371 | P 21 | 95/96 | died, weak tree, cyclone |
| Apr-97 | 4 | 387 | D 140 | 95/96 | died, replaced twice |
| Apr-97 | 4 | 391 | D 168 | 95/96 | died, replaced twice |
| Sep-97 | 4 | 394 | D 99X | 95/96 | died in cyclone |
| Apr-97 | 4 | 395 | D 2 | 95/96 | died, weak tree, cyclone |
| Sep-97 | 4 | 400 | D 24 | 95/96 | died in cyclone |
| Apr-97 | 4 | 401 | D 2 | 95/96 | died twice |
| Sep-97 | 4 | 402 | D 24 | 95/96 | died, replaced twice |
| Dec-99 | 4 | 403 | D 24 | 95/96 | died, weak tree, cyclone |
| Apr-97 | 5 | 405 | D 16 | 95/96 | died, weak tree, cyclone |
| Sep-97 | 5 | 406 | D 24 | 95/96 | died, replaced twice |
| Dec-99 | 6 | 431 | D10 | 95/96 | died in cyclone |
| Apr-97 | 1 | 449 | D 96 | 96/97 | died in cyclone |
| May-99 | 1 | 450 | Gumpun | 93/94 | died, weak tree, cyclone |
| Apr-97 | 2 | 471 | Chanee | 96/97 | died, weak tree, cyclone |
| Apr-97 | 3 | 500 | D 188 | 95/96 | died, weak tree, cyclone |
| Apr-97 | 3 | 503 | D 188 | 95/96 | died, weak tree, cyclone |
| Apr-97 | 3 | 512 | Ampung | 95/96 | died, weak tree, cyclone |
| Apr-97 | 3 | 528 | Kan Yao | 95/96 | died, weak tree, cyclone |
| May-99 | 4 | 538 | Hew 7 | 95/96 | died, weak tree, cyclone |
| May-99 | 5 | 563 | D 120 | 95/96 | died, weak tree, cyclone |
| May-99 | 6 | 573 | D 24 | 96/97 | died, weak tree, cyclone |
| May-99 | 6 | 583 | D 24 | 96/97 | died, weak tree, cyclone |
| May-99 | 6 | 587 | D 24 | 96/97 | died, weak tree, cyclone |
| Dec-99 | 7 | 590 | XA | 96/97 | died, weak tree, cyclone |
| May-99 | 7 | 595 | Chin | 96/97 | died, weak tree, cyclone |
| Jun-01 | 7 | 597 | Chin | 96/97 | died, weak tree, cyclone |
| May-99 | 7 | 599 | D 160 | 96/97 | died, weak tree, cyclone |
| May-99 | 8 | 615 | D 145 | 96/97 | died, weak tree, cyclone |
| May-99 | 8 | 616 | D 24 S | 96/97 | died, weak tree, cyclone |
| **Total Losses at the House site: 35 trees** | | | | | |

## 2.6 Recommendations

Healthy planting material is a pre-requisite for orchard establishment and demonstrates the need for a combination of advanced planting material produced with sterile potting media to maximise orchard survival. This is best achieved by:

1. Australian Durian Nurseries to adopt the most suitable aspects from the Avocado Nursery Voluntary Accreditation Scheme (ANVAS),

2. Research findings from ACIAR Project PHT95/134, titled “Management of Phytophthora Diseases in Durian” should be closely monitored and adopted by Australia’s durian nurseries, and,

3. Beneficial fungi such as *Trichoderma sp*, should be trialed in a nursery situation (under DPI supervision), as a supplement to sterile potting mixes.

## 2.7 References

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# 3. Clonal Evaluation

## 3.1 Introduction

Since 1992, forty new durian clonal introductions from Malaysia, Thailand and Indonesia are now successfully established in Australia from reliable budwood sources fostered by this project's researchers. This research mirrors the extensive evaluation of approximately 50 rambutan (*Nephelium lappaceum*) clones by Brian Watson, OIC, Kamerunga Research Station during the 1970's. Brian Watson's rambutan evaluation has lead to the development of an industry based in north Queensland and the Northern Territory, which now exports fresh fruit to Japan. The major difference between the DPI rambutan evaluation and this durian evaluation is that in the durian evaluation more replicates were used and trees were grown under orchard conditions using two differing soil types.

The original project objective was to trial 30 clones by 5 replications at both soil types. (Total 300 trees.) The project researchers decided to increase the numbers of plantings in trial sites so additional imported clones were included for evaluation within the existing budget and timeframe. This risk management plan ensures additional clonal replications in the event of tree losses occurring from unexpected weather conditions or diseases. This action will supply existing and prospective growers with more clonal information from this project.

## 3.2 Climatic Observations

As mentioned in the summary of findings, the 5-year period of clonal observations was one of the most extreme encountered by the researchers. This provided an excellent test for the imported clones. Yearly averages of temperature, rainfall, evaporative transpiration (ET) and Short wave solar radiation are listed in the following tables. The complete 5-year daily data set is available upon request from the researchers.

**Table 10. Weather Summary 1997 to 2001.**

| | **1997** | **1998** | **1999** | **2000** | **2001** |
|---|---|---|---|---|---|
| Av Temperature (C°) | 23.0 | 24.7 | 23.7 | 23.5 | 23.8 |
| Av. Max Temp (C°) | 28.2 | 29.5 | 28.4 | 28.2 | 29.0 |
| Max Max Temp (C°) | 33.9 | 35.3 | 36.2 | 35.8 | 36.1 |
| Min Max Temp (C°) | 20.2 | 20.6 | 19.6 | 20.0 | 22.1 |
| Av. Min Temp (C°) | 17.9 | 19.9 | 18.9 | 18.8 | 18.6 |
| Max Min Temp (C°) | 24.6 | 25.0 | 25.3 | 24.6 | 28.3 |
| Min Min Temp (C°) | 6.9 | 8.4 | 7.2 | 5.3 | 4.8 |
| Highest Daily Rainfall (mm) | 323.2 | 319.6 | 368.2 | 322.8 | 346 |
| Total Rainfall (mm) | 3968 | 4335 | 5850 | 6278 | 4002 |
| Highest Daily ET (mm) | 6.19 | 5.69 | 5.72 | 5.93 | 4.93 |
| Total ET (mm) | 1102 | 1062 | 1067 | 1006 | 909 |
| Rainfall minus ET (mm) | 2866 | 3273 | 4783 | 5272 | 3093 |
| Total SWSR (mJ/m²) | 5741 | 5479 | 5364 | 5049 | 4685 |

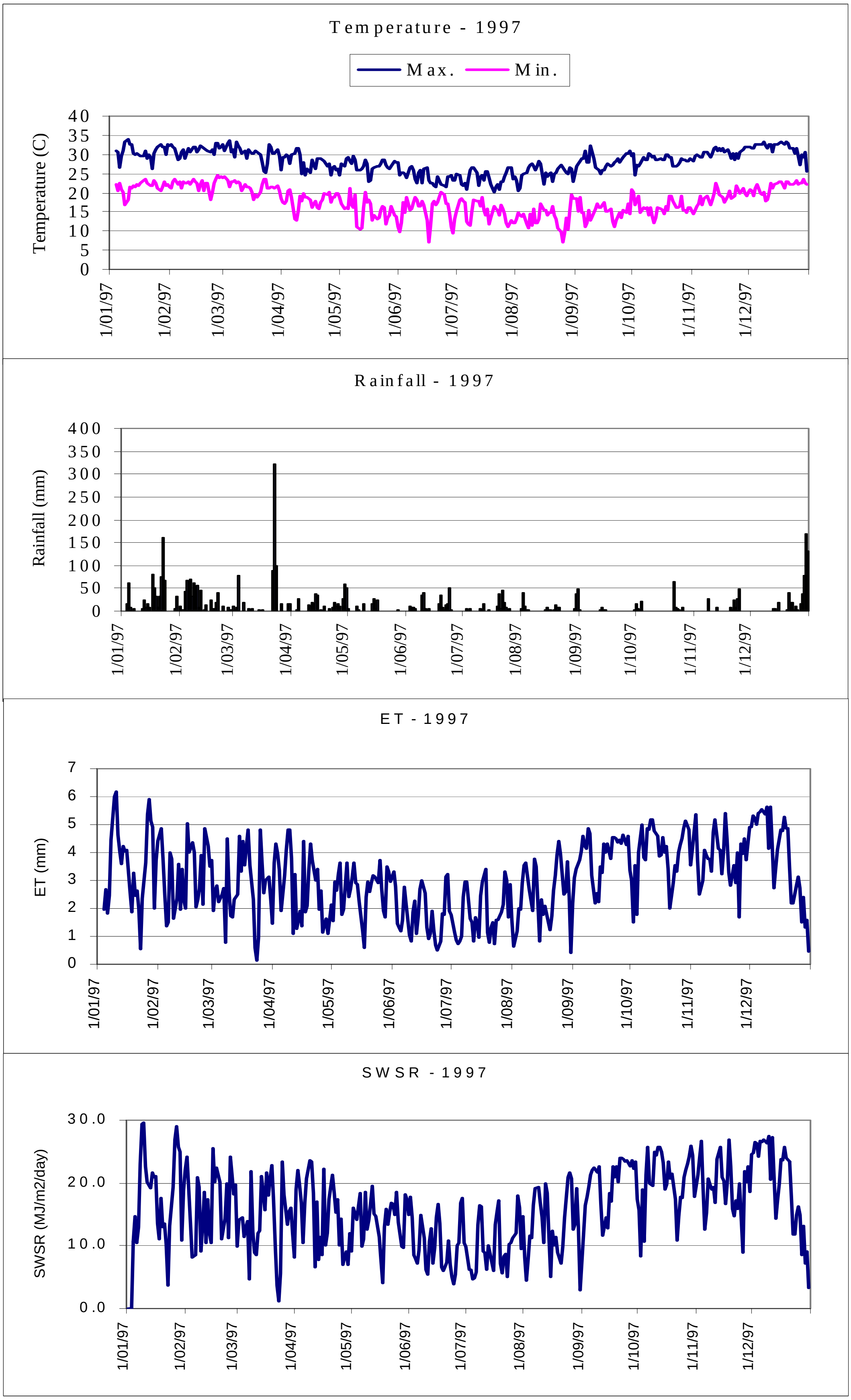


**Figure 1. Daily temperature (max and min), rainfall, evapotranspiration (ET) and short wave solar radiation (SWSR) recorded at Zappala Tropicals in 1997.**

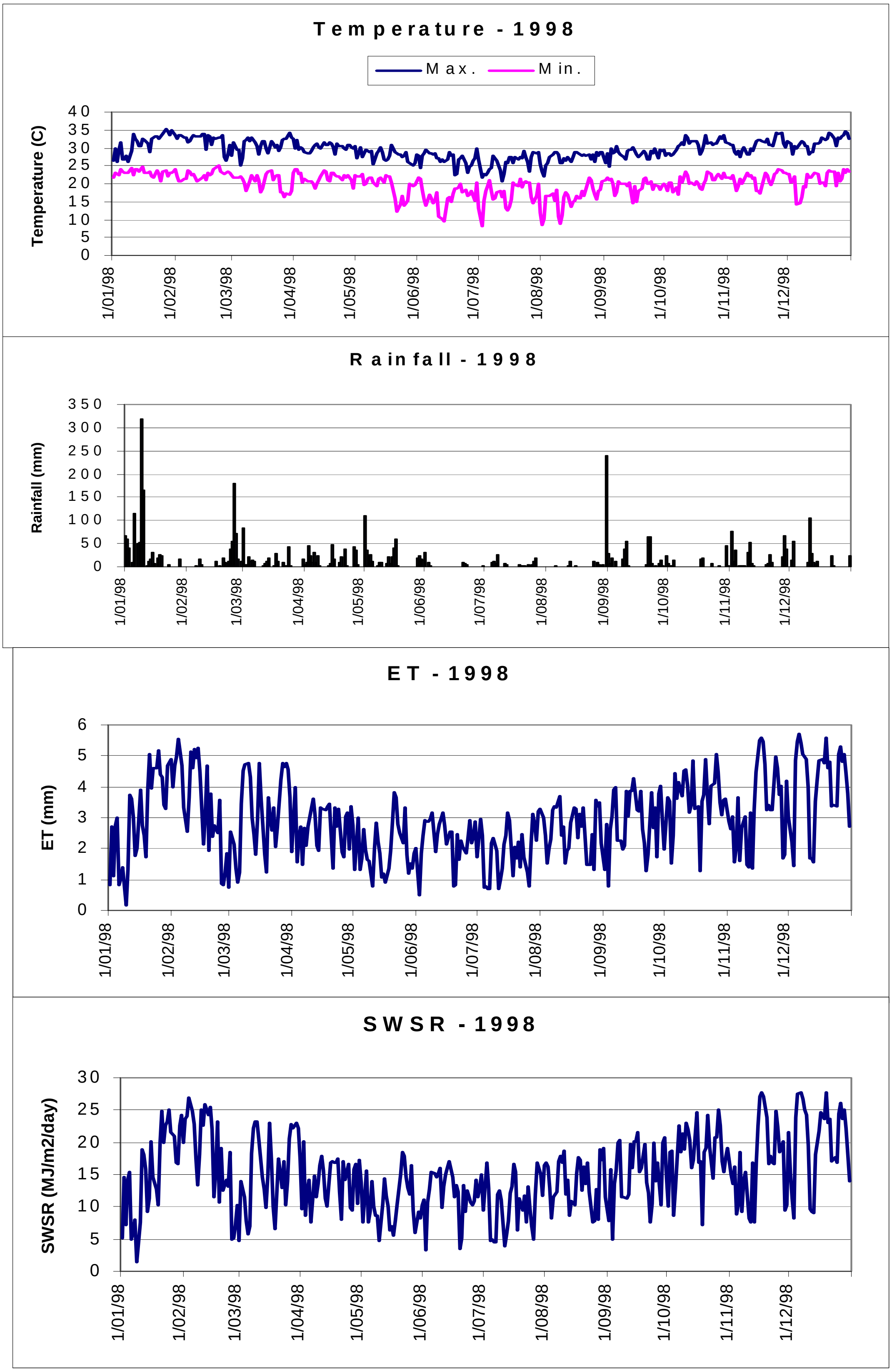


**Figure 2. Daily temperature (max and min), rainfall, evapotranspiration (ET) and short wave solar radiation (SWSR) recorded at Zappala Tropicals in 1998.**

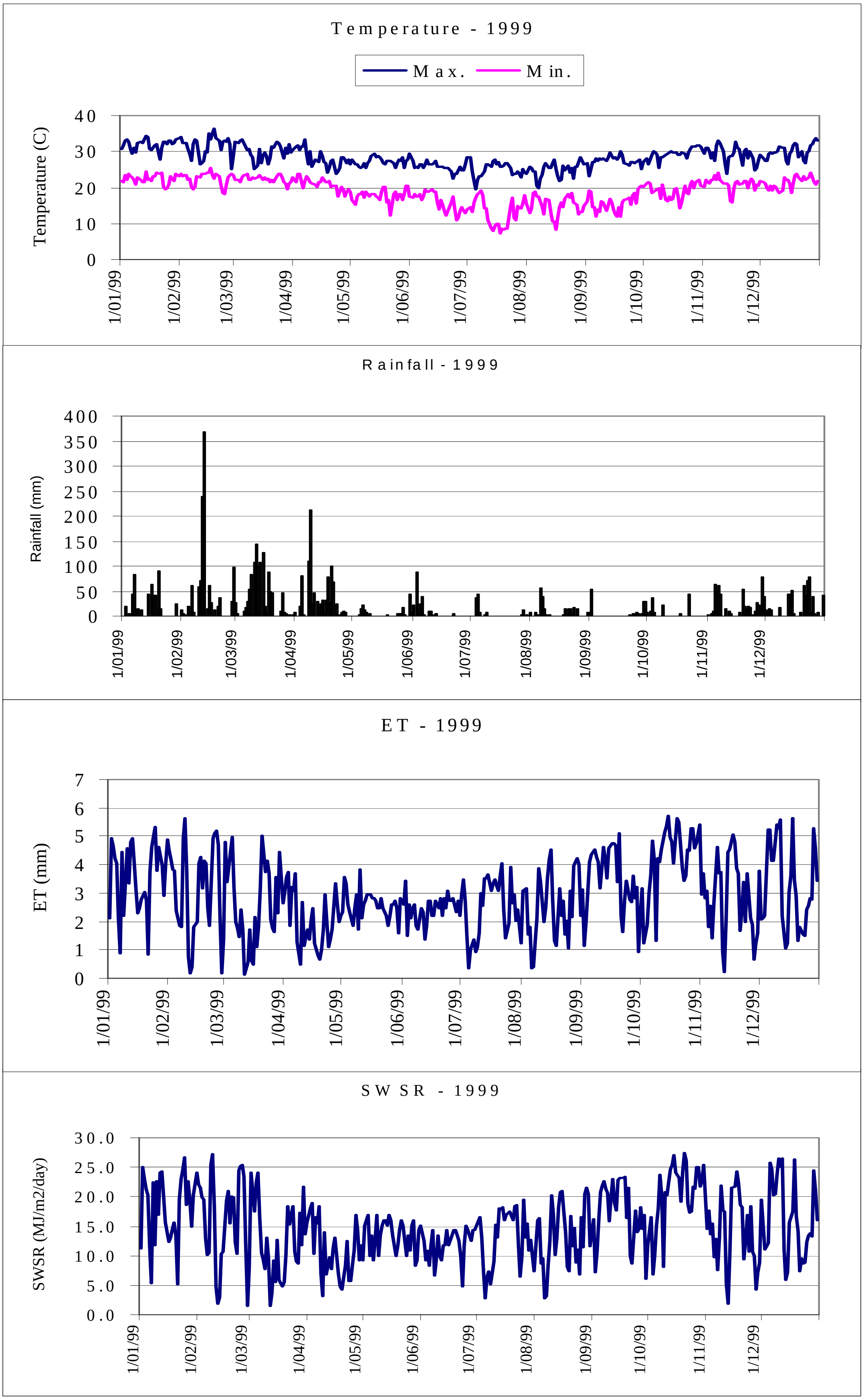


**Figure 3. Daily temperature (max and min), rainfall, evapotranspiration (ET) and short wave solar radiation (SWSR) recorded at Zappala Tropicals in 1999.**

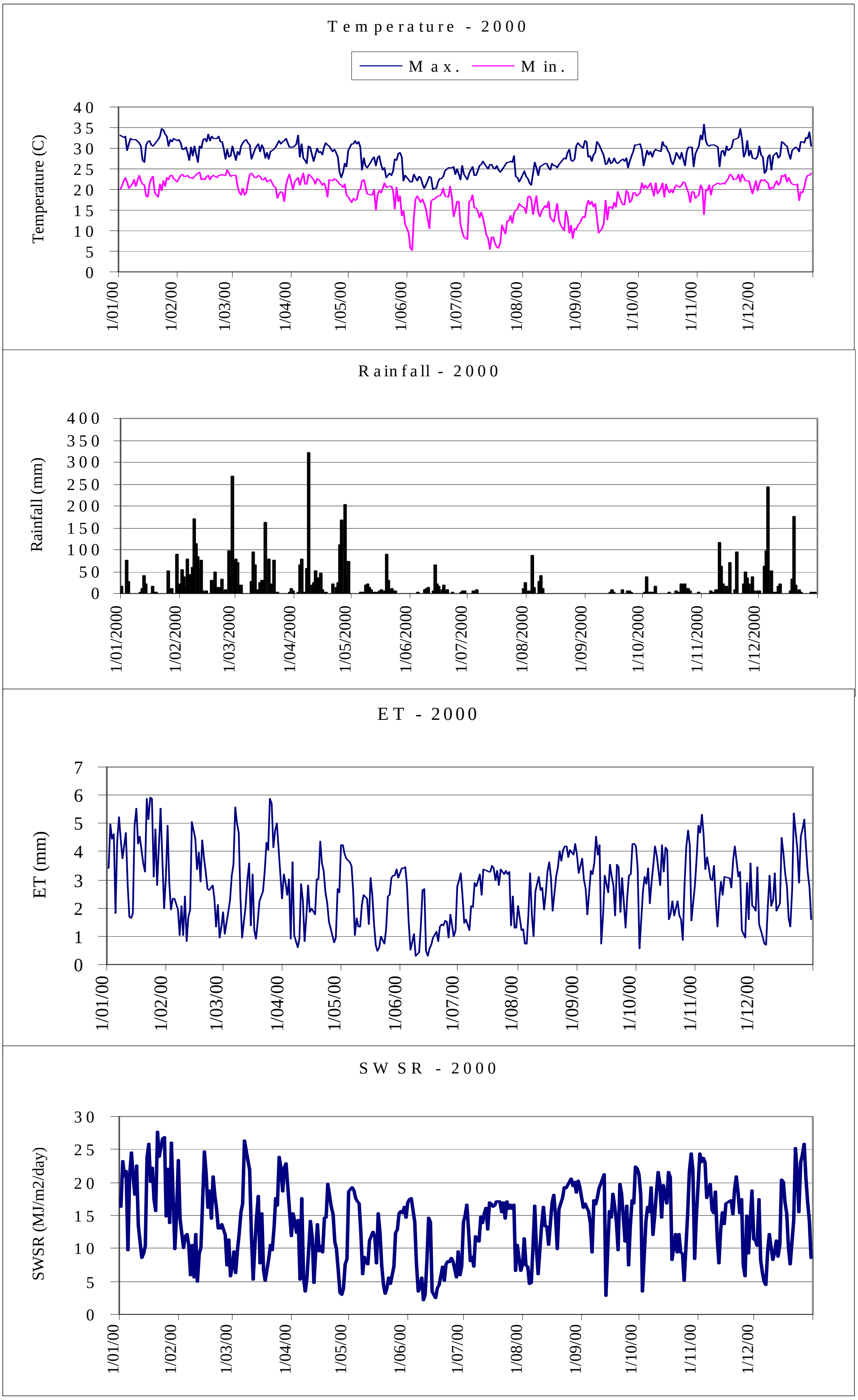


**Figure 4. Daily temperature (max and min), rainfall, evapotranspiration (ET) and short wave solar radiation (SWSR) recorded at Zappala Tropicals in 2000.**

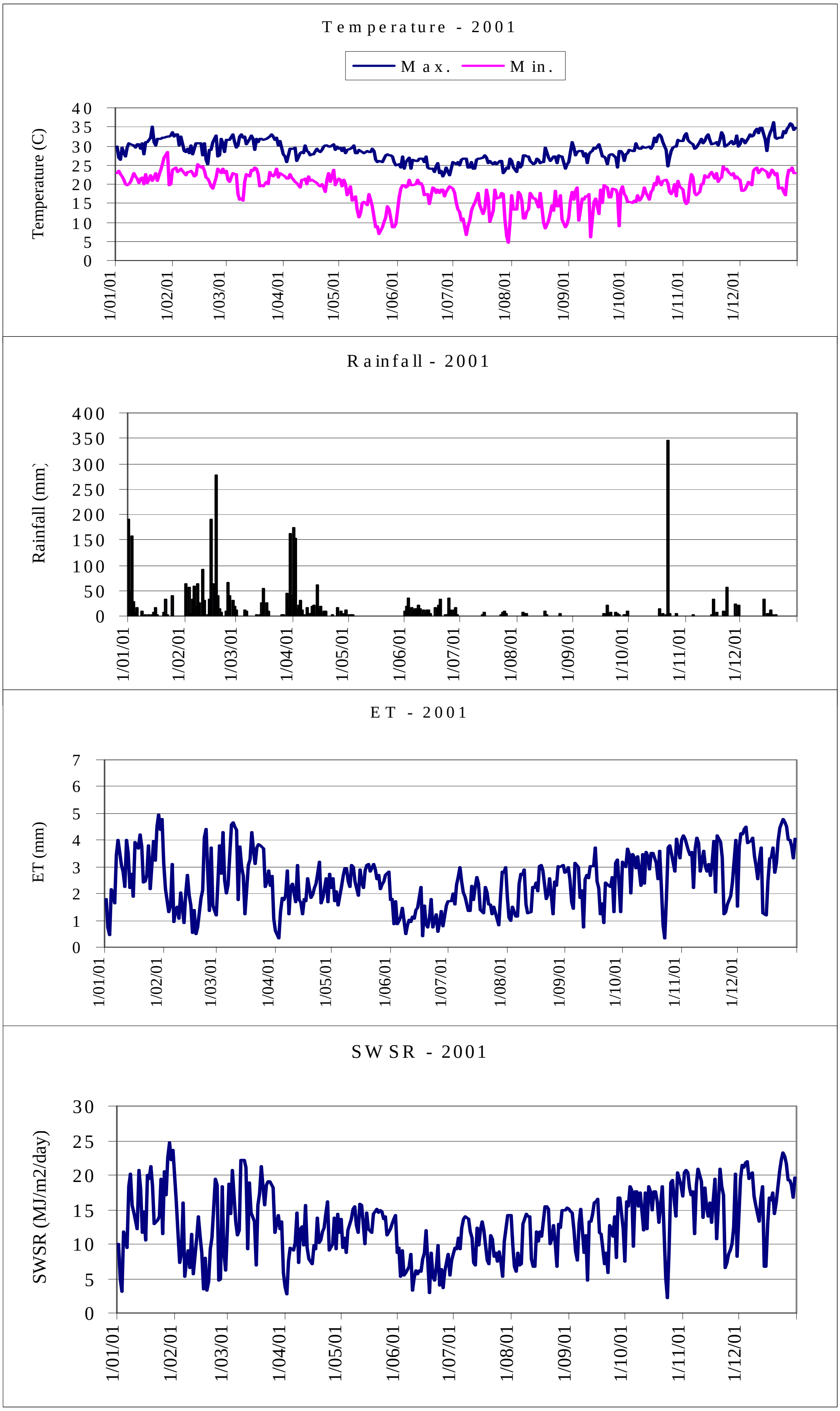


**Figure 5. Daily temperature (max and min), rainfall, evapotranspiration (ET) and short wave solar radiation (SWSR) recorded at Zappala Tropicals in 2001.**

Planting out of the project's clones was completed in January 1997. Unfortunately the last plantings were severely affected by Cyclone Justin on 22 March 1997. The House site (granite gravel) lost 12% of its plantings and the Hall site (red volcanic) lost almost 15% of its plantings (Table 11).

Total planting at the House site were 288, 5 replicates of 32 clones and total planting at the Hall site were 304, 5 replicates of the same 32 clones. In 2000, tree numbers 16 to 71 (55 trees) were deleted from further research as they failed to recover from Cyclone Justine. Unfortunately these rows contained the replicates of Chanee (4), Permasuri (4), Chin (5), D 163 (4), Sukun (5), D 96 (4), Hew 6 (3), D 120 (3), D 123 (3) D 16 (3), 2 each of the following, D 118, KK 11, D 178, D 144, D 164, Hew 7, D 99X and Sahom (1). This has disadvantaged these clones due to limited observations.

**Table 11. Tree Losses due to Cyclone Justin, March 1997.**

| RIRDC Trial sites | Total Trees planted at 1/1/97 | Total Losses at 13/9/97 | % of Losses at 13/9/97 |
|---|---|---|---|
| House site | 292 | 35 | 12.0 |
| Hall site | 296 | 44 | 14.9 |
| Total | 588 | 79 | 13.4 |

## 3.3 Clonal Evaluation Criteria

Clones were evaluated on a number of selection criteria. These included:

1. the authenticity of the budwood source,
2. classification and identification of 28 clones by DNA testing,
3. planting survival rate,
4. tree growth rate and structure,
5. comparison of clonal survival between both sites,
6. pest and disease observation,
7. response to cold temperature and strong wind,
8. early flowering and fruiting habit,
9. fruit quality and yield data from project trees identified in Group 1.

All of the above were considered influences in the evaluation process. Selection of the clones for their particular groupings listed in Chapter 3.7 Recommendations. The researchers considered the ability to survive the north Queensland climatic conditions was one of the major considerations for selection. These results are listed in Table 12.

Growth rates measured by increased trunk diameter and clonal growth comparisons between the two sites are discussed in Chapter 3.5 Statistical Analysis to support observations.

Clonal responses to cold temperature are listed in Table 35. Early flowering, fruit yield and quality are listed in Table 36. When fruit yield and quality data was not available, data was used from reliable overseas sources and personal observations by the researchers (Chapter 7. Clonal Recommendations).

The classification and identification of 28 clones by DNA testing is listed in Figures 16 and 17. All of Group 1 have been classified by DNA.

## 3.4 Results and Discussion

The coldest minimum temperatures are listed in Table 3 and 10 causing severe leaf drop on many trees. Several weeks after 18 July 1999 cold snap, all project trees were monitored for leaf defoliation /abscission. Rating of each of the clones was noted using three groupings of tolerance. These were Nil to 10%, Light 10 – 25% and Moderate 25 – 50%. Results are included in Table 35.

One clone D175 (Red Prawn) which originated from Penang, Malaysia, proved to be the most tolerant of this temperature. D175 is a popular clone in Penang with both consumers and growers as it is highly productive and has excellent fruit shape and flesh qualities. It was a winner of many durian competitions in Penang during the 1990's (Lim B. T., personal communications, 1996). No leaf drop occurred with D175, which is an important observation and could mean that the current Queensland durian production area may be successfully extended further to the south than at present.

Other clones to perform well included Chanee, D 118, D 144, D 190, D 197, *D. macrantha*, Kan Yao and Kradum Thong while D 7, D 16, D 143, D 179, Hepe, Hew 6, Luang, Sukun and P 21 all performed poorly in low temperatures. An example of severe cold damage was Luang tree number 299, planted in 1992/93, died following severe leaf drop in 2001.

The remaining clones were observed to have had light defoliation. This is one of the most critical areas for durian orchard management as when a major leaf drop occurs, affected plants commence a vegetative growth phase to recover. A healthy leaf canopy is a pre-requisite for a successful and sustainable crop. Low winter temperatures or drought is a trigger for flowering but severe leaf drop can cause the grower to miss a complete crop cycle.

Yaacob and Subhadrabandhu (1995) report that "*The durian tolerates neither a cold climate nor a dry one. However in equatorial regions, it requires a relatively dry period to induce flowering. In some places (e.g. Malaysia), it may occasionally not fruit for 1 or 2 years because the dry season is too short or absent altogether.*"

Therefore identifying cold tolerant clones is one of the major objectives for a consistent supply of fruit to the consumer. When this selection criteria is coupled to the known fruit quality of the productive clone in Malaysia, this will be a real bonus for the industry. D 175 clearly was outstanding in this category followed by Chanee, D 118, D 144, D 190, D 197, *D. macrantha*, Kan Yao and Kradum Thong.

**Table 12. Original Planting Survival (32 clonal replicates).**

| Clone | Origin and Alternative Name | No's planted House Site. | No's planted Hall Site | No's Alive Plot 1 June 2001 | No's Alive Plot 2 June 2001 | % Survival House | % Survival Hall | Comments |
|---|---|---|---|---|---|---|---|---|
| Ampung | Malaysia | 5 | 5 | 4 | 4 | 80 | 80 | Weak tree |
| Chanee | Thailand | 6 | 5 | 5 | 1 | 83 | 20 | Hall results severely affected by the deletion of 4 replicate trees in rows 1 and 2. |
| Chin | Malaysia | 5 | 5 | 3 | - | 60 | 0 | Hall results severely affected by the deletion of 5 replicate trees |
| D 118 | Malaysia<br>Tembaga | 5 | 5 | 2 | 3 | 40 | 60 | Flaming colour flesh. Hall results severely affected by deletion of 2 replicate trees in rows 1 and 2 |
| D 120 | Malaysia<br>KK5 | 5 | 5 | 3 | 2 | 60 | 40 | Cyclone damage to Hall replicates. Hall results severely affected by deletion of 3 replicate trees in rows 1 and 2 |
| D 16 | Malaysia<br>Putih Manis | 5 | 5 | 3 | 1 | 60 | 20 | Weak tree. Hall results affected by deletion of 3 replicate trees in rows 1 and 2. |
| D 144 | Malaysia Hybrid (D 2 X D24) | 7 | 5 | 6 | 1 | 86 | 20 | Hall results affected by deletion of 2 replicate trees in rows 1 and 2. |
| D 163 | Malaysia<br>Hor Lor | 5 | 5 | 2 | - | 40 | 0 | Penang selection, weak tree, very strong flavour, lantern shape fruit Hall results severely affected by deletion of 4 replicate trees in rows 1 and 2. Lack of budwood |

**Table 12 continued.** **Original Planting Survival Table for the 32 clonal replicates**

| Clone | Origin and Alternative Name | No's planted site 1 House Block. | No's planted site 2. Hall Block | No's Alive Plot 1 June 2001 | No's Alive Plot 2 June 2001 | % Survival House | % Survival Hall | Comments |
|---|---|---|---|---|---|---|---|---|
| D 164 | Malaysia Ang Bak, Red Flesh | 5 | 5 | 3 | - | 60 | 0 | Hall results affected by deletion of 2 replicate trees Penang selection |
| D 168 | Malaysia<br>Mas Muar | 6 | 5 | 5 | 1 | 83 | 20 | Hall results affected by deletion of 4 replicate trees in rows 1 and 2. |
| D 175 | Malaysia Udang Merah, Ang Hea, Red Prawn | 5 | 5 | 5 | 4 | 100 | 80 | Penang selection, most cold tolerant clone<br>Regular durian competition winner in Penang |
| D 178 | Malaysia<br>Penang 88 | 6 | 5 | 5 | 3 | 83 | 60 | Penang selection, upright tree, fruiting for the first time in Australia<br>Hall results affected by deletion of 2 replicate trees in rows 1 and 2. |
| D 179 | Malaysia<br>Penang 99 | 7 | 5 | 5 | 3 | 71 | 60 | Penang selection |
| D 190 | Malaysia<br>MDUR 88 | 10 | 5 | 8 | 4 | 80 | 80 | Latest MARDI hybrid |

**Table 12 continued.** **Original Planting Survival Table for the 32 clonal replicates**

| Clone | Origin and Alternative Name | No's planted site 1 House Block. | No's planted site 2. Hall Block | No's Alive Plot 1 June 2001 | No's Alive Plot 2 June 2001 | % Survival House | % Survival Hall | Comments |
|---|---|---|---|---|---|---|---|---|
| D 2 | Malaysia<br><br>Dato Nina | 6 | 9 | 2 | 7 | 33 | 78 | Strong upright tree |
| D 24 | Malaysia<br><br>Bukit Merah | 20 | 24 | 10 | 15 | 50 | 63 | Weak tree, needs well protected site, most losses due to cyclone damage |
| D 99 | Malaysia | 5 | 5 | 5 | 2 | 100 | 40 | Thai clone similar to Kradum Thong. Hall results affected by deletion of 2 replicate trees |
| D 99X | Malaysia<br><br>Kop | 9 | 6 | 7 | 3 | 78 | 50 | Hall results affected by deletion of 2 replicate trees in rows 1 and 2. Large fruit |
| *D. macrantha* | Indonesia | 11 | 5 | 10 | 5 | 91 | 100 | Only tree to be replanted was the result of an incompatible graft union. |
| DPI Mon Thong | Thailand | 5 | 5 | 5 | 4 | 100 | 80 | Brian Watson was responsible for introducing this clone into Australia |
| Kan Yao | Thailand | 5 | 11 | 5 | 9 | 100 | 82 | Excellent tasting clone |
| Hawaiian Mon Thong | Hawaii | 5 | 8 | 4 | 7 | 80 | 88 | Hall losses due to cyclone damage |
| Hepe | Indonesia | 5 | 16 | 5 | 14 | 100 | 88 | Upright tree with leaves similar to *D. macrantha* |
| Hew 6 | Malaysia | 5 | 5 | 3 | 1 | 60 | 20 | Hall results affected by deletion of 3 replicate trees in rows 1 and 2. |

**Table 12 continued. Original Planting Survival Table for the 32 clonal replicates**

| Clone | Origin and Alternative Name | No's planted Site 1 House Block. | No's planted Site 2. Hall Block | No's Alive Site 1 June 2001 | No's Alive Site 2 June 2001 | % Survival House | % Survival Hall | Comments |
|---|---|---|---|---|---|---|---|---|
| Hew 7 | Malaysia | 5 | 5 | 4 | 3 | 80 | 60 | Hall results affected by deletion of 2 replicate trees in rows 1 and 2. |
| KK 11 | Malaysia | 5 | 5 | 4 | 3 | 80 | 60 | Hall results affected by deletion of 2 replicate trees in rows 1 and 2. Information from MARDI suggests that this is *Phytophthora palmivora* |
| Kradum Thong | Thailand | 13 | 5 | 13 | 3 | 100 | 60 | Reliable fruiting clone, easy to flower |
| Luang | Thailand | 5 | 20 | 4 | 19 | 80 | 95 | This is not the true Thai Luang clone |
| P21 | Malaysia<br><br>Baby Red Flesh | 5 | 5 | 3 | 4 | 60 | 80 | Penang selection |
| Permasuri | Malaysia | 5 | 5 | - | 1 | 20 | 0 | Hall results severely affected by deletion of 4 replicate trees in rows 1 and 2 |
| Sahom | Malaysia | 5 | 5 | 4 | 1 | 80 | 20 | Hall results slightly affected by deletion of 1 replicate trees in rows 1 and 2. |
| Sukun | Indonesia | 5 | 7 | 3 | 1 | 60 | 14 | Hall results severely affected by deletion of 5 replicate trees in rows 1 and 2. Defoliates badly in lower temperatures. |

## 3.5 Statistical Analysis to support observations

Mr Gary Doak, CSIRO Brisbane and a rare fruit enthusiast kindly offered to assist with a statistical analysis comparing changes in trunk diameter from May 1998 to June 2001.

Statistical analysis has been difficult. Differing numbers of introductions through quarantine, differing planting date, dual rootstocks and cyclone damage have impacted on an accurate analysis of the growth measurements. Here is just one example using the clone "Sahom" of how the researchers have had to identify the superior clones. Sahom tree number 262 was introduced from Malaysia as a bare rooted tree. Other tree numbers 108, 109, 182, 361, 363, 365, 529 and 530 were budded in quarantine. Tree number 262 has increased in trunk diameter from planting out in 1994/95 by 110 mm hence topped the performance in Hall site. The other 3 replicates of this clone on the hall site all died. On the house site tree number 363, 365 (planted in 1994/95) 529, and 530 (planted in 1995/96) all increased their trunk diameter by 51, 14, 61 and 47 mm respectively, while 361 died. After an analysis of this clone, the researchers have decided to place it in Group 2, "Potential additions for grower plantings."

Statistical analysis by the Quartile method has generally supported the research observations to designate the Malaysian clones Ampung, D 7, and D 16 to Group 3 (deleted from further research) as these were placed in either Quartile 1 or 2 on both sites.

When checking increases in trunk against the Group 1 recommendations, D 190 and *D. macrantha* were both identified in Quartile 4 (Q4) at the house site and Quartile 3 (Q3) in the Hall site. DPI Mon Thong and Kradum Thong both secured a Q3 rating in the House site and Q2 rating at the Hall site. Hawaiian Mon Thong was a Q1 rating in the House site and Q4 rating at the hall and D 175 received a Q3 rating in the House site and Q1 rating at the hall.

The researchers had to remove two rows planted in Hall site (numbers 16- 71) from the data analysis due to tree death. All other clones that failed to survive the 5-year period were also removed from the data collection. This resulted in the Hall site having 74% of the data entries compared to the House site (Hall: n = 156, House: n = 210). Canopy width and height measurements were disregarded in the analysis and only trunk diameter measured 150mm above the graft unions were used. Canopy width and tree height data could easily be affected by pruning or wind damage and trunk diameter as used in Forestry research, and was considered the most consistent measurement for the final analysis.

### 3.5.1 Hall site. Discussion and Results

The trunk diameter growth measurements between May 1998 and June 2001 for all trees that survived on the Hall site were analysed. A total of 156 measurements were available and the descriptive statistics are outlined in table 13 below.

To assist growers to digest these statistical terms, the following explanation is provided.

**Mode** – Value which occurs with the greatest frequency,
**Median** –The value above which half the data is lower in value and half is higher,
**Range** – The difference between the lowest and highest,
**Skewness** – Characterises of the degree of asymmetry of a distribution around the mean,
**Kurt** – Characterises the relative peakness or flatness of a distribution compared to a normal distribution.

**Table 13. Hall trunk growth – descriptive statistics**

| HALL Trunk growth Descriptive statistics | |
|---|---|
| Mean | 65.5 |
| Standard Error | 2.2 |
| Median | 67.0 |
| Mode | 76.0 |
| Standard Deviation | 26.9 |
| Sample Variance | 725.2 |
| Kurtosis | 0.7 |
| Skewness | 0.3 |
| Range | 167 |
| Minimum | 6 |
| Maximum | 173 |
| Count | 156 |

The distribution of these measurements were examined and plotted in Figure 6 below.

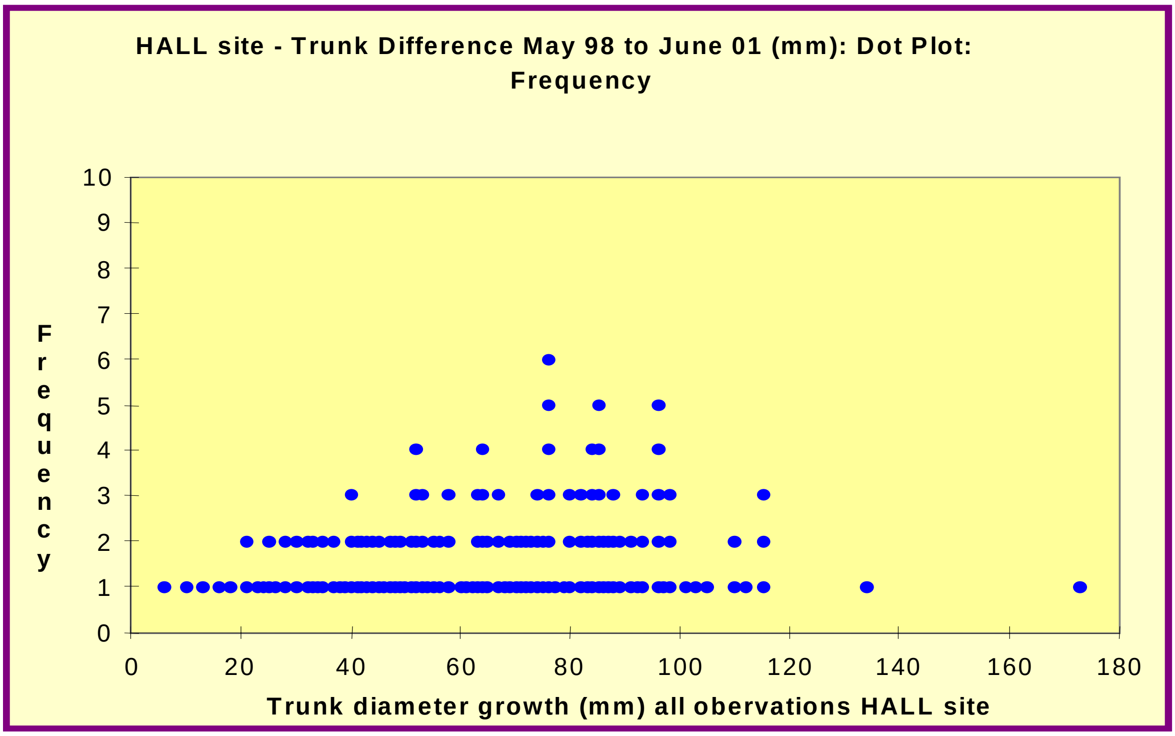


**Figure 6. HALL site - Trunk Difference May 98 to June 01 (mm): Dot Plot: Frequency**

The distribution of the growth measurements indicates a relatively even distribution of measurements but is slightly negatively skewed. The mean growth of 65.5mm is a reasonable representation of the growth of the varieties in this site.

The growth measurements were also examined for variation or spread by determining the location of values divided into four equal parts or quartiles. The first quartile (Q1) is the value below which 25 percent of the observations occur, the second quartile (Q2) is the value below which 50 percent of the observations occur and the third quartile (Q3) the value below which 75 percent of observations occur. The fourth quartile represents the highest 25 percent of measurements.

The quartile information for the Hall site is outlined in Table 14 below.

**Table 14. Hall site quartile information**

| HALL | |
|---|---|
| **Quartile information** | |
| Minimum value = 6 mm | |
| Q1= 45 mm | |
| Q2 = 67 mm (median value) | |
| Q3 = 85 mm | |
| Maximum value = 173 mm | |

A graphical display of the quartiles for Hall site is presented in the box plot Figure 7, below.

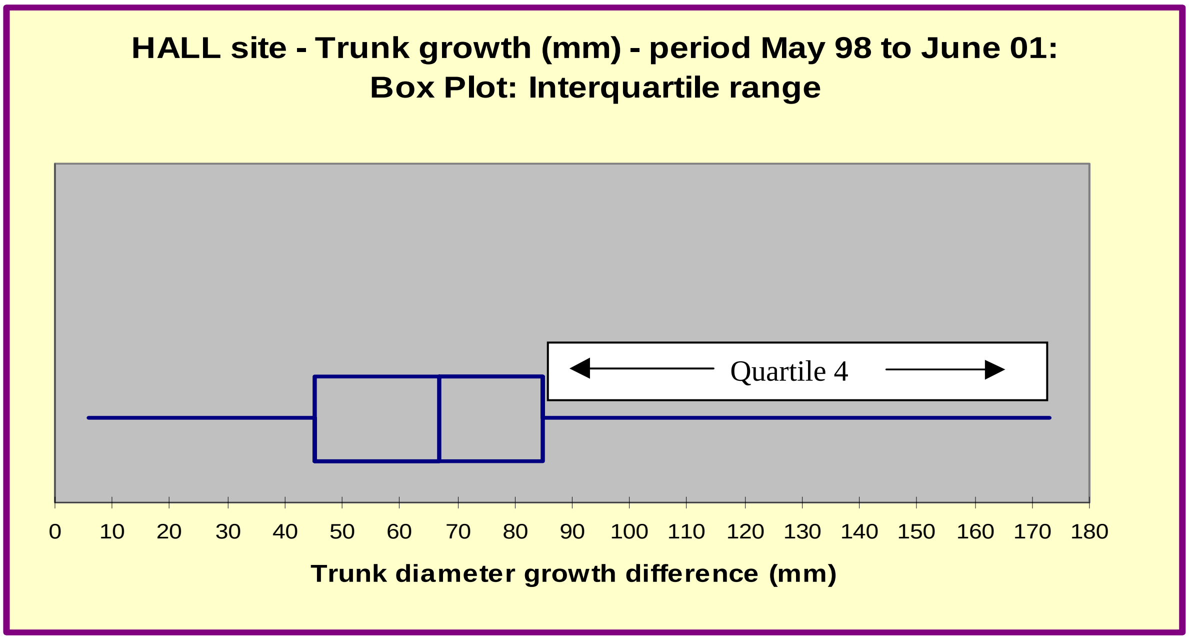


**Figure 7. HALL site - Trunk growth (mm) - period May 98 to June 01 Box Plot: Interquartile range**

In the Hall site, the fourth quartile has a relatively wide range of values (85mm to 173mm). The highest values are relatively very high compared to the values in the second and third quartiles. It is the varieties which feature in the fourth quartile, that are the top 25 percent of trunk growth that are selected for attention. The average growth for each variety was considered as this is expected to give a better picture of the performance of varieties, than just examining the individual highest growth values obtained.

To determine the varieties that lie in the top 25 percent, average trunk growth for each variety was calculated. Data on the average trunk growth for Hall site varieties is outlined in Table 16 on page27, and presented in Figure 8, page 28.

### 3.5.2 House site. Discussion and Results

The trunk diameter growth measurements for all trees that survived on the Hall site were analysed. A total of 210 measurements were available and the descriptive statistics are outlined in Table 15 below.

**Table 15. House trunk growth – descriptive statistics**

| **HOUSE Trunk Difference Descriptive statistics** | |
|---|---|
| Mean | 47.8 |
| Standard Error | 1.6 |
| Median | 46.0 |
| Mode | 46.0 |
| Standard Deviation | 23.0 |
| Sample Variance | 529.8 |
| Kurtosis | 0.1 |
| Skewness | 0.5 |
| Range | 135 |
| Minimum | 0 |
| Maximum | 135 |
| Count | 210 |

**Table 16. Average trunk growth (mm) for each durian variety in Hall site in descending order by quartile**

| Quartile Range | HALL site varieties average growth (mm) | | |
|---|---|---|---|
| Q4 | **Variety** | **TD diff av (mm)** | **Count (n)** |
| Q4 | Sahom | 110 | 1 |
| Q4 | HEW 1 | 101 | 1 |
| Q4 | D 24 | 90 | 15 |
| Q4 | Permasuri | 88 | 1 |
| Q4 | Gumpun | 87 | 2 |
| Q4 | Luang | 82 | 17 |
| Q4 | H. Mon Thong | 81 | 7 |
| Q4 | D 140 | 79 | 2 |
| Q4 | Chanee | 76 | 1 |
| Q3 | D 144 | 73 | 1 |
| Q3 | D 10 | 73 | 4 |
| Q3 | D 118 | 72 | 3 |
| Q3 | D Macrantha | 71 | 4 |
| Q3 | Gob Yaow | 68 | 9 |
| Q3 | D 2 | 65 | 7 |
| Q3 | D 120 | 65 | 2 |
| Q3 | D 190 | 62 | 4 |
| Q3 | Petruk | 61 | 2 |
| Q3 | P 21 | 61 | 4 |
| Q3 | D 179 | 61 | 3 |
| Q2 | HEW 7 | 60 | 3 |
| Q2 | P 601 | 60 | 2 |
| Q2 | D Mansoni | 60 | 1 |
| Q2 | Hepe | 59 | 14 |
| Q2 | DPI Mon Thong | 57 | 4 |
| Q2 | D 99X | 57 | 3 |
| Q2 | D 123 | 55 | 2 |
| Q2 | Kradum Thong | 54 | 3 |
| Q2 | Kan Yao | 54 | 9 |
| Q2 | Ampung | 50 | 3 |
| Q2 | D 188 | 47 | 2 |
| Q1 | Yeao | 46 | 2 |
| Q1 | D 175 | 45 | 4 |
| Q1 | D 178 | 42 | 3 |
| Q1 | D 7 | 41 | 4 |
| Q1 | D99 | 38 | 2 |
| Q1 | HEW 6 | 37 | 1 |
| Q1 | KK 11 | 32 | 3 |
| Q1 | D 168 | 32 | 1 |
| Q1 | D 16 | 25 | 1 |
| Q1 | D 143 | 6 | 1 |

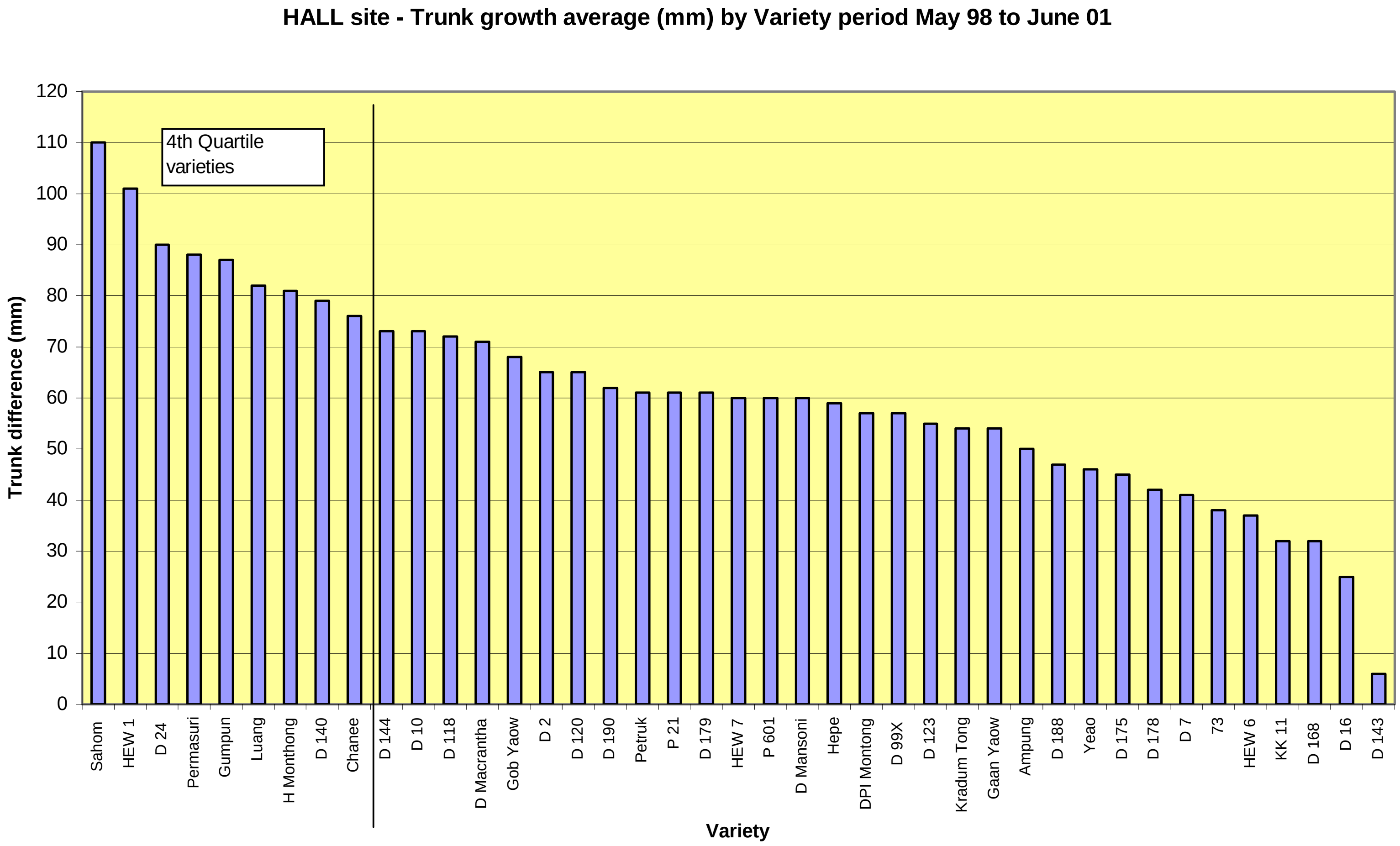


**Figure 8. Average trunk growth (mm) for each durian variety in Hall site in descending order by quartile**

The distribution of these measurements were examined and plotted in Figure 9 below.

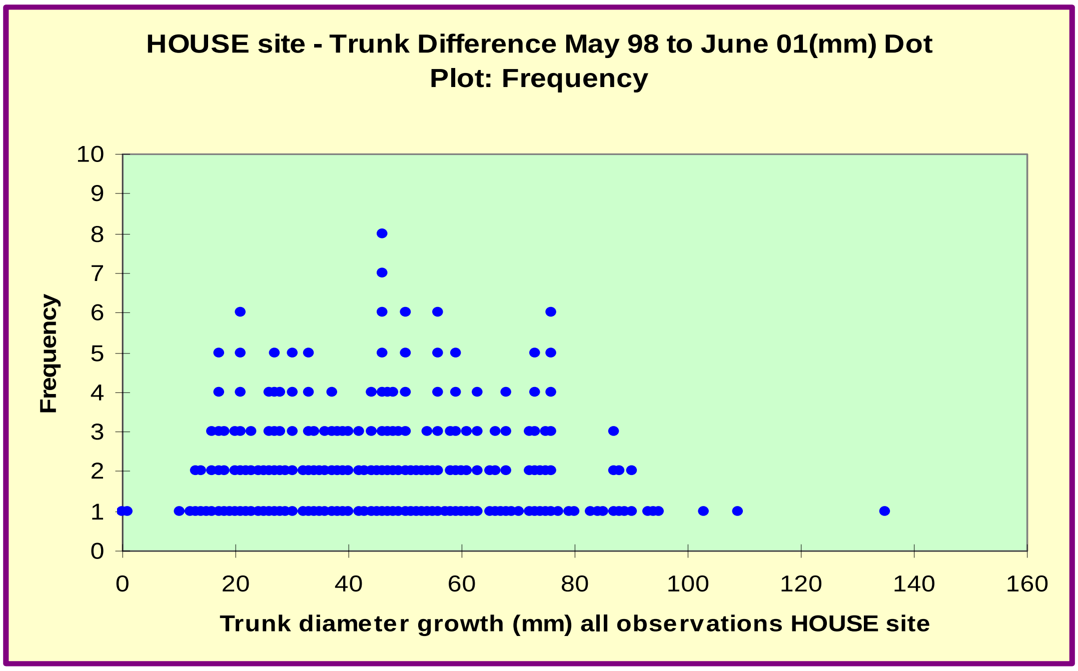


**Figure 9. HOUSE site - Trunk Difference May 98 to June 01(mm) Dot Plot: Frequency**

The distribution of the growth measurements indicates a relatively even distribution of measurements but is positively skewed. The mean growth of 47.8mm is a reasonable representation of the growth of the varieties in this site.

The growth measurements were also examined for variation or spread by determining the location of values divided into four equal parts or quartiles. The fourth quartile represents the highest 25 percent of measurements.

The quartile information for the House site is outlined in Table 17.

**Table 17. House site quartile information**.

| **HOUSE** |
|---|
| **Quartile information** |
| Minimum value = 0 mm<br>Q1 = 29 mm<br>Q2 = 46 mm (median value)<br>Q3 = 63 mm<br>Maximum value = 135 mm |

A graphical display of the quartiles for House site is presented below.

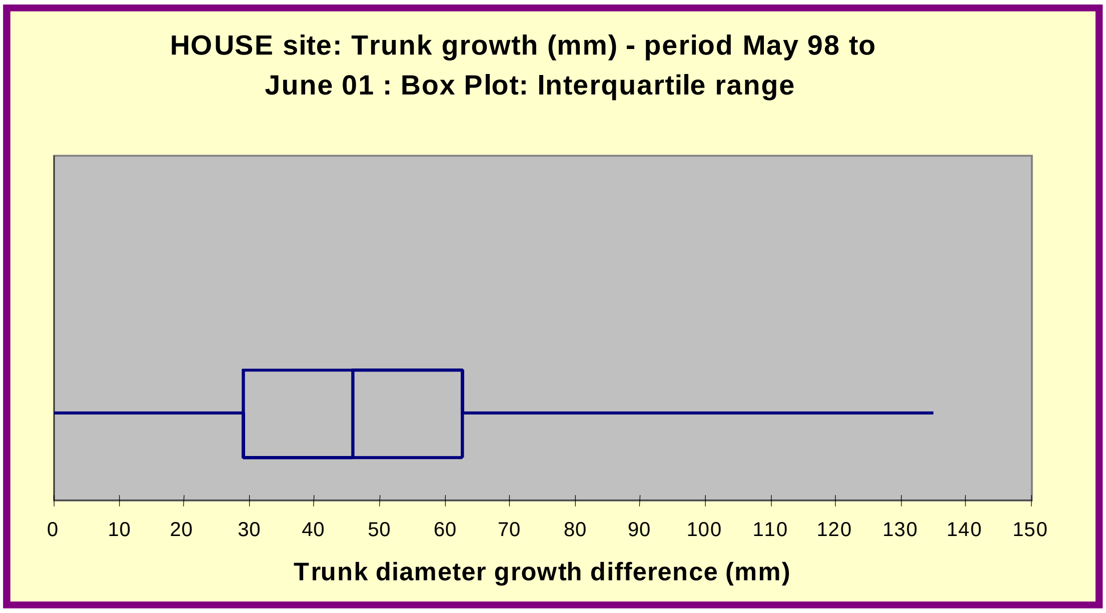


**Figure 10. HOUSE site: Trunk growth (mm) - period May 98 to June 01 : Box Plot: Interquartile range**

In the House site, the fourth quartile has a relatively wide range of values (63mm to 135mm). The highest values are relatively high compared to the values in the second and third quartiles. It is the varieties which feature in the fourth quartile, that are the top 25 percent of trunk growth that are selected for attention. The average growth for each variety was considered as this is expected to give a better picture of the performance of varieties, than just examining the individual highest growth value s obtained.

To determine the varieties that lie in the top 25 percent, average trunk growth for each variety was calculated. Data on the average trunk growth for Hall site varieties is outlined in Table 18.

**Table 18. Average trunk growth (mm) for each durian variety in House site in descending order by quartile**

| Quartile Range | HOUSE site varieties average growth (mm | | |
|---|---|---|---|
| **Q4** | **Variety** | **TD diff av (mm)** | **Count (n)** |
| **Q4** | NG/Mon Thong | 95 | 1 |
| **Q4** | Yeao | 93 | 1 |
| **Q4** | D 140 | 84 | 1 |
| **Q4** | Luang | 76 | 4 |
| **Q4** | D 24 S | 76 | 1 |
| **Q4** | D 178 | 70 | 5 |
| **Q4** | Gumpun | 67 | 8 |
| **Q4** | D Macrantha | 65 | 10 |
| **Q4** | Hepe | 63 | 5 |
| **Q4** | Chin | 62 | 3 |
| **Q4** | HEW 7 | 61 | 4 |
| **Q4** | D 190 | 57 | 8 |
| **Q4** | D 163 | 55 | 2 |
| **Q3** | HEW 6 | 54 | 3 |
| **Q3** | DPI Mon Thong | 54 | 5 |
| **Q3** | D 24 | 54 | 10 |
| **Q3** | HEW 1 | 52 | 11 |
| **Q3** | D 118 | 51 | 2 |
| **Q3** | D 179 | 49 | 5 |
| **Q3** | Kan Yao | 48 | 5 |
| **Q3** | KradumTong | 47 | 13 |
| **Q3** | KK 11 | 46 | 4 |
| **Q3** | D 175 | 44 | 5 |
| **Q3** | Sahom | 43 | 4 |
| **Q3** | Chanee | 43 | 5 |
| **Q3** | Sukun | 42 | 3 |
| **Q3** | D 168 | 42 | 6 |
| **Q2** | XA | 40 | 4 |
| **Q2** | D 96 | 40 | 4 |
| **Q2** | D 197 | 40 | 6 |
| **Q2** | D 144 | 39 | 6 |
| **Q2** | HEW 2 | 38 | 6 |
| **Q2** | Gob Yaow | 38 | 3 |
| **Q2** | D 99X | 38 | 7 |
| **Q2** | D 164 | 37 | 3 |
| **Q2** | D 120 | 37 | 3 |
| **Q2** | P 21 | 36 | 3 |
| **Q2** | D 160 | 36 | 3 |

Table 18 continued. Average trunk growth (mm) for each durian variety in House site in descending order by quartile

| Quartile Range | HOUSE site varieties average growth (mm | | |
|---|---|---|---|
| **Q1** | H.Mon Thong | 35 | 4 |
| **Q1** | D 16 | 34 | 3 |
| **Q1** | Taiping 1 | 30 | 1 |
| **Q1** | D 2 | 30 | 2 |
| **Q1** | D 188 | 30 | 3 |
| **Q1** | Sunan | 28 | 4 |
| **Q1** | D 7 | 28 | 1 |
| **Q1** | D 99 | 25 | 5 |
| **Q1** | D 143 | 25 | 1 |
| **Q1** | P 601 | 24 | 3 |
| **Q1** | Ampung | 23 | 4 |
| **Q1** | D 123 | 22 | 2 |
| **Q1** | D 145 | 5 | 2 |

The average trunk growth for House site durian varieties is presented in Figure 11.

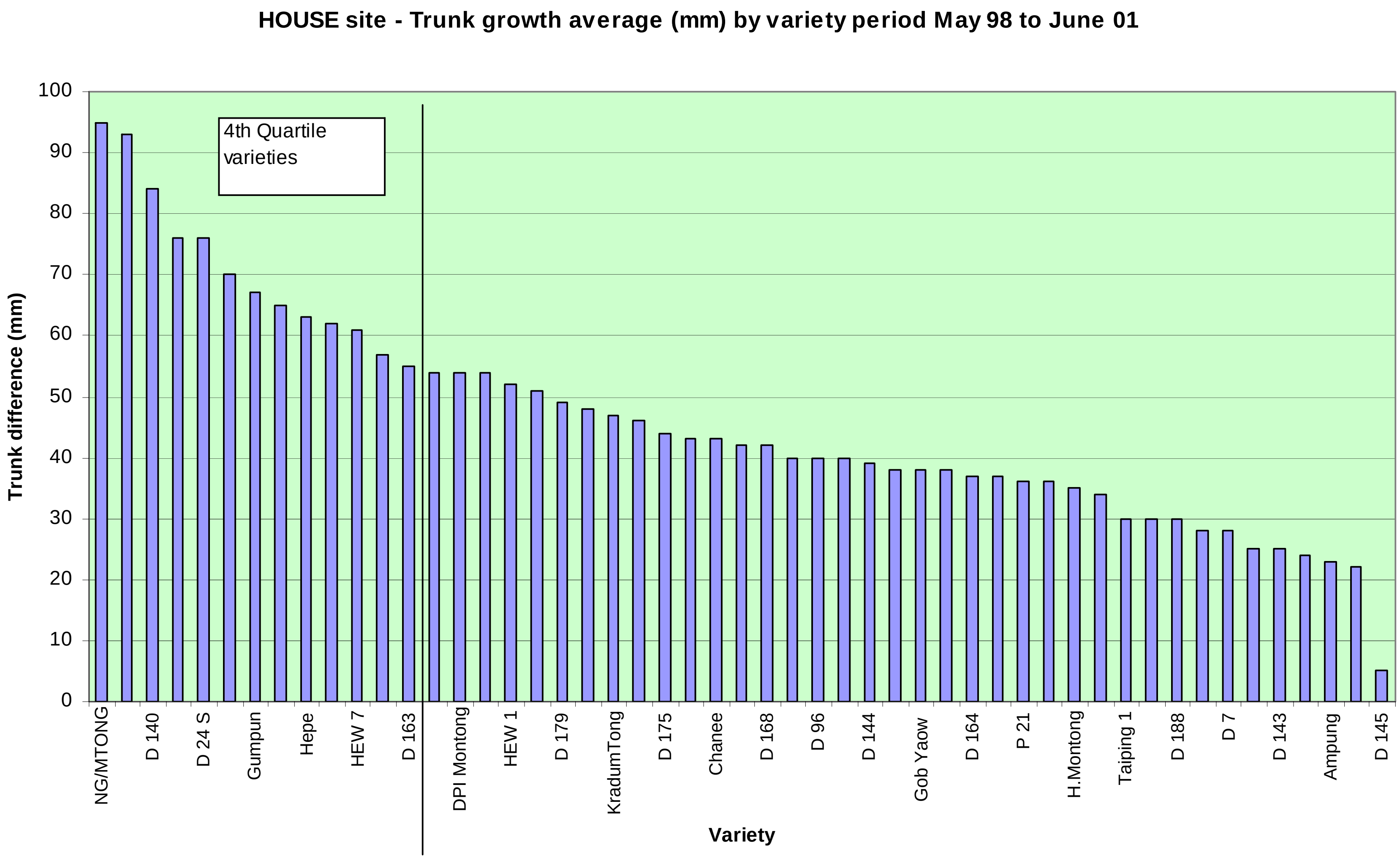


**Figure 11. Average trunk growth (mm) for each durian variety in House site in descending order by quartile.**

### 3.5.3 Comparing Hall and House site trunk diameter growth

The mean trunk diameter growth for all Hall site trees above was noted at 65.5mm and the mean trunk diameter growth for all the House site trees was noted at 47.8 mm. At face value this appears to be significant. To check this difference a test of hypothesis about the difference between the two site means was conducted.

$H_o : \mu_1 = \mu_2$
$H_i : \mu_1 \neq \mu_1$
**The 0.01 level of significance is chosen. $\alpha = 0.01$**
**Two tailed test and $\alpha/2 = 0.005$ with Z critical = $\pm$ 2.58**
Z calculated = 6.62
As Z calculated: 6.62 > Z critical: 2.58, we reject the null hypothesis and accept the alternative hypothesis. There is a statistically significant difference between the mean trunk diameter growth of trees in each site.

There is extremely strong statistical evidence that the growth of the trees is different in each site (*p* – value less than 0.001). The potential factors contributing to this difference are that Hall rows 6, 7, 9 and 10 were planted in the 1992/93 and 1994/95 periods (Appendix 2). These contain 84 evaluation trees which averaged 74.4 mm increase in trunk diameter over the period, compared with the other Hall rows 3, 4 and 5 (planted in 1994/95 and 1995/96) with 72 observations which averaged 57.19 mm increase in trunk diameter over the period.

The house site also had two distinct planting periods although they were closer together. Rows 1 to 7 North (Appendix 2) were planted in the 1994/95 and the 1995/96 periods. These rows contained 88 observations, which increased in trunk diameter by 53.64mm, while Rows 1 to 8 South, mainly planted in the 1995/96 and the 1996/97 periods averaged a trunk increase of 43.58mm.

## 3.6 Selecting the best performing varieties on the basis of trunk growth

The method of selecting the best overall durian varieties will include a combination of survival rates, growth measurements, fruiting quality and yield, tree habit and structure and suitability to local weather conditions.

On the basis of trunk growth only three varieties are common in the fourth quartiles from both sites (Table 19). These varieties are Luang, D140 and Gumpun. The best individual growth results in each site were not replicated in both sites. The varieties Sahom and HEW 1, which had the best growth rates in the Hall site, were only rated in the third quartiles for the House site. Similarly the varieties NG/Mon Thong and Yeao that had the best growth rates in the House site were not replicated in high growth quartiles in the Hall site.

To extend the list of the best overall varieties beyond the three varieties common in the fourth quartiles, varieties which made the fourth quartile in one site, but the third quartile in the other site were listed. Also varieties common to the third quartiles were examined.

The number of replicates for each of the sites for quartile 4 and 3 are listed in Table 19. Caution must be used in Table 20 as indicated previously, small numbers (counts) for some varieties make statistical inferences difficult. Examples are that Hew 1 and Sahom in the Hall site (Table 19) were only single trees.

**Table 19. Listing of third and fourth quartiles varieties for Hall and House sites.**

| HALL site varieties average growth (mm) | | | |
|---|---|---|---|
| | Variety | TD diff av (mm) | Count (n) |
| Q4 | Sahom | 110 | 1 |
| Q4 | HEW 1 | 101 | 1 |
| Q4 | D 24 | 90 | 15 |
| Q4 | Permasuri | 88 | 1 |
| Q4 | Gumpun | 87 | 2 |
| Q4 | Luang | 82 | 17 |
| Q4 | H. Mon Thong | 81 | 7 |
| Q4 | D 140 | 79 | 2 |
| Q4 | Chanee | 76 | 1 |
| Q3 | D 144 | 73 | 1 |
| Q3 | D 10 | 73 | 4 |
| Q3 | D 118 | 72 | 3 |
| Q3 | D Macrantha | 71 | 4 |
| Q3 | Gob Yaow | 68 | 9 |
| Q3 | D 2 | 65 | 7 |
| Q3 | D 120 | 65 | 2 |
| Q3 | D 190 | 62 | 4 |
| Q3 | Petruk | 61 | 2 |
| Q3 | P 21 | 61 | 4 |
| Q3 | D 179 | 61 | 3 |

| HOUSE site varieties average growth (mm) | | | |
|---|---|---|---|
| | Variety | TD diff av (mm) | Count (n) |
| Q4 | NG Mon Thong | 95 | 1 |
| Q4 | Yeao | 93 | 1 |
| Q4 | D 140 | 84 | 1 |
| Q4 | Luang | 76 | 4 |
| Q4 | D 24 S | 76 | 1 |
| Q4 | D 178 | 70 | 5 |
| Q4 | Gumpun | 67 | 8 |
| Q4 | D Macrantha | 65 | 10 |
| Q4 | Hepe | 63 | 5 |
| Q4 | Chin | 62 | 3 |
| Q4 | HEW 7 | 61 | 4 |
| Q4 | D 190 | 57 | 8 |
| Q4 | D 163 | 55 | 2 |
| Q3 | HEW 6 | 54 | 3 |
| Q3 | DPI Mon Thong | 54 | 5 |
| Q3 | D 24 | 54 | 10 |
| Q3 | HEW 1 | 52 | 11 |
| Q3 | D 118 | 51 | 2 |
| Q3 | D 179 | 49 | 5 |
| Q3 | Kan Yao | 48 | 5 |
| Q3 | KradumThong | 47 | 13 |
| Q3 | KK 11 | 46 | 4 |
| Q3 | D 175 | 44 | 5 |
| Q3 | Sahom | 43 | 4 |
| Q3 | Chanee | 43 | 5 |
| Q3 | Sukun | 42 | 3 |
| Q3 | D 168 | 42 | 6 |

Combining the growth averages from both sites, the ten best varieties are listed in their order of ranking outlined in Table 20.

**Table 20. Highest ranked durian varieties combined sites by trunk growth.**

| Overall Rank | Durian clone | Total Count Hall + House | Hall + House average growth (mm) |
|---|---|---|---|
| 1 | Luang | 21 | 83 |
| 2 | D140 | 3 | 82 |
| 3 | Gumpun | 10 | 77 |
| 4 | HEW 1 | 12 | 77 |
| 5 | Sahom | 5 | 77 |
| 6 | D 24 | 25 | 72 |
| 7 | D Macrantha | 14 | 68 |
| 8 | D 118 | 5 | 62 |
| 9 | Chanee | 6 | 60 |
| 10 | D 190 | 12 | 60 |

## 3.7 Recommendations

After careful consideration of all selection criteria, the researchers have listed their clonal preferences into the following sections.

### Group 1. Highly recommended Top 9 clones (including 2 "standards")

Seven new introductions are highly recommended. All of these clones achieved an 80% survival or greater, from the original plantings for the 5-year period i.e.: a minimum of 8 plants survived from the original 10 planted (Table 12). These clones are listed in decreasing % of survival and are Hepe, *D. macrantha*, D 175 (Red Prawn), DPI Mon Thong, Hawaiian Mon Thong, D 190 and Kradum Thong. The results obtained from the clones included as "standards", Kan Yao and Luang, demonstrated their suitability for Australian conditions and justify their inclusion in the current recommended Australian planting list.

Luang achieved the highest rating in Table 20, while *D. macrantha* was placed at 7 and D 190 tenth. Hawaiian Mon Thong was placed highly in Q4 at the Hall site (Table 19). Hepe was similarly placed in the House site (Table 19) while DPI Mon Thong was placed in Q3 with Kan Yao, Kradum Thong and D 175 (Table 19).

### Group 2. Potential additions for grower plantings (13) via ZTR-1A Phase 2

D 178, P 21, KK11, Hew 7, D 179, D 99X, D 144, D 24, Chanee, D 168, D 99, D 118 and Sahom.

All of these clones achieved a greater than 50% survival from the original plantings for the 5 year period, with half of the original plantings surviving. The results of the clones D 144, Chanee, D 168, D 118 and Sahom were disadvantaged when compared to the rest of this group as some of their original replicate trees were lost to cyclone damage (Table 12).

The highlights of trunk diameter increases for this group were Sahom was ranked 5, D 24 ranked 6, D 118 ranked 8 and Chanee ranked 9 (Table 20). D 24 was ranked highly in both sites but it has a weaker branch structure than other trees, requiring extensive windbreak protection, therefore has been included in Group 2 (Table 19). P 21 and D 144 were listed in Q3 Hall site, while D 178 and Hew 7 made the Q4 listing in House site.

Other performances of note included D 179 with Q3 placing over both sites, D 168 and KK11 were listed in Q3 House site. D 99 and D 99X were the lowest rated of this group (Table 15 and 18).

### Group 3. Deleted from future evaluation (6)

Ampung, D 16, D 120, Hew 6, Permasuri and Sukun.

Ampung, D 16, and Hew 6 performed poorly under the weather conditions (Table 19). Permasuri results (Table 19) were from the only remaining tree (Table 12). Hew 6, Sukun and D 120 lack tolerance to cool temperatures. Ampung and D 16 were the worst performers in this group and received lowest rankings in Table 15 and 18. Ampung did manage a high survival rate (Table 12) but failed to impress with the trunk growth increases. D 7 was only planted at the Hall site but is severely affected by cold weather and is not recommended for further evaluation.

### Group 4. Require further evaluation (4) via ZTR-1A Phase 2

Chin, D 163, D 164, and D 2.

D 2 was ranked in Q3, Hall site while Chin and D 163 was ranked in Q4 on the house site (Table 19). D 2 had 7 replicates but Chin only had 3 replicates while D 163 was replicated twice. D 2 is an excellent fruiting clone from Malaysia therefore requires further evaluation. D 163 and D 164 are excellent clone in Penang, with a similar reputation to D 175. Both of these clones were quality performers in Penang durian competitions with D 163 placed first in 1987 and D 164 placed third in the same year (Lim, 1997). These clones deserve futher evaluation.

A further 19 clones were also observed but unfortunately these clones were not replicated by 5 at both sites to ensure a thorough analysis. Their evaluation was restricted by the lack of planting material, as some of these were late introductions. These are listed in Group 5.

### Group 5. Insufficient replicates for evaluation (20 clones)

Capri, D 7, D 10, D 24 Serawak, D 96, D 123, D 140, D 143, D 145, Ng Mon Thong, D 160,D 188, D 197, Hew 1, Hew 2, P 601, Petruk, Taiping 1, XA and Yeao. Gob Yaow, Gumpun and Sunan were also included as standards with this group. Of this group, D 140 was an outstanding performer with a rating of 2 in Table 20. Hew 1and NG Mon Thong also performed strongly. This group together with group 4 will continue to be observed at Zappala Tropicals Pty Ltd for future selection possibilities.

## 3.8 References

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Yaacob, O. and Subhadrabandhu, S. 1995. *The production of Economic Fruits of Southeast Asia*. Oxford University Press.

# 4. Pest, Disease, Nutrition and Irrigation Findings

## 4.1 Insect Pests

Insect pests and their damage were observed over the project. Observations mirrored the detailed insect surveys of durian orchards in NQ, by DPI entomologist David Astridge (1999). The major pest of young durian trees was the black swarming leaf beetles (*Rhyparida sp*.) which fed on young leaf growth. Astridge (1999) states that black swarming leaf beetles (*Rhyparida sp*.) are active throughout the year with peak periods occurring between November to April. Under high populations black swarming leaf beetles can severely set back tree development especially when the timing of beetle attacks coincides with a new flush. Our observations would support this finding. Observations did however indicate that leaf damage was up to 50% less in the project trees interplanted with *Heliconia sp*. Observations concluded that no clones were more susceptible to this specific pest than others. Methods of control are difficult especially as damage usually concides with continuing wet conditions. This makes successful chemical and foliar spray applications extremely difficult to achieve. Carbaryl® is currently the only insecticide registered for use for this pest.

Fruit spotting bugs (FSB) are a major pest of durian and other crops in Queensland. The common name used by NQ growers refers to the banana spotting bug (*Amblypelta lutescens lute* Distant). It is a serious problem for developing fruit and damage can occur from early fruit set (six weeks after bud-break) through to almost fully developed fruit. Astridge (1999) found banana spotting bug to be most active in durians between October and January causing large numbers of fruit to drop prematurely as a result of bugs feeding on pedicels. On fruit, feeding causes cracked sunken areas as the surrounding tissue dies and the fruit continues to grow. Endosulfan® was the only insecticide registered for use on durian but since the Nation Registration Authority (NRA) has reviewed the use of this product and it is no longer available for grower use.

Green tree ants, citrus mealy bugs and yellow peach moth and an unidentified trunk borer larva were of lesser concern.

Green tree ants nest in durian trees and could assist in controlling FSB as reported by Peng (2001). Konam (1999) suggests that *P. palmivora* is spread in Papua New Guinea's Cocoa plantations through the action of ants carrying infected soil up the trunks of cocoa plants. Therefore green tree ants could be a vector for *P. palmivora* in durian trees, though this is still to be confirmed. Green tree ants farm any citrus mealy bugs present on the developing durian fruit between November and March, (Astridge, 1999). Bagging of fruit to control FSB increases the population of citrus mealy bugs and green tree ants.

The yellow peach moth cause damage to the fruit as it matures between February and April. The larvae feed on the fruit surface between the spines covering themselves with frass (Astridge, 1999). An unidentified trunk borer caused damage to 3 project trees over the 5-year period. One tree was cut down in an attempt to locate and identify the insect but this was unsuccessful. Listings for insects observed during the project appear in Table 15.

## 4.2 Disease Observations

*Phytophthora palmivora* and *Pythium sp* are the major diseases that effect durian production worldwide. These are both long established serious diseases of durian in Asia (Thompson, 1934., Thompson, 1938, and Navaratnam 1966).

Dr T.K. Lim first identified *P. palmivora* as the cause of tree death in our older durian orchard during his April 1998 visit. Branch twisting and limb breakage from Cyclone Justin is thought to have pre-disposed the infection. Losses are listed in Table 21.

**Table 21. Disease Losses in Old Durian Plantings ( Hall Block).**

| Hall Block Old Clonal site | Tree Numbers Total planted at 1/1/95 | Total Losses to 13/9/97 | % of Losses at 13/9/97 |
|---|---|---|---|
| Mixed plantings of clones introduced by DPI 1980's | 133 | 72 | 54% |

Lynton Vawdrey, Plant Pathologist, DPI Centre for Wet Tropics Agriculture, inspected our older durian orchard twice during November 1997. Root samples were collected, and laboratory tests recovered both *Pythium vexans* and *Phytophthora palmivora* from diseased roots.

In May 1997, seven isolates of *Phytophthora palmivora* and one of a *Pythium sp* were recovered from samples collected by Matthew Weinert, Pathologist, (CRC for Tropical Plant Pathology U.Q.). On May 21 1998, Matthew Weinert again collected samples from some of our evaluation trees. *P. palmivora* was mostly recovered from soils beneath the canopy of durian trees and not from durian roots.

David Guest, University of Melbourne (Leader of the ACIAR funded project Management of Phytophthora diseases of durian) and Lynton Vawdrey, Pathologist, DPI Centre for Wet Tropics Agriculture, inspected the older durian orchard during November 1997 and April 1998. They collected root and soil samples and results have shown an association between the many diseased trees and the plant pathogen *P. palmivora*. Further tests at the DPI laboratory and glasshouse at South Johnstone were conducted (Table 23).

In 1998, Lynton Vawdrey established a replicated trial consisting of 3 treatments (hay mulch, hay mulch+chicken manure, and an untreated) to examine the effect of organic amendments on durian decline. After 12 months, two applications of straw+chicken manure had resulted in a significant increase in the number of viable feeder roots (Figure 12). Due to the encouraging results from the mulching experiment conducted by DPI, straw mulches were applied to all plantings during December 1999 and again in 2000 and 2001 to build up organic matter. It is hoped this will increase feeder root development and become part of an Integrated Disease Management (IDM) strategy for *P. palmivora* control. This strategy includes the use of planting on mounds, ground covers and tree injection with potassium phosphonate.

The researchers have continued with a preventative program as outlined above and feel that the results are demonstrating that this IDM program is successful. Part of the preventative strategy has included regular application of a Bordeaux mixture to tree trunk from ground level to a height of approximately 1 metre. Bordeaux mixture was recommended to assist with control of *P. palmivora* in younger trees (Navaratnam 1966).

The researchers have observed that the symptoms for phytophthora exhibited in Australia vary greatly from the severe trunk cankers that ooze from infected durian trunks in southeast Asia. For example the severe patch cankers illustrated in Anon, 2000 and Lim, 1990, is never seen in Australia. In 1998 tree no. 261 did have a slight ooze on the main trunk from an area 40mm by 20mm located 2 metres above ground level. 4 Chemjet® needles each containing 20mls of Phosjet 40® cleared up the infection within days.

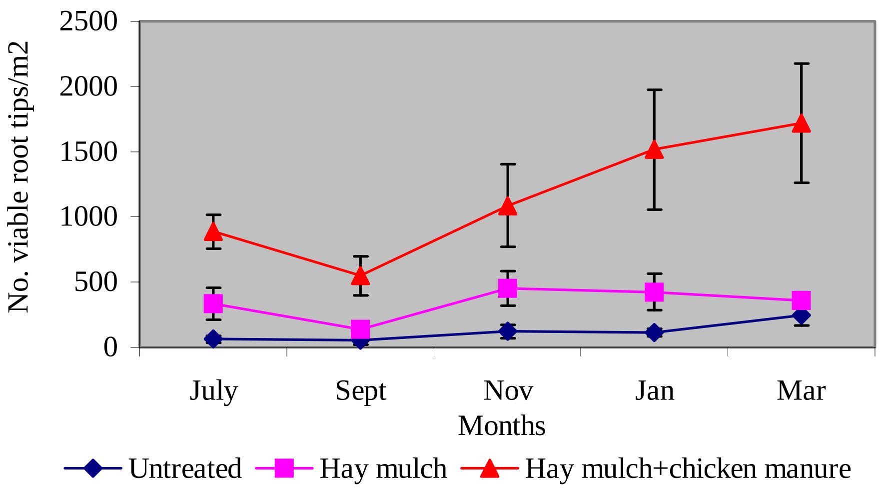


**Figure 12. Effect of hay mulch and chicken manure on the number of viable root tips of durian - Zappala Hall site.**

Chemjet needles were used during the early morning to enhance uptake of Phosjet 40®. Needles were then collected in the afternoon, sterilised and prepared for use the following morning. Injections can damage the trunk with vertical cracks, some as long as 150 mm occurring after trunk injections. Injection results need to be monitored carefully, as twice-yearly injections would require up to 8 needle sites per year to be drilled into mature trees.

Excessive crop load can lead to stress and tree decline and this management strategy is not well defined in north Queensland. Many growers often harvest as many fruit as possible to return funds on their long investment phase to the detriment of their tree's health.

Yaacob and Subhadrabandhu (1995) describe the practices of eastern Thailand growers where fruit load is regulated according to tree age, health and clone. For example, Chanee is allowed to bear 0 – 40 fruit at year 6 – 7, 40 – 60 fruit at year 8 to 10 and 80 – 100 fruit when trees are 15 to 30 years of age. Mon Thong trees 6 – 7 years old are allowed to bear 0 - 30 fruit, 8 – 10 year old trees 50 fruit and 15 – 30 year old trees 70 fruit. This information should be used by Australian growers as a guide.

As well as *Phytophthora* and *Pythium* isolates (Table 23) there also seems to be an underlying effect on tree decline in north Queensland. It is hoped that the 18 month extension of ACIAR Project PHT95/134 and continuing monitoring and sampling of durian orchards across north Queensland will shed further light on the interaction between *Phytophthora* and *Pythium*. The commencement of RIRDC Project No. DAQ – 288A *"Nutrition of Durian and Mangosteen Orchards in North Queensland"* will also assist to define nutrition inputs from a wider range of growers and improve understanding of the requirements of durian production in north Queensland.

**Table 22. Major and Minor Pests of Durian, found at the Project Site complied by David Astridge DPI.**

| ORDER | FAMILY | GENUS | SPECIES | FEEDING SITE |
|---|---|---|---|---|
| **Major Pests** | | | | |
| Hemiptera | Coreidae | *Amblypelta* | *lutescens* | fruit |
| Hemiptera | Pseudococcidae | *Planococcus* | *citri* | fruit/stems/flower |
| Hymenoptera | Formicidae | *Oecophylla* | *smaragdina* | farms mealy bug |
| Coleoptera | Chrysomelidae | *Rhyparida* | *discopunctulata* | flush leaves |
| **Minor Pests** | | | | |
| Coleoptera | Cerambycidae | * *Prosoplus* | *Sp.* | Trunk girdler |
| Coleoptera | Chrysomelidae | *Monolepta* | *australis* | flush leaves |
| Hemiptera | Flatidae | *Colgaroides* | *acuminata* | stems/shoots/fruit |
| Hemiptera | Pentatomidae | *Ancanthidiellum* | *souefi* | stems/shoots/fruit |
| Hemiptera | Pentatomidae | *Accarana* | *australica* | stems/shoots/ fruit |
| Hymenoptera | Formicidae | *Tetramorium* | *bicarinatum* | Farms mealybug |
| Hymenoptera | Formicidae | *Pheidole* | *megacephala* | Farms mealybug |
| Hymenoptera | Formicidae | * | * | Farms mealybug |
| Lepidoptera | Noctuidae | *Autoba* | *versicolor* | leaves/flowers |
| Lepidoptera | Noctuidae | * | * | leaves |
| Lepidoptera | Tortricidae | * | * | leaves |

*= To be identified

Table 23. Durian Pathology Diagnostic Record – Zappala, Bellenden Ker 1997 to 2001 compiled by Lynton Vawdrey DPI.

| Date | Part sampled | Isolations | Comments |
|---|---|---|---|
| 6/2/97 | Roots | *Fusarium oxysporum, Trichoderma sp., Pythium sp.* | Root Rot |
| 10/11/97 | Roots | *Pythium sp.* | Tree die back |
| 2/12/97 | Roots | *Pythium sp., Fusarium sp.* | Root rot |
| 2/12/97 | Bark and wood | *Fusarium sp.* | Trunk Canker |
| 8/12/97 | Roots | *Pythium sp.* | Root Rot |
| 1/5/98 | Soil | *Pythium sp* | Tree 1 House block (tree decline) |
| | Soil | *Nil* | Tree 2. Healthy tree |
| | Soil | *Nil* | Tree 3. Luang one side of tree in decline |
| | Soil | *Phytophthora palmivora* | Tree 4. Trial block (tree decline) |
| | Soil | *Nil* | Tree 5. House block bottom corner 9tree decline |
| | Soil | *Phytophthora palmivora* | Tree 6. Z5R5 (tree decline) |
| | Soil | *Pythium sp.* | Tree 7. Corner tree (tree decline) |
| | Soil | *Phytophthora palmivora* | Tree 8. Z3R6 (tree decline) |
| | Leaf | *Colletotrichum gloeosporioides; Phemopsis sp.; Curvularia sp.* | Leaf blight |
| 19/5/98 | Potting mix | *Pythium sp.* | Root root symptoms in potted trees |
| 18/6/98 | Leaf | *Colletotrichum gloeosporioides; Pestalotiopsis sp.* | Necrotic leaf blotch |
| | Bark and wood | *Pestalotiopsis sp. Colletotrichum gloeosporioides.* | Branch canker |
| 26/6/98 | Leaf | *Colletotrichum gloeosporioides* | Leaf spot |
| 4/3/99 | Roots | *Pythium sp.* | Tree 1 (mulch trial block) – tree decline |
| | Roots | *Phytophthora palmivora* | Tree 2. Tree decline |
| | Roots | *Pythium sp.* | Tree 3. Tree decline |
| | Roots | *Pythium sp.* | Tree 4. Tree decline |
| | Soil | *Phytophthora palmivora* | Tree 5. Tree decline |
| | Soil | *Nil* | Tree 6. Tree decline |
| | Soil | *Phytophthora palmivora* | Tree 7. Tree decline |
| | Soil | *Nil* | Tree 8. Tree decline |
| | Soil | *Nil* | Tree 9. Tree decline |
| | Soil | *Phytophthora palmivora* | Tree 10. Tree decline |
| | Soil | *Nil* | Tree 11. Tree decline |
| | Soil | *Nil* | Tree 12. Tree decline |
| 7/5/99 | Leaf | *Colletotrichum gloeosporioides* | Leaf blight and tip dieback |
| 22/9/99 | Roots | *Pythium sp.* | Root rot |
| 13/7/00 | Branch and shoots | *Fusarium solani; Fusarium decemcellularae* | Tip die back |
| 29/1/01 | Fruit | *Phytophthora palmivora* | Fruit rot |

## 4.3 Durian leaf and soil monitoring

### 4.3.1 Introduction

Soil and plant nutrition plays a vital role in the productivity of tree crops, however, the interaction between nutrient levels and productivity is poorly understood in durian. Recommended plant nutrient levels exist in Thailand and Malaysia. The Northern Territory DPIF started soil and leaf monitoring research in the mid 90's. However, the information is limited to a few farms and specific to the NT growing environment. The wet tropics of north Queensland, Cape Tribulation to Cardwell, is home to the larger part of the industry yet little research relevant to the area has occurred.

Although durian has been grown in north Queensland since the early 70's there is a paucity of data on leaf and soil standards suited to its production in this region. Climatically the region differs greatly from that in Thailand, Malaysia and Darwin, with the region experiencing cooler and wetter winter conditions. Yaacob and Subhadrabandhu (1995) report that "*durian is adapted to a wide variety of soils. It appears to be particularly suited to inland soils derived from granite or similar parent materials, or even volcanic soils in Indonesia and the Philippines. Peat and poorly drained or sandy soils are not suitable. The durian appears to do better in the less fertile upland soils than in the more fertile alluvial and marine soils.*"

The evaluation sites soil types are described as an alluvial Brown Kandosol (Canoe series; Murtha *et al*., CSIRO Rep. 123) for House site, while the Hall site is a krasnozem or Red, Ferrosol (Pin Gin series, Murtha *et al*., 1996).

### 4.3.2 Materials and Methods

As part of this project five leaf and three soil samples were taken from March 2000 to March 2001 to document local soil and leaf nutrient status. At each sampling occasion two to six trees were sampled. The sampling regime is shown in Table 16. Nutrient inputs were applied at regular intervals including Nitrophoska TE® and Long Life Chicken Manure. Various mulches were also recorded in Table 24.

**Table 24. Durian leaf and soil sampling schedule.**

| Date | Leaf sample | Soil Sample | Tree sampled |
|---|---|---|---|
| March 2000 | ✔ | ✔ | D24, Mon Thong (315) |
| July 2000 | ✔ | | D24, Jacky, Kradum Thong, *D. macrantha*, Mon Thong |
| October 2000 | ✔ | ✔ | D24, Jacky, Kradum Thong, *D. macrantha*, Mon Thong |
| January 2001 | ✔ | | D24, Jacky, D. macrantha, Mon Thong, D 175 |
| March 2001 | ✔ | ✔ | D24, H. Mon Thong, Jacky, *D. macrantha*, Mon Thong, D 175 |

Leaf selected for sampling were the 5$^{th}$ to 6$^{th}$ mature green leaves as recommended by Lim *et al*., (1999). Leaf samples were labelled and forwarded by airfreight to Pivot Analytical Laboratory in Victoria. Leaves were analysed for the following macro-elements; nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg) and Sulphur (S) and micro-elements; Iron (Fe), Zinc (Zn), Manganese (Mn), Copper (Cu) and Boron (B). Samples were also analysed for Sodium (Na) and Chloride (Cl) levels. Soil samples were composed of multiple samples (4 – 6) per tree with sampling depth to 20 cm occurring within the tree canopy. Following sampling the soil was well mixed and a subsample was taken and packed in a plastic bag. Samples were dispatched for analysis as above. Soils were analysed for electrical conductivity (EC), pH and organic Carbon (OC), nitrate nitrogen ($NO_3$), Phosphorus – Collwell (P), potassium (K), magnesium (Mg), Calcium (Ca), sulphur (S), zinc

(Zn), Copper (Cu), Iron (Fe), Manganese (Mn), Boron (B), Chloride (Cl), Sodium (Na) and Aluminium (Al).

For each sampling occasion the leaf and soil data was pooled and mean and SE data calculated.

**Table 25. Nutrition Application schedule 1997 – 2001.**

| Nutrition Input | Tree Age (Years) | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 and over |
| Nitrophoska TE® | 250g | 400g | 500g | 750g | 1500g | 2500g |
| Long Life | 100g | 200g | 400g | 600g | 1000g | 1500g |
| Gypsum | 100g | 200g | 400g | 600g | 1000g | 1500g |
| Mulch, Hay or Cane Trash | Used as weed control in early stage, then used as required to cover the area of drip line for mature trees | | | | | |
| Foliar, Triple 10 Nutri-Teck | | 50mls/ 10L | 50mls/ 10L | 50mls/ 10L | 50mls/ 10L | 50mls/ 10L |

### 4.3.3 Results and Discussion

### 4.3.4 Soil Analysis

Soil pH (water and $CaCl_2$), electrical conductivity and organic carbon levels are shown in Table 26. pH (water) varied from 5.6 to 5.8 over the year with the mean value being 5.74. This is typical of high rainfall tropical soils where pH ranges from 5.0 to 7.0. EC values varied from 0.07 to 0.11 dS/m with a mean value of 0.08 dS/m. These values are lower than levels commonly regarded as affecting salt sensitive crops (Shaw, 1999). OC varied from 1.62 to 2.10 % with a mean value of 1.79 % (17.9g C/kg). This value is normal for soils in high rainfall areas.

**Table 26. Soil pH, EC and OC values (± SE)**

| Date | PHw | PHCaCl2 | EC (dS/m) | OC % |
|---|---|---|---|---|
| March 2000 | 5.60±0.00 | 5.10±0.10 | 0.11±.00 | 2.10±0.00 |
| October 2000 | 5.72±0.18 | 5.00±0.08 | 0.08±0.02 | 1.62±0.02 |
| March 2001 | 5.80±.0.12 | 5.05±0.13 | 0.07±0.01 | 1.83±0.01 |
| Mean | 5.74±0.08 | 5.04±0.07 | 0.08±0.01 | 1.79±0.13 |

Soil nitrate ($NO_{3}$), phosphorus (P), sulphur (S), zinc (Zn), copper (Cu), iron (Fe), manganese (Mn), boron (B) and Chloride (Cl) are shown in Table 27. The variation over time is generally less than the SE for each occasion, suggesting that the levels of these soil nutrients remains relatively stable under the management regime sampled. Nitrate levels (9.1 mg/kg) are low relative to other orchard crops such as lychee and macadamia where levels of 40 to 60 mg/kg are considered as normal (Strong and Mason, 1999). This is most likely due to longer cropping histories in SE Queensland orchards where these levels were derived and the higher rainfall in north Queensland and hence nitrates leaching out of the sampling zone. Despite the low nitrate levels leaf nitrogen levels were relatively high (Table 30).

Soil phosphorus levels were high (442 mg/kg) and far exceed levels normally recommended (23 – 60 mg/kg) for orchard crops (Moody and Bolland, 1999). The P sorption values of these soils is unknown, however, despite the high soil P levels leaf P levels were within the Malaysian recommendations and only slightly exceeded the recommended NT levels (Table 30).

Soil sulphur levels (31 mg/kg) were also similarly high and well above critical concentrations considered for most crops (5–10 mg/kg). As for phosphorus leaf S levels, these were within Malaysian recommendations (Table 30).

Soil micro-nutrient levels were generally higher than levels normally prescribed as critical for production. In all cases, corresponding leaf levels were within Malaysian standards.

**Table 27. Soil $NO_3$, P, S, Zn, Cu, Fe, Mn, B and Cl levels (± se).**

| Date | $NO_3$ | P | S | Zn | Cu | Fe | Mn | B | Cl |
|---|---|---|---|---|---|---|---|---|---|
| Value | mg/kg for all | | | | | | | | |
| March 2000 | 15.5± 1.5 | 460 ±60 | 44 ±10 | 6.71 ±1.01 | 9.84 ±1.16 | 86 ±5 | 48 ±4 | 0.8 ±0.08 | 35 ±21 |
| Oct 2000 | 5.4 ±0.6 | 412 ±44 | 39 ±19 | 4.11 ±1.49 | 4.47 ±0.09 | 116 ±12 | 19 ±9 | NA | NA |
| March 01 | 10.1± 0.4 | 462 ±27 | 20 ±8 | 6.96 ±1.68 | 6.78 ±1.40 | NA | 33 ±11 | 0.6 ±0.08 | 15 ±5 |
| **Mean** | **9.1 ±1.1** | **442 ±22** | **31 ±8** | **5.83 ±1.00** | **6.36 ±0.88** | **107 ±10** | **30 ±7** | **0.6 ±0.07** | **20 ±6** |

The cation exchange capacity (CEC) and mean soil cation levels are shown in Table 28. The mean CEC (3.77 meq/100g) is low relative to mean CEC values for Australian soils 10 meq/100g (Rengasamy and Churchman, 1999). As a consequence the levels of the individual cations that make up the total are also low. The proportion of each of the cations is shown in Table 29 and the mean percentage of each element is Al 4.9%, Ca 64.9%, Mg 23.4%, K 5.7% and Na 1.2%. McLean (1977) suggested that an ideal soil has the principal cations in the following proportions; 65-85% Ca, 6-12% Mg and 2-5% K.

Hence, this suggests that in the orchard sampled the cation ratio is skewed toward Magnesium. Some researchers believe this may effect the efficiency of uptake of Ca and K, however, it has been noted that there can be substantial departures from the ideal without effecting yield. In this case leaf Mg and Ca levels are well above Malaysian standards and Leaf K levels are below the minimum Malaysian standard (Table 30). Hence it is possible that the higher percentage of Mg is inhibiting K uptake.

**Table 28. Soil Cations Al, Ca, Mg, K, Na and C.E.C. (± SE).**

| Date | Al | Ca | Mg | K | Na | CEC |
|---|---|---|---|---|---|---|
| Value | meq/100g for all | | | | | |
| March 2000 | 0.07 ±0.00 | 2.58 ±0.57 | 0.81 ±0.02 | 0.17 ±0.01 | 0.04 ±0.00 | 3.66 ±0.54 |
| Oct 2000 | 0.15 ±0.03 | 1.90 ±0.29 | 1.01 ±0.17 | 0.15 ±0.01 | 0.05 ±0.01 | 3.26 ±0.28 |
| March 2001 | 0.22 ±0.07 | 2.99 ±0.44 | 0.73 ±0.08 | 0.27 ±0.02 | 0.04 ±0.00 | 4.24 ±0.42 |
| Mean | 0.17 ±0.04 | 2.51 ±0.27 | 0.85 ±0.08 | 0.21 ±0.02 | 0.04 ±0.00 | 3.77 ±0.25 |

**Table 29. Soil cation percentage.**

| Date | Al % | Ca % | Mg % | K % | Na % |
|---|---|---|---|---|---|
| March 2000 | 2 | 69.5 | 23.0 | 4.5 | 1.0 |
| October 2000 | 4.8 | 57.8 | 30.6 | 5.4 | 1.4 |
| March 2001 | 5.8 | 69.3 | 17.5 | 6.3 | 1.0 |
| Mean | 4.9 | 64.9 | 23.4 | 5.7 | 1.2 |

### 4.3.5 Leaf Analysis

Leaf nutrient levels were determined from the 5$^{th}$ and 6$^{th}$ mature leaf from the end of the shoot. There is evidence of seasonal variation in macro and micro nutrient levels. The leaf levels are similar to those obtained in Malaysia and the NT (Table 30).

In durians, Lim *et al.*, (1999) has presented the most detailed work undertaken in Australia to date. His work monitored seasonal changes, over 3 years, in durian leaf and soil nutrient concentrations in two durian orchards in the Lambell's lagoon area, approximately 40 km to the east of Darwin. He concluded that durian leaf and soil nutrient levels were closely related to seasonal changes in crop phenology, which are governed by fluctuations in weather conditions. Lim *et al.*, (1999) provided tentative leaf nutrient standards for NT growing areas. All leaf macro-elements and the micro-elements zinc and boron 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 cations K, Ca and Mg also exhibited similar trends, lower during fruit development in October-November and during active leaf flushing from March to May. This work, although informative, does not link durian yield with tree nutritional status and hence a determination of tree nutrient requirements.

In this study sampling was mainly carried out on trees, which were four to seven years of age, (those that had not flowered and fruited). Hence no link has been established between tree nutrient status, flowering and tree productivity. Mansfield (1995) reports that the fertiliser inputs at South Johnstone Research Station (North Queensland) may have been excessive because the trees tended to flush actively throughout the year, even during the winter months. His data also suggests that despite active flowering and good fruit set very few fruit matured.

Thai researchers have suggested that active leaf flushing during fruit set can cause lower fruit set due to an increase in fruitlet drop (Chandraparnik, 1989 cited by Punnachit *et al*., 1992). Ng and Thambo (1967) provided information on primary macro-nutrient removal by harvested fruit as a basis for crop fertiliser recommendations. Yaacob and Subhadrabandhu (1995) report that the fertiliser timings and quantities for eastern Thailand are: "after harvest apply 2 to 3 kg of 15N, 15 $P^2O^5$ and 15 $K^2O$ in the July period with a similar quantity of 9N, 24 $P^2O^5$ and 24 $K^2O$ applied in the September -October period.

### 4.3.6 Nutrition Conclusions

This study has quantified leaf and soil nutrient status of durian trees grown on a farm on the wet tropical coast of north Queensland. The lack of leaf deficiency or toxicity symptoms and the rapid growing nature of the trees suggest that these levels are appropriate for the vegetative phase of the trees.

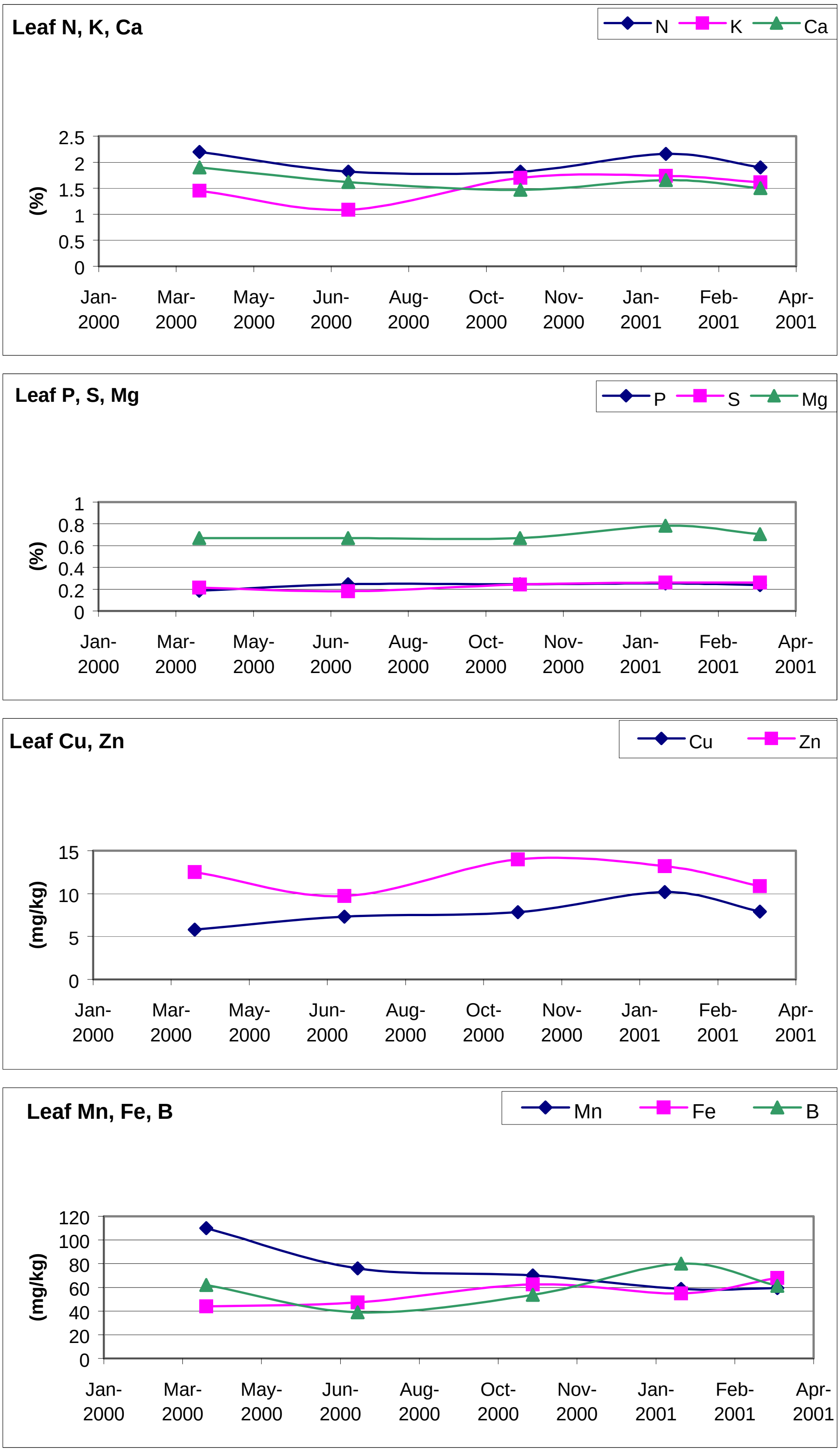


**Figure 13. Mean seasonal trends in leaf macro and micro elements of durian grown in the wet tropics of far north Queensland.**

**Table 30. Comparison of durian leaf nutrient levels.**

| Durian Leaf Analysis | | N % | P % | K % | S % | Ca % | Mg % | Na % | Cl % | Mn mg/kg | Fe mg/kg | Cu mg/kg | Zn mg/kg | B mg/kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Durian (Project samples) | Av. | 1.95 | 0.24 | 1.53 | 0.24 | 1.59 | 0.70 | 0.04 | 0.02 | 69.52 | 57.35 | 8.06 | 11.95 | 58.96 |
| 23 samples March 2000 to March 2001 | St dev | 0.23 | 0.05 | 0.40 | 0.05 | 0.37 | 0.09 | 0.01 | 0.01 | 30.18 | 18.45 | 1.71 | 2.57 | 18.65 |
| Malaysian Recommended | min | 1.80 | 0.12 | 1.60 | 0.16 | 0.90 | 0.25 | na | na | 25.00 | 50.00 | 6.00 | 15.00 | 15.00 |
| Range (leaf age 4 - 6 months) | max | 2.30 | 0.25 | 2.20 | 0.25 | 1.80 | 0.50 | na | na | 50.00 | 150.0 | 10.00 | 40.00 | 80.00 |
| NT Standards (TK Lim) | min | 1.58 | 0.18 | 1.48 | 0.17 | 1.11 | 0.25 | 0.01 | 0.05 | 6.25 | 15.02 | 5.82 | 11.92 | 33.29 |
| | max | 1.98 | 0.22 | 1.96 | 0.22 | 1.88 | 0.50 | 0.09 | 0.07 | 27.65 | 30.86 | 12.47 | 14.64 | 38.52 |

## 4.4 Irrigation monitoring

The weather data summaries have indicated that excessive rainfall has been the serious concerns for the researchers rather than water stress. The irrigation system used at the house site was a high volume centrifugal pump with a submersible pump used at the hall site. In the early project phase, sprinklers were located on 1.5m standpipes with nozzles that watered in a pattern three metres each side of the tree row but only 1 metre in width. As tree size increased all project trees were converted to Waterbird® 3 anti-ant sprinklers with a rated hourly output of 190L per tree at 2 bars.

Water meters were installed and several banks of tensiometers were placed at strategic locations around both sites. However due to the excessive rainfall experienced, the tensiometer readings were often missed or inconsequential. There was an unusual dry period in September 2001 to December 2001. Water meter readings were taken for this extended period and are presented in Table 31. Seven project trees were located in this row section, hence the meter readings ($m^3$) were divided by seven then converted to litres per tree. The average water supplement per tree for the 15 irrigation rounds was 1191.32 litres.

**Table 31. Water Use Monitoring (House site frequency).**

| Date | Meter Reading ($m^3$) | Litres / tree |
|---|---|---|
| 26/08/01 | 442.907 | |
| 1/09/01 | 453.000 | 1441.86 |
| 6/09/01 | 462.913 | 1416.14 |
| 9/09/01 | 472.913 | 1428.57 |
| 12/09/01 | 483.683 | 1538.57 |
| 7/10/01 | 489.549 | 838.00 |
| 11/10/01 | 495.470 | 845.86 |
| 16/10/01 | 501.589 | 874.14 |
| 26/10/01 | 507.275 | 812.29 |
| 4/11/01 | 511.740 | 637.86 |
| 14/11/01 | 529.171 | 2490.14 |
| 21/11/01 | 535.018 | 835.27 |
| 1/12/02 | 540.888 | 838.57 |
| 7/12/01 | 552.486 | 1656.86 |
| 11/12/01 | 558.222 | 819.43 |
| 25/12/01 | 567.996 | 1396.29 |
| 30/12/01 | 577.768 | |
| Average litre per tree per application | | 1191.32 |

Further irrigation monitoring is recommended once fruit load is experienced across a wider section of project trees. Hiranpradit *et al.*, (1998) state that for a durian tree during March, which is the late fruit development period in Chantaburi, Thailand, the potential evapotranspiration (ETp) is 3.83 mm/day per square metre of canopy. Subhadrabandhu and Ketsa (2001) state "*These calculations may not be exact in every production season as the ETp value given …. represents the average over only the last 25 years, as recorded by the Meteorological Department of Thailand.*"

Climatic comparisons for the Chantaburi and Australian durian growing regions are included in Table 32. Hiranpradit *et al.*, (1998) stated that the effective root depths for water and nutrition for durian is 20 – 30 cm compared to rambutan (30 – 60 cm) and mangosteen (90 – 120 cm). Subhadrabandhu and Ketsa (2001) states "*The above information suggests that frequent watering in small amounts will be more beneficial to durian trees than applying large infrequent quantities of water.*"

Project observations have noted that most of the root systems are at ground level. This is why mulching is so critical to protect these roots from damage from mowing equipment. Mulching has the added benefit of assisting with *P. palmivora* control as discussed earlier in this Chapter.

Subhadrabandhu and Ketsa (2001) states *"The manipulation of crops by irrigation is widely practiced in Thailand. This is especially the case when early flowering is induced by withholding water before the initiation stage. The major durian harvesting season is from May to June, and crops that ripen outside this period are likely to command premium prices. In particular, crops that ripen earlier than normal seem to gain the best price advantage. Those trees growing on sandy loams have been observed to respond most favourably to this method of forced flowering. Some cultivars such as Kradum Thong and Chanee, are more responsive to the withholding of irrigation to induce flowering than others, such as Kan Yao or Kob."*

**Table 32. Climatic Comparisons for World Durian Production Regions (ASEAN 1982).**

| Location | Latitude | Mean Max. Temp (C) | Mean Min. Temp (C) | Annual Rainfall (mm) | Annual Evap (mm) | Months Moisture Deficit |
|---|---|---|---|---|---|---|
| Chantaburi Thailand | 12.36° N | 33.4 | 19.6 | 3015 | 1556 | 6 |
| Darwin N.T. | 12.25° S | 33.1 | 19.3 | 1665 | 2685 | 8 |
| South Johnstone, N.Q. | 17.36° S | 31.2 | 14.4 | 3308 | 1572 | 4 |

## 4.5 Recommendations

The implications the results in this Chapter have for mature yielding trees is still not known and further research is required to identify leaf standards for producing trees.

Further research through RIRDC Project No DAQ–288A "Nutrition of Durian and Mangosteen Orchards in North Queensland" will quantify the nutrient requirements and management of bearing trees in this environment.

Growers need to experiment with the manipulation of flowering to spread their harvest and increase their returns.

Trunk injection methods need to be monitored to avoid excessive trunk splitting. Foliar sprays may be the alternative method of application for durian.

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# 5. Durian Phenology Monitoring

## 5.1 Introduction

The work described below is linked to the fourth project aim: "compare tree growth rates under different soil and climates." Phenological activity of a range of durian varieties were monitored over 12 months to establish whether there were any major differences in growth characteristics between varieties and between trees grown on differing soil types.

## 5.2 Materials and Methods

Eighteen varieties of *Durio zibethinus* consisting of 46 trees and one tree of *Durio macrantha* were chosen for phenological monitoring. The tree varieties and numbers of trees per variety being monitored are shown in Table 33. For six of the eighteen varieties of *D. zibethinus* only one tree was available for monitoring. In the remaining 12 varieties replicate numbers ranged from two to five.

**Table 33. Durian varieties and number of replicate trees utilised for phenology monitoring.**

| Variety | Variety No. | Tree No. |
|---|---|---|
| Chanee | 1 | 1 |
| *D. macrantha* | 2 | 1 |
| D159 | 3 | 1 |
| D175 | 4 | 1 |
| D190 | 5 | 2 |
| D24 | 6 | 5 |
| DPI Mon Thong | 7 | 1 |
| Gob Yaow | 8 | 2 |
| Gumpun | 9 | 4 |
| Hawaiian Mon Thong | 10 | 4 |
| Hepe | 11 | 2 |
| Hew 2 | 12 | 4 |
| Hew 7 | 13 | 4 |
| KK11 | 14 | 1 |
| Kradum Thong | 15 | 4 |
| Luang | 16 | 5 |
| Permasuri | 17 | 1 |
| Sahom | 18 | 2 |
| Sukun | 19 | 2 |

Trees monitored were further divided by location with 28 trees, representing seventeen varieties, in the "House Block" on a alluvial Brown Kandosol (Canoe series; Murtha *et al*., CSIRO Rep. 123) and the remaining 19 trees representing 10 varieties on the "Hall Block" on Krasnozem or Red, Ferrosol (Pin Gin series, Murtha *et al*., CSIRO Rep. 123). The two growing areas are located within 1000 m of each other.

Whole tree monitoring for vegetative flush activity (new flush, green flush and mature leaves) was carried out approximately every 14 days from the 6 May 1999 until 16 March 2000. At the same time trees were rated for flowering activity and fruit set. The vegetative flush activity was determined on a whole tree basis, each tree being carefully examined and the flushing percentage subjectively determined. The same observer determined flushing percentage throughout the monitoring period.

Phenology data was pooled across varieties in each block, due to the lack of replicates for some of the varieties. Data is presented graphically with percentage activity for new, green and mature flush accompanied with standard error data.

Weather data, including temperature (°C), rainfall (mm/day) and short wave solar radiation (MJ/m²/day) was recorded on a Campbell Scientific automatic weather station adjacent to the "Hall Site". Data from the 21 April to 1 July 1999 was unavailable due to battery failure over that period. Replacement "indicative" data have been provided through a comparison of known weather station data (y-axis) and SILO data drill estimates (x-axis) for the appropriate latitude and longitude (17$^o$ 15.8'S, 145$^o$ 55.3'E). The relationships utilised are as follows:

| **Variable** | Relationship and $r^2$ value |
|---|---|
| Maximum temperature (C) | Y=0.9622x + 1.3533 ($r^2$ = 0.76) |
| Minimum temperature (C) | Y= 1.2009x – 5.7665 ($r^2$ = 0.94) |
| Rainfall (mm) | Y= 0.8235x ($r^2$ = 0.71) |
| Shortwave solar radiation (MJ/M2/day) | Y= 0.8579x – 1.1723 ($r^2$ = 0.44) |

## 5.3 Results

### 5.3.1 Weather data

During the monitoring period daily maximum temperatures ranged from a high of 34.8 °C to a low of 19.63 °C with the average maximum temperature being 28.3 °C. The daily minimum temperature ranged from a low of 7.23 °C to a high of 24.6 °C with the average minimum equal to 18.8 °C. The average temperature for the whole period was 23.5 °C. These conditions are substantially cooler than durian trees experience in their native environment where the average temperature ranges from 24-30$^o$C (ASEAN, 1982).

Rainfall for the period totalled 5706 mm with the daily average equal to 15.81 mm/day. The highest daily rainfall was 322.8 mm. Over the same period evapo-transpiration ranged from 0.21 mm/day to 5.93 mm/day with the average Et equal to 2.97 mm/day. Solar shortwave radiation (SWSR) ranged from a low of 1.81 to 27.7 MJ/m²/day with the average for the period being 14.7 MJ/m²/day. Weather data is graphically represented in Figure 14.

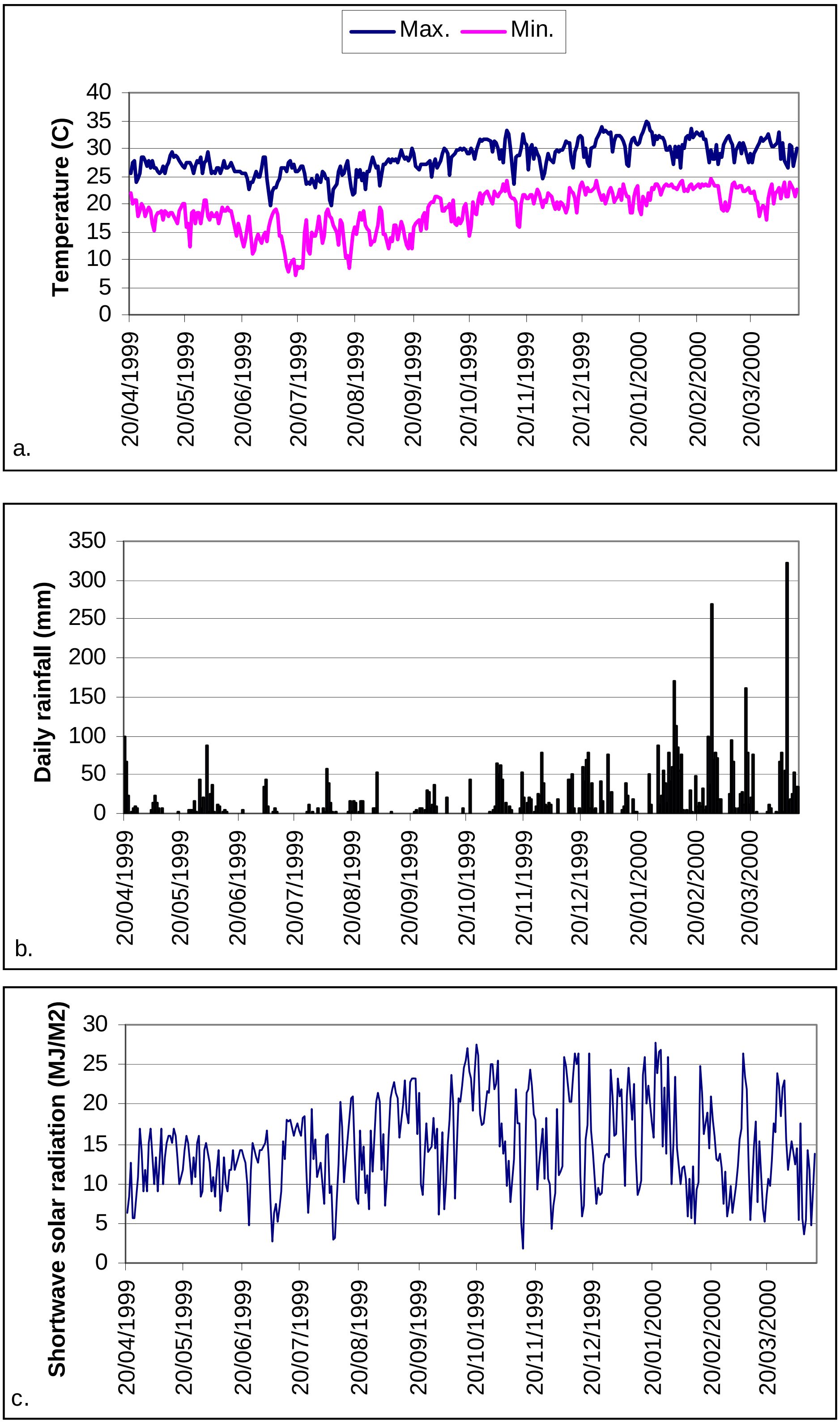
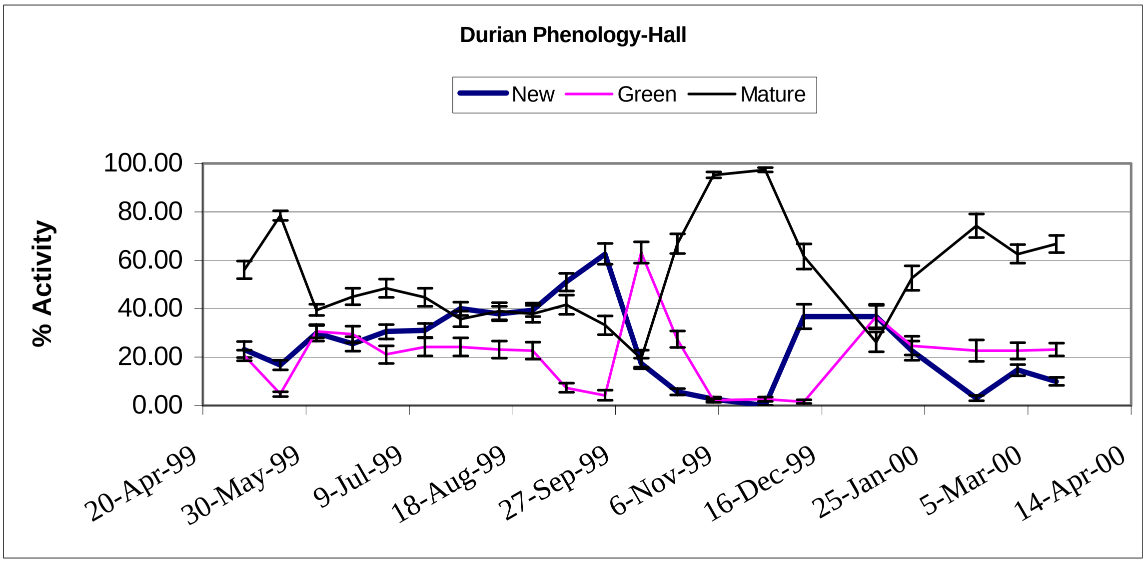



**Figure 14. Climate data during the phenology monitoring period (20 April 1999 – 14 April 2000), (a) daily max and min temperature, (b) daily rainfall, (c) daily short wave solar radiation. Note; data from 21/4/99 to 1/7/99 was computed using relationships between actual weather station data and the SILO data drill.**

### 5.3.2 Tree Phenology

New flush activity occurred throughout most of the monitoring period with a major peak in spring (late September) and a smaller peak in mid December following a dormant period through October and November (Figure 15). The patterns of flushing are similar for trees grown on both soil types. Despite relatively cool conditions from May through to the end of September (minimum temperatures ranging from 10° to 18° C) there was active vegetative flushing taking place during this time.



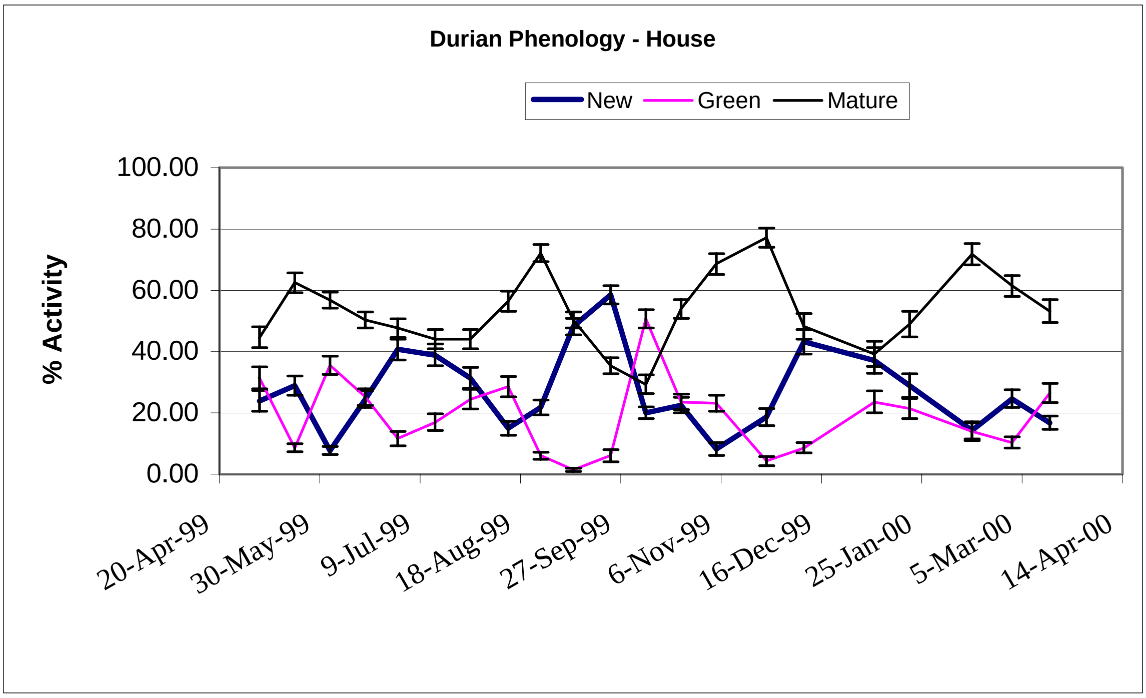




**Figure 15. Shoot activity (%) for durians grown on two project sites (Hall and House).**

Individual trees varied in their flushing response. However, in almost all cases trees remained relatively active (10 – 30 % new flush) during the autumn/winter period. At times trees of the same variety within the same row had markedly different phenological activity ratings. This suggests that shoot flushing is to an extent tree dependent rather then solely weather dependent.

### 5.3.3 Flowering and Fruiting

Flowering and fruiting activity was relatively low among the trees monitored. This is due to the young age of the trees with the bulk of trees monitored being less than six years old. In trees, which did flower, first flowers were noted on the 15 July, with peak flowering occurring in mid to late August. Flowering activity then tailed off with flowering completed by late October to early December. Recordable fruit set did not occur until early to late November. The only tree to produce harvestable fruit was a 8-year-old Luang tree**,** which started with seven fruit set and ended up with two fully developed fruit approximately 5 months after peak flowering (Table 34).

**Table 34. Flowering (1st and peak), fruit set and harvest date for durian monitored in the phenology monitoring trial**

| | Flowering | | | | | |
|---|---|---|---|---|---|---|
| **Variety** | **1st** | **Peak** | **Complete** | **Fruit set** | **Harvest Date** | **Comment** |
| Hew 7 (No 359) | 15-Jul 1999 | 13-Aug 1999 | 21-Oct 1999 | - | no harvest | No set |
| Gob Yaow (No 470) | 15-Jul 1999 | 26-Aug 1999 | 9-Dec 1999 | 4-Nov 1999 | no harvest | Fruit drop by 1 Mar 2000 |
| Luang (No 800) | 29-Jul 1999 | 7-Oct 1999 | 24-Nov 1999 | 24-Nov 1999 | 16 March 2000 | 2 fruits to harvest |
| D159 (No 411) | 13-Aug 1999 | 23-Sep 1999 | 9-Dec 1999 | 24-Nov 1999 | no harvest | Fruit drop by 6 Jan 2000 |
| D24 (No 399) | 8-Sep 1999 | 4-Nov 1999 | 6-Jan 1999 | - | no harvest | No set |
| Hawaiian Mon Thong (No 305) | 26-Aug 1999 | 4-Nov 1999 | 6-Jan 2000 | - | no harvest | No set |

## 5.4 Discussion

The phenology-monitoring period of 12 months is relatively short given the variability in climate and tree activity over that time. In north Queensland durian shoot development appears to be active throughout the year despite the relatively cool conditions which occur during the winter months. This finding concurs with that observed by Mansfield (1995). These conditions are considerably cooler than the tree experiences in its native environment yet tree shoot development appears to be unaffected. Notably peak shoot production occurred from late September as night and day temperatures increased. This may have also coincided with a period of higher radiation inputs.

Observations have revealed that flushing activity often occurs in parts of the tree rather than uniformly over the canopy. Hence it is rare that flushing activity on any single tree is synchronous. Activity also varies considerably from tree to tree within the same block and variety. Hence, it was not unusual for trees side by side to exhibit entirely different phases of activity. This feature makes it difficult to present any realistic generalisation of flushing activity, because the variation among individual trees is high.

Another interesting feature of our observations was the large difference between flower numbers, fruit set and final fruit harvested. The durian tree can flower profusely yet the final fruit numbers harvested are often extremely low. Lim (1997) suggests that this is often due to self incompatibility. The researchers believe that in some cases environmental conditions following flowering may be inappropriate for fruit set. For example extreme wet conditions following flowering, as occurred during the monitoring period, are most likely deleterious to fruit set. High wind conditions during summer storms and periods of cyclone activity are also responsible for causing fruit drop.

A few varieties, most notably Luang, appear to be sensitive to night temperatures below 10°C. In late July following 10 days of minimum temperatures below 10°C severe leaf drop was noted in Luang trees grown on the Hall block. This same reaction has been noted in previous and subsequent seasons.

Leaf drop following August 1999 observations indicated that Luang and Sukun, performed poorly under cold conditions. D 175 (Red Prawn) performed best. Individual tree observations are listed in Table 35.

Lim (1997) reported 2 distinct flushing periods, with a main period from February to April and another minor period from October to December. In north Queensland during the 1999 season, there were 4 flushing periods, with the peak flush occurring through September. The differences between NT and NQ flushing patterns is most likely due to temperature and relative humidity differences, with NT having a lower relative humidity during May to October. In conclusion, shoot activity is more prolific then imagined, with trees exhibiting the ability to remain vegetatively active during periods of relatively cool conditions.

## 5.5 Recommendations

The researchers collected flowering and fruiting observations on all project trees. These are presented in Table 36. In summary Hawaiian Mon Thong has performed extremely well this season with one 10 year-old-tree yielding more than 100kg of marketable fruit.

Future yield data for the newer clones needs to be compiled through ZTR-1A Phase 2 or a similar project. Interested growers will further assist with identifying the best clones for north Queensland conditions.

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**Table 35. Tree rating for cold tolerance (August 1999).**

| Site | No. | Clone | Year Planted | Nil to 10% | Light 10 - 25% | Moderate 25-50% |
|---|---|---|---|---|---|---|
| Hall | 111 | Ampung | 95/96 | x | | |
| Hall | 185 | Ampung | 96/97 | x | | |
| Hall | 263 | Ampung | 94/95 | x | | |
| Hall | 239 | Chanee | 94/95 | x | | |
| House | 412 | Chanee | 95/96 | x | | |
| House | 428 | Chanee | 94/95 | x | | |
| Hall | 269 | D 10 | 94/95 | x | | |
| Hall | 270 | D 10 | 94/95 | x | | |
| Hall | 130 | D 118 | 95/96 | x | | |
| Hall | 131 | D 118 | 95/96 | x | | |
| Hall | 186 | D 118 | 96/97 | x | | |
| House | 420 | D 118 | 94/95 | x | | |
| Hall | 241 | D 123 | 94/95 | x | | |
| Hall | 268 | D 123 | 94/95 | x | | |
| Hall | 94 | D 140 | 95/96 | x | | |
| Hall | 95 | D 140 | 95/96 | x | | |
| Hall | 96 | D 143 | 95/96 | x | | |
| Hall | 99 | D 144 | 95/96 | x | | |
| House | 388 | D 144 | 95/96 | x | | |
| House | 389 | D 144 | 95/96 | x | | |
| House | 467 | D 144 | 96/97 | x | | |
| House | 607 | D 160 | 96/97 | x | | |
| House | 609 | D 160 | 96/97 | x | | |
| Hall | 100 | D 168 | 95/96 | x | | |
| Hall | 124 | D 175 | 95/96 | x | | |
| Hall | 125 | D 175 | 95/96 | x | | |
| Hall | 164 | D 175 | 96/97 | x | | |
| Hall | 165 | D 175 | 96/97 | x | | |
| House | 375 | D 175 | 95/96 | x | | |
| House | 521 | D 175 | 95/96 | x | | |
| House | 522 | D 175 | 95/96 | x | | |
| House | 523 | D 175 | 95/96 | x | | |
| Hall | 83 | D 178 | 95/96 | x | | |
| House | 384 | D 178 | 95/96 | x | | |
| Hall | 85 | D 179 | 95/96 | x | | |
| Hall | 176 | D 188 | 96/97 | x | | |
| Hall | 127 | D 190 | 95/96 | x | | |
| Hall | 184 | D 190 | 96/97 | x | | |
| Hall | 322 | D 190 | 94/95 | x | | |
| House | 366 | D 190 | 94/95 | x | | |
| House | 367 | D 190 | 94/95 | x | | |
| House | 598 | D 190 | 96/97 | x | | |
| House | 602 | D 190 | 96/97 | x | | |
| House | 603 | D 190 | 96/97 | x | | |
| House | 604 | D 190 | 96/97 | x | | |
| House | 423 | D 197 | 94/95 | x | | |

**Table 35 continued.  Tree rating for cold tolerance (August 1999)**

| Site | No. | Clone | Year Planted | Nil to 10% | Light 10 - 25% | Moderate 25-50% |
|---|---|---|---|---|---|---|
| House | 606 | D 197 | 96/97 | x | | |
| House | 608 | D 197 | 96/97 | x | | |
| House | 610 | D 197 | 96/97 | x | | |
| House | 612 | D 197 | 96/97 | x | | |
| House | 614 | D 197 | 96/97 | x | | |
| Hall | 88 | D 2 | 95/96 | x | | |
| Hall | 181 | D 2 | 96/97 | x | | |
| Hall | 191 | D 2 | 94/95 | x | | |
| Hall | 192 | D 24 | 94/95 | x | | |
| Hall | 207 | D 24 | 94/95 | x | | |
| House | 572 | D 24 | 96/97 | x | | |
| House | 575 | D 24 | 96/97 | x | | |
| House | 581 | D 24 | 96/97 | x | | |
| House | 589 | D 24 | 96/97 | x | | |
| House | 446 | D 96 | 96/97 | x | | |
| House | 448 | D 96 | 96/97 | x | | |
| House | 451 | D 96 | 96/97 | x | | |
| Hall | 157 | D 99 | 96/97 | x | | |
| Hall | 160 | D 99X | 96/97 | x | | |
| Hall | 161 | D 99X | 96/97 | x | | |
| Hall | 162 | D 99X | 96/97 | x | | |
| Hall | 103 | *D. macrantha* | 95/96 | x | | |
| Hall | 128 | *D. macrantha* | 95/96 | x | | |
| Hall | 129 | *D. macrantha* | 95/96 | x | | |
| Hall | 183 | *D. macrantha* | 96/97 | | x | |
| House | 432 | *D. macrantha* | 94/95 | x | | |
| House | 433 | *D. macrantha* | 94/95 | x | | |
| House | 434 | *D. macrantha* | 94/95 | x | | |
| House | 435 | *D. macrantha* | 94/95 | x | | |
| House | 436 | *D. macrantha* | 94/95 | x | | |
| House | 437 | *D. macrantha* | 94/95 | x | | |
| House | 438 | *D. macrantha* | 94/95 | x | | |
| House | 440 | *D. macrantha* | 94/95 | x | | |
| House | 441 | *D. macrantha* | 94/95 | x | | |
| House | 442 | *D. macrantha* | 94/95 | x | | |
| Hall | 118 | *D. mansoni* | 95/96 | x | | |
| Hall | 75 | DPI Mon Thong | 95/96 | x | | |
| Hall | 76 | Kan Yao | 95/96 | x | | |
| Hall | 187 | Kan Yao | 94/95 | x | | |
| Hall | 188 | Kan Yao | 94/95 | x | | |
| Hall | 189 | Kan Yao | 94/95 | x | | |
| Hall | 202 | Kan Yao | 94/95 | x | | |
| Hall | 205 | Kan Yao | 94/95 | x | | |
| Hall | 208 | Kan Yao | 94/95 | x | | |
| Hall | 214 | Kan Yao | 94/95 | x | | |
| House | 540 | Kan Yao | 95/96 | x | | |
| House | 541 | Kan Yao | 95/96 | x | | |
| House | 443 | Gumpun | 94/95 | x | | |

Table 35 continued. Tree rating for cold tolerance (August 1999)

| Site | No. | Clone | Year Planted | Nil to 10% | Light 10 - 25% | Moderate 25-50% |
|---|---|---|---|---|---|---|
| House | 444 | Gumpun | 94/95 | x | | |
| House | 445 | Gumpun | 94/95 | x | | |
| House | 465 | Gumpun | 94/95 | x | | |
| House | 466 | Gumpun | 94/95 | x | | |
| Hall | 216 | Hepe | 94/95 | x | | |
| Hall | 137 | HEW 7 | 95/96 | x | | |
| Hall | 107 | KK 11 | 95/96 | x | | |
| House | 605 | Kradum Thong | 96/97 | x | | |
| House | 574 | KradumTong | 96/97 | x | | |
| House | 576 | KradumTong | 96/97 | x | | |
| House | 580 | KradumTong | 96/97 | x | | |
| House | 582 | KradumTong | 96/97 | x | | |
| Hall | 261 | Permasuri | 94/95 | x | | |
| Hall | 199 | Petruk | 94/95 | x | | |
| House | 363 | Sahom | 94/95 | x | | |
| House | 365 | Sahom | 94/95 | x | | |
| Hall | 262 | Sahom | 94/95 | x | | |
| House | 453 | Sunan | 96/97 | x | | |
| House | 454 | Sunan | 96/97 | x | | |
| House | 455 | Sunan | 96/97 | x | | |
| Hall | 120 | Yeao | 95/96 | x | | |
| Hall | 121 | Yeao | 95/96 | x | | |
| House | 404 | Ampung | 95/96 | | x | |
| House | 487 | Ampung | 96/97 | | x | |
| House | 513 | Ampung | 95/96 | | x | |
| House | 514 | Ampung | 95/96 | | x | |
| House | 472 | Chanee | 96/97 | | x | |
| House | 536 | Chanee | 95/96 | | x | |
| House | 537 | Chanee | 95/96 | | x | |
| House | 594 | Chin | 96/97 | | x | |
| House | 596 | Chin | 96/97 | | x | |
| House | 619 | Chin | 96/97 | | x | |
| Hall | 236 | D 10 | 94/95 | | x | |
| Hall | 285 | D 10 | 94/95 | | x | |
| House | 511 | D 118 | 95/96 | | x | |
| Hall | 132 | D 120 | 95/96 | | x | |
| Hall | 133 | D 120 | 95/96 | | x | |
| House | 491 | D 120 | 96/97 | | x | |
| House | 475 | D 123 | 96/97 | | x | |
| House | 476 | D 123 | 96/97 | | x | |
| House | 620 | D 140 | 96/97 | | x | |
| House | 424 | D 143 | 94/95 | | x | |
| House | 497 | D 144 | 96/97 | | x | |
| House | 548 | D 144 | 95/96 | | x | |
| House | 613 | D 145 | 96/97 | | x | |
| House | 411 | D 159 | 95/96 | | x | |
| Hall | 93 | D 16 | 95/96 | | x | |

**Table 35 continued. Tree rating for cold tolerance (August 1999)**

| Site | No. | Clone | Year Planted | Nil to 10% | Light 10 - 25% | Moderate 25-50% |
|---|---|---|---|---|---|---|
| House | 555 | D 16 | 95/96 | | x | |
| House | 556 | D 16 | 95/96 | | x | |
| House | 557 | D 16 | 95/96 | | | x |
| House | 600 | D 160 | 96/97 | | x | |
| House | 427 | D 163 | 94/95 | | x | |
| House | 567 | D 163 | 95/96 | | x | |
| House | 378 | D 164 | 95/96 | | x | |
| House | 468 | D 164 | 96/97 | | x | |
| House | 518 | D 164 | 95/96 | | x | |
| House | 611 | D 166 | 96/97 | | x | |
| House | 390 | D 168 | 95/96 | | x | |
| House | 552 | D 168 | 95/96 | | x | |
| House | 553 | D 168 | 95/96 | | x | |
| House | 554 | D 168 | 95/96 | | x | |
| House | 374 | D 175 | 95/96 | | x | |
| Hall | 82 | D 178 | 95/96 | | x | |
| Hall | 169 | D 178 | 96/97 | | x | |
| House | 381 | D 178 | 95/96 | | x | |
| House | 382 | D 178 | 95/96 | | x | |
| House | 383 | D 178 | 95/96 | | x | |
| House | 385 | D 178 | 95/96 | | x | |
| Hall | 84 | D 179 | 95/96 | | x | |
| Hall | 171 | D 179 | 96/97 | | x | |
| House | 377 | D 179 | 95/96 | | x | |
| House | 549 | D 179 | 95/96 | | | x |
| House | 550 | D 179 | 95/96 | | | x |
| House | 551 | D 179 | 95/96 | | | x |
| House | 570 | D 179 | 95/96 | | x | |
| Hall | 116 | D 188 | 95/96 | | x | |
| House | 392 | D 188 | 95/96 | | x | |
| House | 501 | D 188 | 95/96 | | x | |
| House | 502 | D 188 | 95/96 | | x | |
| Hall | 126 | D 190 | 95/96 | | x | |
| House | 561 | D 190 | 95/96 | | x | |
| House | 601 | D 190 | 96/97 | | x | |
| Hall | 89 | D 2 | 95/96 | | x | |
| Hall | 203 | D 2 | 94/95 | | x | |
| Hall | 218 | D 2 | 94/95 | | x | |
| Hall | 308 | D 2 | 92/93 | | x | |
| House | 504 | D 2 | 95/96 | | x | |
| House | 506 | D 2 | 95/96 | | x | |
| Hall | 142 | D 24 | 95/96 | | x | |
| Hall | 144 | D 24 | 95/96 | | x | |
| Hall | 146 | D 24 | 95/96 | | x | |
| Hall | 148 | D 24 | 95/96 | | x | |
| Hall | 194 | D 24 | 94/95 | | x | |
| Hall | 196 | D 24 | 94/95 | | x | |

**Table 35 continued. Tree rating for cold tolerance (August 1999)**

| Site | No. | Clone | Year Planted | Nil to 10% | Light 10 - 25% | Moderate 25-50% |
|---|---|---|---|---|---|---|
| Hall | 201 | D 24 | 94/95 | | x | |
| Hall | 217 | D 24 | 94/95 | | x | |
| Hall | 246 | D 24 | 94/95 | | x | |
| Hall | 250 | D 24 | 94/95 | | x | |
| Hall | 258 | D 24 | 94/95 | | x | |
| Hall | 260 | D 24 | 94/95 | | x | |
| House | 396 | D 24 | 95/96 | | x | |
| House | 397 | D 24 | 95/96 | | x | |
| House | 399 | D 24 | 95/96 | | x | |
| House | 407 | D 24 | 95/96 | | x | |
| House | 425 | D 24 | 94/95 | | x | |
| House | 585 | D 24 | 96/97 | | x | |
| Hall | 90 | D 24 | 95/96 | | x | |
| House | 618 | D 24 S | 96/97 | | x | |
| Hall | 306 | D 7 | 92/93 | | | x |
| Hall | 310 | D 7 | 92/93 | | | x |
| Hall | 312 | D 7 | 92/93 | | | x |
| Hall | 314 | D 7 | 92/93 | | | x |
| House | 386 | D 7 | 95/96 | | x | |
| House | 447 | D 96 | 96/97 | | x | |
| Hall | 156 | D 99 | 96/97 | | x | |
| House | 430 | D 99 | 94/95 | | x | |
| House | 519 | D 99 | 95/96 | | x | |
| House | 520 | D 99 | 95/96 | | x | |
| House | 351 | D 99 | 94/95 | | x | |
| House | 352 | D 99 | 94/95 | | x | |
| House | 524 | D 99X | 95/96 | | x | |
| House | 525 | D 99X | 95/96 | | x | |
| House | 526 | D 99X | 95/96 | | x | |
| House | 527 | D 99X | 95/96 | | x | |
| House | 584 | D 99X | 96/97 | | x | |
| House | 586 | D 99X | 96/97 | | x | |
| House | 588 | D 99X | 96/97 | | x | |
| Hall | 153 | DPI Mon Thong | 96/97 | | x | |
| Hall | 154 | DPI Mon Thong | 96/97 | | x | |
| Hall | 155 | DPI Mon Thong | 96/97 | | x | |
| House | 410 | DPI Mon Thong | 95/96 | | x | |
| House | 544 | DPI Mon Thong | 95/96 | | x | |
| House | 545 | DPI Mon Thong | 95/96 | | x | |
| House | 546 | DPI Mon Thong | 95/96 | | x | |
| House | 547 | DPI Mon Thong | 95/96 | | x | |
| Hall | 123 | Kan Yao | 95/96 | | x | |
| House | 528 | Kan Yao | 95/96 | | x | |
| House | 542 | Kan Yao | 95/96 | | x | |
| House | 543 | Kan Yao | 95/96 | | x | |
| Hall | 272 | Gob Yaow | 92/93 | | x | |

**Table 35 continued. Tree rating for cold tolerance (August 1999)**

| Site | No. | Clone | Year Planted | Nil to 10% | Light 10 - 25% | Moderate 25-50% |
|---|---|---|---|---|---|---|
| Hall | 275 | Gob Yaow | 92/93 | | x | |
| Hall | 279 | Gob Yaow | 92/93 | | x | |
| Hall | 282 | Gob Yaow | 92/93 | | x | |
| Hall | 286 | Gob Yaow | 92/93 | | x | |
| Hall | 289 | Gob Yaow | 92/93 | | x | |
| Hall | 297 | Gob Yaow | 92/93 | | x | |
| Hall | 300 | Gob Yaow | 92/93 | | x | |
| Hall | 304 | Gob Yaow | 92/93 | | x | |
| House | 470 | Gob Yaow | 96/97 | | x | |
| House | 477 | Gob Yaow | 94/95 | | x | |
| House | 480 | Gob Yaow | 94/95 | | | x |
| Hall | 198 | Gumpun | 94/95 | | x | |
| Hall | 206 | Gumpun | 92/93 | | x | |
| House | 452 | Gumpun | 94/95 | | x | |
| House | 456 | Gumpun | 94/95 | | | x |
| House | 462 | Gumpun | 94/95 | | x | |
| Hall | 305 | H. Mon Thong | 92/93 | | x | |
| Hall | 309 | H. Mon Thong | 92/93 | | x | |
| Hall | 311 | H. Mon Thong | 92/93 | | x | |
| Hall | 313 | H. Mon Thong | 92/93 | | x | |
| Hall | 315 | H. Mon Thong | 92/93 | | x | |
| Hall | 317 | H. Mon Thong | 92/93 | | x | |
| Hall | 319 | H. Mon Thong | 92/93 | | x | |
| House | 479 | H. Mon Thong | 96/97 | | x | |
| House | 481 | H. Mon Thong | 96/97 | | x | |
| House | 482 | H. Mon Thong | 96/97 | | x | |
| House | 486 | H. Mon Thong | 96/97 | | x | |
| Hall | 104 | Hepe | 95/96 | | x | |
| Hall | 105 | Hepe | 95/96 | | x | |
| Hall | 139 | Hepe | 95/96 | | | x |
| Hall | 141 | Hepe | 95/96 | | | x |
| Hall | 143 | Hepe | 95/96 | | | x |
| Hall | 147 | Hepe | 95/96 | | | x |
| Hall | 149 | Hepe | 95/96 | | | x |
| Hall | 193 | Hepe | 94/95 | | x | |
| Hall | 197 | Hepe | 94/95 | | x | |
| Hall | 219 | Hepe | 94/95 | | x | |
| Hall | 221 | Hepe | 94/95 | | x | |
| Hall | 222 | Hepe | 94/95 | | x | |
| Hall | 223 | Hepe | 94/95 | | x | |
| House | 350 | Hepe | 94/95 | | x | |
| House | 368 | Hepe | 94/95 | | x | |
| House | 558 | Hepe | 95/96 | | | x |
| House | 559 | Hepe | 95/96 | | | x |
| House | 560 | Hepe | 95/96 | | | x |
| Hall | 234 | HEW 1 | 94/95 | | x | |
| House | 327 | HEW 1 | 94/95 | | x | |

Table 35 continued. Tree rating for cold tolerance (August 1999)

| Site | No. | Clone | Year Planted | Nil to 10% | Light 10 - 25% | Moderate 25-50% |
|---|---|---|---|---|---|---|
| House | 329 | HEW 1 | 94/95 | | x | |
| House | 331 | HEW 1 | 94/95 | | x | |
| House | 333 | HEW 1 | 94/95 | | x | |
| House | 335 | HEW 1 | 94/95 | | x | |
| House | 337 | HEW 1 | 94/95 | | x | |
| House | 339 | HEW 1 | 94/95 | | x | |
| House | 343 | HEW 1 | 94/95 | | x | |
| House | 345 | HEW 1 | 94/95 | | x | |
| House | 347 | HEW 1 | 94/95 | | x | |
| House | 349 | HEW 1 | 94/95 | | x | |
| House | 326 | HEW 2 | 94/95 | | x | |
| House | 328 | HEW 2 | 94/95 | | x | |
| House | 330 | HEW 2 | 94/95 | | x | |
| House | 334 | HEW 2 | 94/95 | | x | |
| House | 336 | HEW 2 | 94/95 | | x | |
| House | 338 | HEW 2 | 94/95 | | x | |
| Hall | 134 | HEW 6 | 95/96 | | | x |
| House | 354 | HEW 6 | 94/95 | | x | |
| House | 356 | HEW 6 | 94/95 | | x | |
| House | 358 | HEW 6 | 94/95 | | x | |
| Hall | 136 | HEW 7 | 95/96 | | x | |
| Hall | 245 | HEW 7 | 94/95 | | x | |
| House | 355 | HEW 7 | 94/95 | | x | |
| House | 357 | HEW 7 | 94/95 | | x | |
| House | 359 | HEW 7 | 94/95 | | x | |
| House | 539 | HEW 7 | 95/96 | | x | |
| House | 360 | KK 11 | 94/95 | | x | |
| House | 362 | KK 11 | 94/95 | | x | |
| House | 531 | KK 11 | 95/96 | | x | |
| House | 533 | KK 11 | 95/96 | | x | |
| Hall | 238 | Kradum Thong | 94/95 | | x | |
| Hall | 240 | Kradum Thong | 94/95 | | x | |
| Hall | 316 | Kradum Thong | 94/95 | | x | |
| House | 353 | Kradum Thong | 94/95 | | x | |
| House | 413 | Kradum Thong | 95/96 | | x | |
| House | 414 | Kradum Thong | 95/96 | | x | |
| House | 415 | Kradum Thong | 95/96 | | x | |
| House | 416 | Kradum Thong | 95/96 | | x | |
| House | 417 | Kradum Thong | 95/96 | | x | |
| House | 418 | Kradum Thong | 95/96 | | x | |
| House | 578 | Kradum Thong | 96/97 | | x | |
| Hall | 152 | Luang | 95/96 | | | x |
| Hall | 271 | Luang | 92/93 | | | x |
| Hall | 273 | Luang | 92/93 | | | x |
| Hall | 277 | Luang | 92/93 | | | x |
| Hall | 278 | Luang | 92/93 | | | x |
| Hall | 280 | Luang | 92/93 | | | x |

**Table 35 continued. Tree rating for cold tolerance (August 1999)**

| Site | No. | Clone | Year Planted | Nil to 10% | Light 10 - 25% | Moderate 25-50% |
|---|---|---|---|---|---|---|
| Hall | 281 | Luang | 92/93 | | | x |
| Hall | 284 | Luang | 92/93 | | | x |
| Hall | 287 | Luang | 92/93 | | | x |
| Hall | 288 | Luang | 92/93 | | | x |
| Hall | 291 | Luang | 92/93 | | | x |
| Hall | 292 | Luang | 92/93 | | | x |
| Hall | 293 | Luang | 92/93 | | | x |
| Hall | 296 | Luang | 92/93 | | | x |
| Hall | 298 | Luang | 92/93 | | | x |
| Hall | 302 | Luang | 92/93 | | | x |
| Hall | 303 | Luang | 92/93 | | | x |
| House | 483 | Luang | 94/95 | | x | |
| House | 485 | Luang | 94/95 | | x | |
| House | 498 | Luang | 94/95 | | x | |
| Hall | 80 | P 21 | 95/96 | | x | |
| Hall | 81 | P 21 | 95/96 | | x | |
| Hall | 166 | P 21 | 96/97 | | | x |
| Hall | 168 | P 21 | 96/97 | | | x |
| House | 373 | P 21 | 95/96 | | x | |
| House | 566 | P 21 | 95/96 | | | x |
| Hall | 86 | P 601 | 95/96 | | x | |
| Hall | 87 | P 601 | 95/96 | | x | |
| House | 369 | P 601 | 95/96 | | x | |
| House | 419 | P 601 | 94/95 | | x | |
| House | 507 | P 601 | 95/96 | | x | |
| Hall | 224 | Petruk | 94/95 | | x | |
| House | 529 | Sahom | 95/96 | | x | |
| House | 530 | Sahom | 95/96 | | x | |
| House | 340 | Sukun | 94/95 | | x | |
| House | 346 | Sukun | 94/95 | | x | |
| House | 348 | Sukun | 94/95 | | x | |
| House | 458 | Sunan | 96/97 | | x | |
| House | 421 | Taiping 1 | 94/95 | | x | |
| House | 409 | XA | 95/96 | | x | |
| House | 591 | XA | 96/97 | | x | |
| House | 592 | XA | 96/97 | | x | |
| House | 593 | XA | 96/97 | | x | |
| House | 408 | Yeao | 95/96 | | x | |

**Table 36 Flowering and Fruiting Observations - January 1998 to January 2002.**

| Clone | No | Year of Planting | Site | Dates of Flowering | Dates of Fruiting (Estimates) | Yield (Estimates) | Observations |
|---|---|---|---|---|---|---|---|
| D 2 | 7 | 96/97 | Hill | November 2001 | Nil | N/A | First flowering only light |
| *D. macrantha* | 14 | 96/97 | Hill | November 2001 | (March 2002) | (20kg) | 7 fruit ranging in size from fist to football are hanging on the tree. |
| D 24 | 6 | 96/97 | Hill | November 2001 | Nil | N/A | First flowering only light |
| D 24 | 15 | 96/97 | Hill | November 2001 | Nil | N/A | First flowering only light |
| Hew 1 | 345 | 94/95 | House | December 2001 | May 2002 (Estimated) | 2.5kg | First fruiting only light flowering |
| Hew 2 | 332 | 94/95 | House | November 2000 | February 2001 | 3kg | Tree died after fruit ripened |
| Hew 2 | 334 | 94/95 | House | December 2001 | March/ April 2002 (Estimated) | 12kg (Estimated) | Good fruit set for first flowering, currently fist sized fruit |
| Hew 7 | 359 | 94/95 | House | 15 July 1999<br><br>November 2000 | No set<br><br>No set | N/A<br><br>N/A | First flowering only light<br><br>Flowering only light |
| D 178 | 381 | 95/96 | House | November 2000,<br>November 2001 | No set<br><br>March 2001 (Estimated) | N/A<br><br>15kg (Estimated) | First flowering only light<br><br>5 fruit ranging from fist size to half size currently set |
| DPI Mon Thong | 410 | 95/96 | House | November 2000 | No set | N/A | First flowering only light |
| D 24 | 399 | 95/96 | House | November 1999,<br><br>November 2000,<br><br>November 2001,<br><br>January 2002 | No set<br><br>No set<br><br>No set | N/A<br><br>N/A<br><br>N/A | First flowering only light<br><br>Flowering only light<br><br>Flowering only light<br><br>Flowers still to open |

**Table 36 (continued) Flowering and Fruiting Observations- January 1998 to January 2002**

| Clone | No | Year of Planting | Site | Dates of Flowering | Dates of Fruiting (Estimates) | Yield (Estimates) | Observations |
|---|---|---|---|---|---|---|---|
| NG Mon Thong | 411 | 95/96 | House | September 1999<br>November 2000 | November 1999, small fruit set<br>No set | N/A | First flowering only light, Set fruit dropped immature in January 2000<br>Flowering light |
| Chanee | 412 | 95/96 | House | January 2002 | N/A | N/A | Buds currently developing |
| Kradum Thong | 416 | 95/96 | House | November 2000 | Fruit fell off | N/A | First flowering only light |
| Gob Yaow | 470 | 94/95 | House | August 1999<br>November 2000,<br>November 2001 | Fruit set November 99<br>February 2001<br>Nil | 8kg<br>10kg<br>N/A | Fruit dropped by 6 January 2000<br>Excellent fruit similar to Chanee.<br>No fruit set in 2001 |
| Luang | 477 | 94/95 | House | November 2001 | No set | N/A | First flowering only light |
| Luang | 483 | 94/95 | House | November 2001 | No set | N/A | First flowering only light |
| Luang | 492 | 94/95 | House | November 2001 | No set | N/A | First flowering only light |
| D 144 | 497 | 96/97 | House | November 2000,<br>November 2001 | No set<br>No set | N/A<br>N/A | First flowering only light<br>Flowering only light |
| Luang | 498 | 94/95 | House | November 2000,<br>November 2001 | No set<br>No set | N/A<br>N/A | First flowering only light<br>Flowering only light |
| D 118 | 511 | 95/96 | House | November 2001 | Nil | N/A | First flowering only light |
| D 178 | 82 | 95/96 | Hall | November 2000 | No set | N/A | First flowering only light |

**Table 36 (continued) Flowering and Fruiting Observations- January 1998 to January 2002**

| Clone | No | Year of Planting | Site | Dates of Flowering | Dates of Fruiting (Estimates) | Yield (Estimates) | Observations |
|---|---|---|---|---|---|---|---|
| Gumpun | 198 | | Hall | November, December 2001 | February, March 2002 | 36kg (estimated) | 12 fruit from ¾ to full size are developing |
| D 24 | 201 | 94/95 | Hall | December 2001 | March 2002 (estimated) | 6kg | 2 fruits are developing |
| D 24 | 258 | 94/95 | Hall | November 2000 | No set | N/A | First flowering only light |
| D 24 | 260 | 94/95 | Hall | November 2000 | No set | N/A | First flowering only light |
| Luang | 271 | 92/93 | Hall | November 1999, November 2001 | No set<br><br>February, March 2002 (estimated) | N/A<br><br>60kg (estimated) | First flowering only light<br><br>28 fruit are almost mature |
| Gob Yaow | 272 | 92/93 | Hall | November 1999, December 2001 | No set<br><br>March, April2002 (estimated) | N/A<br><br>20kg (estimated) | First flowering only light<br><br>9 fruit are half size, similar to Chanee |
| Luang | 273 | 92/93 | Hall | November 1999, November 2001 | No set<br><br>February, March 2002 (estimated) | N/A<br><br>40kg (estimated) | First flowering only light<br><br>13 fruit are almost mature |
| Gob Yaow | 275 | 92/93 | Hall | November 1999, November 2001 | No set<br><br>February, March 2002 (estimated) | N/A<br><br>3kg (estimated) | First flowering only light<br><br>1 fruit is almost mature |
| Luang | 277 | 92/93 | Hall | November 2000 | No set | N/A | First flowering only light |

**Table 36 (continued) Flowering and Fruiting Observations- January 1998 to January 2002**

| Clone | No | Year of Planting | Site | Dates of Flowering | Dates of Fruiting (Estimates) | Yield (Estimates) | Observations |
|---|---|---|---|---|---|---|---|
| Luang | 278 | 92/93 | Hall | November 1999,<br><br>November 2001 | No set<br><br>February, March 2002 (estimated) | N/A<br><br>60kg (estimated) | First flowering only light<br><br>28 fruit are almost mature |
| Luang | 280 | 92/93 | Hall | November, December 2001 | February, March 2002 | 36kg (estimated) | 14 fruit from ¾ to full size are developing, 4 are misshapen due to poor pollination |
| Gob Yaow | 282 | 92/93 | Hall | December 2001 | February, March, April 2002 | 65kg | 31 fruit from fist size to fully mature |
| Luang | 287 | 92/93 | Hall | December 2001 | March 2002 | 3kg (estimated) | 1 fruit is developing |
| | | | | | | | |
| Luang | 291 | 92/93 | Hall | December 2001 | March 2002 | 8 kg (estimated) | 3 fruit are developing |
| Luang | 292 | 92/93 | Hall | December 2001 | March 2002 | 3kg (estimated) | 1 fruit is developing |
| Hawaiian Mon Thong | 305 | 92/93 | Hall | November, 1998<br><br>November 1999 | March, April 1999<br><br>No set | 45kg<br><br>N/A | 18 fruit were harvested, all were excellent quality |
| Hawaiian Mon Thong | 309 | 92/93 | Hall | December, 1999 | March, April 2000 | 6kg | 2 fruit were harvested, all were excellent quality |
| Hawaiian Mon Thong | 311 | 92/93 | Hall | December, 1999 | March, April 2000 | 8kg | 3 fruit were harvested, all were excellent quality |
| Hawaiian Mon Thong | 313 | 92/93 | Hall | December, 1999 | March, April 2000 | 9kg | 3 fruit were harvested, all were excellent quality |

**Table 36 continued Flowering and Fruiting Observations January 1998 to January 2002**

| Clone | No | Year of Planting | Site | Dates of Flowering | Dates of Fruiting (Estimates) | Yield (Estimates) | Observations |
|---|---|---|---|---|---|---|---|
| Hawaiian Mon Thong | 315 | 92/93 | Hall | December 2001 | March, April 2002 (estimated) | 140kg (estimated) | 60 fruit currently half size are developing |
| Hawaiian Mon Thong | 317 | 92/93 | Hall | November 99 December 2001 | February, March 2002 | 36kg (estimated) | 14 fruit from ¾ to full size are developing, 4 are misshapen |
| Hawaiian Mon Thong | 319 | 92/93 | Hall | December 2001 | February, March 2002 (estimate) | 12kg (estimated) | 4 half size fruit are developing, |

# 6. DNA Identification Results

## 6.1 Introduction

As identified by stakeholders during the 1997 RIRDC strategic planning process, authentic planting material is the prerequisite for establishing a successful durian industry. Confusion regarding the naming of and the genuineness of clonal planting material must be addressed to ensure that firstly quality clones are propagated. Watson (1991) noted the 1970's importation of Chanee from Thailand, which is actually Kob, as an example of a notable import mistake. Lim (1997) attempted to solve this major industry issue by developing a polygon leaf test. The researchers collected floral buds prior to opening from some of the new clones in an attempt to supplement the leaf polygon test as Lye (1980) had identified 12 Malaysian clones using this method. Buds were measured at various points and initial preliminary observations indicate that the bud shape resembles the final fruit shape. For example buds of Mon Thong are more pointed than those of Chanee. The mature fruits of Mon Thong and Chanee also display these distinctive shapes. This data is not presented as DNA fingerprinting has superseded this work.

Lim (1997) suggested the use of DNA fingerprinting techniques to provide "the determinative identification of clones." Overseas durian-producing countries are also investigating ways to positively identify their clones especially as Plant Variety Rights and intellectual property become important issues. The relationship between various Durio species has been studied using DNA marker technology (Kanzer *et al*., 1998). On a finer scale, development of DNA fingerprinting techniques for durian clones is underway in Malaysia (Wickneswari and Salma, 2000).

Researchers in Thailand have developed a classification system for clones based on leaf, flower, and fruit characteristics (Hiranpradit *et al.*, 1992). Six groups of Thai durian clones were identified:

Group 1 called Kob (Kop, Gob) included 38 clones based around the Kop type,

Group 2 called Lueng (Luang) included 7 clones mainly of the Chanee type,

Group 3 called Kan Yao (Karn-Yao, Gaan Yao) included 7 clones based around Kan Yao,

Group 4 called Kampun (Kam-Pan, Kumpun, Gumpun) included 11 clones based on the Gumpun and Monthong (Mon Thong) type,

Group 5 called Tong-yoi included 12 clones one of which was Nok Yip, a very strong-flavoured Thai clone tasted by the researchers in Chantaburi in 1996,

Group 6 was called Miscellaneous and contained 47 clones such as Kradoom Thong (Kra-dum-tong) not matched to the other groups.

Some clones introduced into Australia such as Luang, Hawaiian Mon Thong, and the original Chanee have fruited but do not have the expected characteristics of their namesake. The identity of such clones needs to be resolved, to determine whether they represent different individuals or whether the Australian growing environment has a significant effect on morphological characteristics. The genetic relationships between the Thai groups are unknown. It is also unclear how clones from other selection origins are related to those from Thailand. Such knowledge is useful in understanding the range of genetic diversity available in Australia and understanding patterns of clonal performance.

DNA marker (fingerprinting) technology was developed for macadamia clones by CSIRO Plant Industry, Brisbane, and following a request from the Australian Durian Industry, Mr. Cameron Peace, a

PhD student with CSIRO and the University of Queensland graciously assisted the durian industry with DNA marker characterisation of 28 clones. This research is presented here.

## 6.2 Material and Methods

Twenty eight clones were surveyed (growing at the orchard of Zappala Tropicals), which included thirteen from Malaysia (D 10, D 24, D 24S, D 99X, D 123, D 140, D 144, D 168, D 190, KK 11, Red Prawn (D 175), Kunyit, and Hew 2), nine considered to be from Thailand (Hawaiian Mon Thong, Chanee, DPI Mon Thong , NG Mon Thong, Australian Luang, Kan Yao, Kradum Thong, Gob Yaow, and Gumpun), two from Indonesia (Sunan and Hepe), two Australian seedlings (Z 1 and Jacky), and two accessions of the related species *D. macrantha* and *D. graveolens*.

According to fruit characteristics, some of these clones can be classified into the Thai groups (Hiranpradit *et al*., 1992) as follows:
Kob –Gob Yaow
Lueng – Chanee, Hawaiian Mon Thong
Kan Yao – Kan Yao
Kampun – DPI Mon Thong, NG Mon Thong, Gumpun, Australian Luang
Tong-yoi - none
Miscellaneous – Kradum Thong

DNA was extracted from the durian clones by a method developed for macadamia (Peace, 2002). Extraction was from leaves posted to the Brisbane laboratory, with the youngest leaves from fresh flushes preferentially used.

The DNA marker system RAF (randomly amplified DNA fingerprinting; Waldron *et al*., 2002) was used to generate profiles of DNA markers for each clone. Two RAF tests (primers A06 and B11) were performed. Fifty-nine markers showing differences amongst the clones were identified. These markers were scored as binary data (presence/absence) for each clone, and the data subject to clustering and ordination steps using the SAS programming language (SAS Institute Inc., Cary NC). The computer program PopGene was employed to determine genetic diversity within and between groups of clones (F statistics and number of polymorphic markers).

## 6.3 Results and Discussion

The genetic relationships amongst clones are presented in two diagrams. The first is a dendrogram, or tree of genetic relatedness (Figure 16). The second is a 3D plot (Figure 17). These two diagrams highlight different aspects of how the clones are related to each other.

The first point to note is that no two clones are the same. Each clone surveyed had its own unique identity that could be assigned with DNA markers. This has ramifications for the naming of certain Thai clones. The three Mon Thong clones were not identical, and they were generally more closely related to other Thai clones than to each other. Therefore, the three sources of Mon Thong are not clonal replicates of the same original tree. As previously suspected by observation of fruit characteristics, Hawaiian Mon Thong was not closely aligned to Mon Thong but is instead closely related to Chanee. Leaf shape, bud shape and fruit thorns of Hawaiian Mon Thong closely resemble those of Chanee in Thailand, Malaysia and Australia. As previously indicated by Lim (1996), the Australian Luang clone was aligned with the Mon Thong section and therefore it is not the true Luang clone from Thailand (the latter being similar to and a parent of Chanee). D 123 is supposed to be Chanee, imported from Thailand to Malaysia and given a Malaysian name. However, DNA analysis indicated that the two were different.

Within the Thai clones, clustering was consistent with the grouping system developed by Hiranpradit *et al.*, (1992). The affinities between these groups could also be ascertained. The four clones of the

Kampun group clustered in the dendrogram and located fairly close in the 3D plot, were distinct from the other Thai clones. These clones also tend to have fruit that take longer to mature on the tree in Thailand (especially for Mon Thong and Gumpun). The Indonesian clone Sunan appeared to be in the same cluster, which suggests that Sunan may have fruit traits similar to the Kampun group clones. The two Luang group clones (Chanee and Hawaiian Mon Thong) were very closely related, and related to the other Thai clones belonging to the Kan Yao, Miscellaneous, and Kob groups. Interestingly, these clones also tend to be those that have faster-maturing fruit (especially Kradum Thong and Chanee). Both diagrams showed D 99X and Z 1 to be the clones most closely related to those from Thailand. D 99X is supposedly the Thai clone Kop, merely renamed in Malaysia, which may explain its genetic location. The Australian seedling Z 1 may have a Thai clone as one or both of its parents.

Although the dendrogram placed the Thai clones in two separate clusters each associated with certain Malaysian clones, Thai clones were actually observed to be very closely related. There was two to seven times as much genetic diversity (2.3 times as many polymorphic markers and 7.1 times as much gene diversity) within the set of Malaysian clones as there was within the Thai clones. The clustering of Thai clones together is noticeable in the 3D plot.

In general, the Malaysian clones are the most diverse group, being found in most clusters of the dendrogram and spread about in the 3D plot. D 168 appeared particularly unusual, and may have a very distinct genetic background. The only clone of the survey with two parents included, D 190, was clearly related to and located in between its two parents (D24 and D10) in the dendrogram. The results of D24 Serawak and D 140 are also interesting. D 24S supposed to be the clone D 24, introduced to Serawak from West Malaysia, but the fruit is a different shape with a pointed base. In the diagrams, D 24 and D 24S were well separated and certainly not the same clone. D 140 is described as a rogue D 24 (Anon, 1994), and appears closely related to D 24S.

The Australian selections are more closely related to other clones than to each other, presumably reflecting the different pedigree origins of each. A Thai background for Z 1 was discussed above, while Jacky appeared to be more associated with Malaysian clones. Jacky is currently fruiting at Zappala Tropicals and the fruit shape and other characteristics indicate a close resemblance to Red Prawn (D 175). These clones are positioned in the same subgroup in the dendrogram.

The two Indonesian clones were quite diverse from each other. Sunan was similar to the Thai Kampun group as previously mentioned, while Hepe was very unusual, and the most closely related clone to *Durio macrantha*. This may reflect a common ancestry in Indonesia, and they were recorded to have similar growth characteristics.

The *D. macrantha* individual had clear genetic differences to the common *D. zibethinus* clones. Likewise the *D. graveolens* clone was distinct, and was the most unusual clone of the survey. This finding is consistent with their taxonomic classification as separate species. Kanzaki *et al.*, (1998) found no close genetic relationships between *D. zibethinus* and the other *Durio* species cultivated for their fruit including *D. graveolens*, though they did not include *D. macrantha* in their study. These researchers suggested that the other *Durio* species evolved independently to D. zibethinus. It remains unclear whether this is true also for *D. macrantha*.

The Top 9 clones recommended for the next phase of the Australian industry D 175 (Red Prawn), D 190, *D. macrantha*, Hepe, Hawaiian Mon Thong, DPI Mon Thong, Kradum Thong, Kan Yao, and Australian Luang) are a diverse range of clones, containing approximately 70-75% of the genetic diversity (71% 0f the polymorphic markers and 74% of the gene diversity) of the entire set of 28 clones. This is a promising sign for the industry, as it ensures a wide range of germplasm will be assessed for feasibility in the Australian production and marketing environment.

## 6.4 Conclusions

DNA typing is an important tool for any developing or developed industry to positively identify their planting material.

Quality is vital to markets and it is recommended a system of typing durian clones be implemented during the planting stage to eliminate inferior and inaccurate clonal budwood from propagation nurseries. DNA typing is also important in assessing the range of germplasm available. At this early stage in the industry, it is important to know that each clone available in Australia has its own genetic identity, which justifies separate performance evaluations. Nevertheless, some clones appear closely related and correspondingly may have a similar field performance. A diverse range of material is collected in Australia and fortunately, the clones recommended for further evaluation in the emerging industry cover much of this diversity.

## 6.5 Recommendations

This study could be broadened by comparing amongst all clones imported into Australian material and ideally with their overseas “standards”, to eliminate the labelling mistakes that have occurred over the past two decades of germplasm exchange. Such work would enable the identity of best performing clones in Australia to be recognised, and allow this industry to move forward with confidence to plant quality material.

If in the future, a preferred fruit shape is a market requirement, then through a breeding program, the relationship between durian floral bud shape and final fruit shape should be quantified.

## 6.6 References


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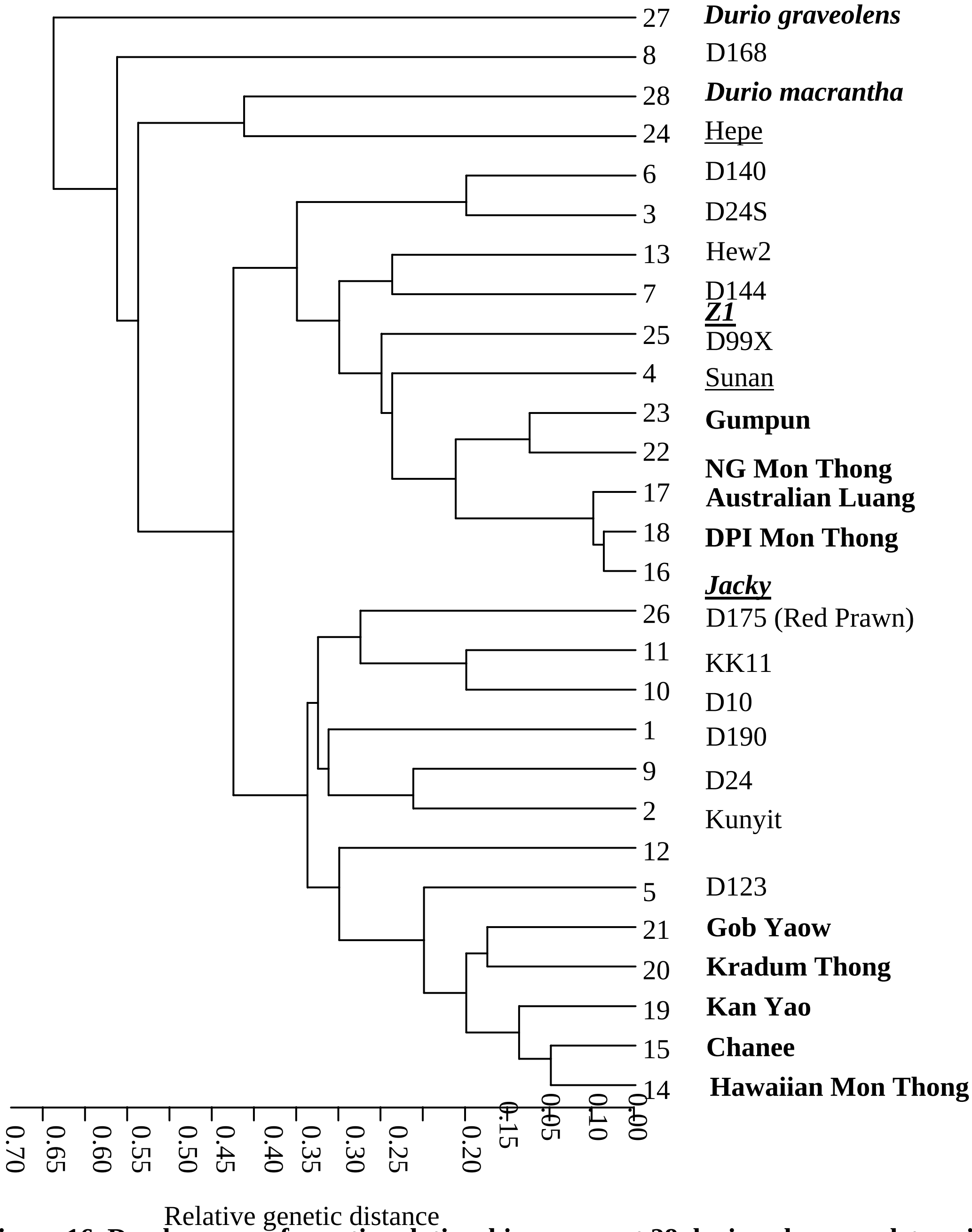


**Figure 16. Dendrogram of genetic relationships amongst 28 durian clones as determined by randomly amplified DNA fingerprinting (RAF) analysis.** Individual clones are font-coded according to collection origin: Normal font = Malaysia, Bold = Thailand, Underscore = Indonesia, Underscored Bold Italics = ***Australia***, Italics = *related species*.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | D10 | 8 | D168 | **15** | **Chanee** | **22** | **Gumpun** |
| 2 | D24 | 9 | D190 | **16** | **DPI Mon Thong** | 23 | Sunan |
| 3 | D24S | 10 | KK11 | **17** | **NG Mon Thong** | 24 | Hepe |
| 4 | D99X | 11 | D175 (Red Prawn) | **18** | **Aus. Luang** | ***25*** | ***Z1*** |
| 5 | D123 | 12 | Kunyit | **19** | **Kan Yao** | ***26*** | ***Jacky*** |
| 6 | D140 | 13 | Hew2 | **20** | **Kradum Thong** | 27 | *Durio graveolens* |
| 7 | D144 | **14** | **Haw. Mon Thong** | **21** | **Gob Yaow** | 28 | *Durio macrantha* |

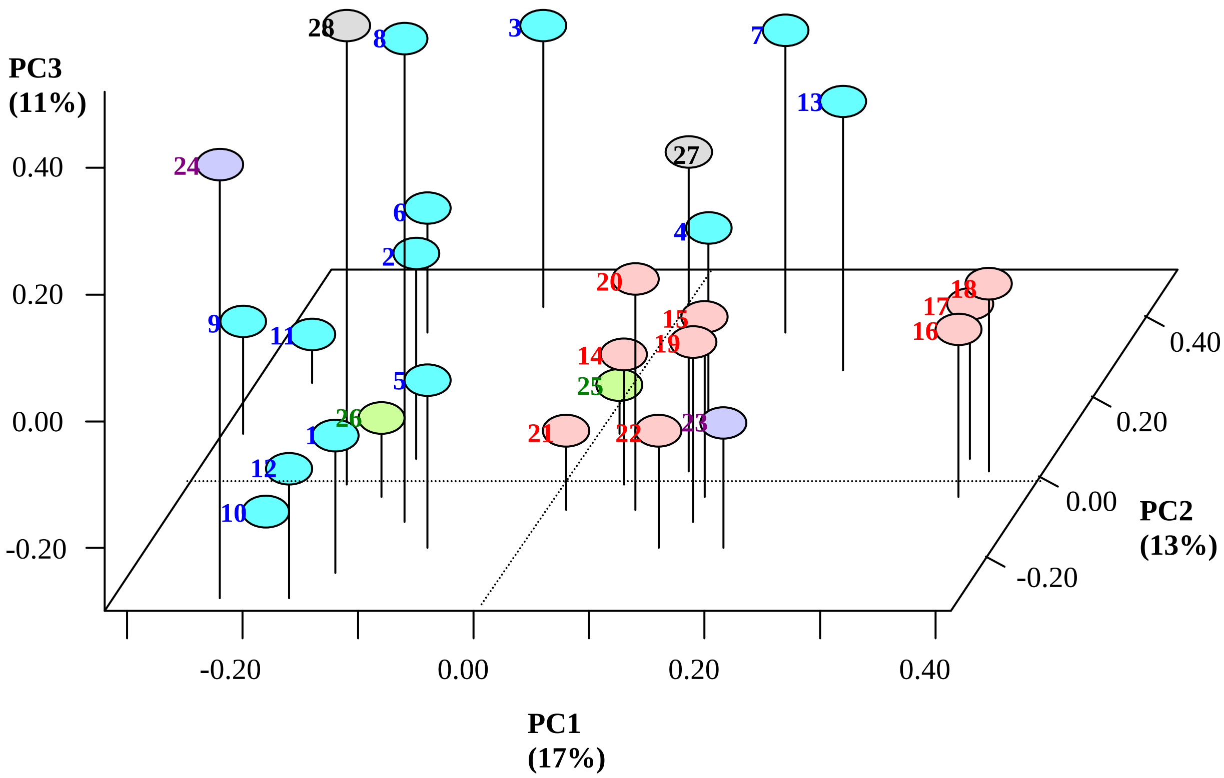


**Figure 17. Three-dimensional plot of genetic relationships amongst 28 durian clones, as determined by randomly amplified DNA fingerprinting (RAF) analysis**. Individual clones are font-coded according to collection origin: Normal font = Malaysia, Bold = **Thailand**, Underscore = Indonesia, Underscored Bold Italics = ***Australia***, Italics = *related species*.

The proportion of DNA marker data accounted for by each of the three dimensions, or principal components (PC), is indicated.

# 7. Clonal Recommendations

## 7.1 Introduction

This final chapter was to identify clones best suited for Phase 2 (Yield and Fruit Quality Assessment) for future Australian planting and export potential. Through the early fruiting of some project clones, the researchers have collected enough data to recommend immediate inclusion of the Group 1 clones to the current Australian variety recommended planting list. Their performances are discussed in-depth and where Australian fruiting information is not available, a collection of personal communications and experiences between the researchers and durian lovers in Thailand and Malaysia have been quoted to assist Australian growers with decisions for their future plantings.

Numerous publications have detailed the clonal fruit qualities and characteristics of the Asian genepool. These include the Malaysian Department of Agriculture list page 129 to 147 published in *Recent Developments in Durian Cultivation*, 1994 (MARDI) in Malay, "Durian" ASEAN Food Handling Bureau (1994) edited by Sonthat Nathachai, *Penanaman Durian* (Durian Cultivation) a MARDI publication edited by Zainal *et al.*, (1991) in Malay and Lim (1996). Most of these have coloured photographs and detailed descriptions and are highly recommended. Some overseas clonal disease tolerances relating to *P. palmivora* are included (Tai, 1983 and Lee, 1994).

## 7.2 Australian and overseas Clonal Observations for Group 1

**Hepe**
21 Project Tree original numbers: 104, 105, 139, 141, 143, 145, 147, 149, 151, 197, 200, 216, 219, 221 –223, 350, 368, 558 –560.

Lim (1997) states "*This variety is found in Jonggol, Bogor, Indonesia. 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 fruit per tree per year. The seeds are flat and shrunken.*"

This clone was introduced through the Berrimah Post Entry Quarantine facility Darwin by Bert Jaminon and Barry Shah in the 1990's. Barry Shah kindly collected budwood from trees grown in Bert Jaminon's orchard and arranged the airfreight to Cairns. This clone has some similar growth characteristics to *D. macrantha.* DNA results show that both clones are closely related. Leaves are concave although this clone has a more upright habit. Hepe has coped well with the extreme weather conditions experienced over the 5-year observation period.

This clone achieved a Quartile 4 ratings from the House site (Table 18) and a Quartile 2 rating from the Hall site (Table 15). This clone is yet to flower in north Queensland.

***Durio macrantha***
16 Project Tree original numbers: 102, 103, 128, 129, 183, 432 – 441.

This new species has results that mirror D 175. It is similar in its tolerance to cold weather. The history of this plant is exciting. An unknown seedling collected from Mt Leuser National Park, North Sumatra by Mr. H. Rijksen of the rehabilitation centre for orangutangs in North Sumatra was passed to Dr A.J.G.H. Kostermans, Herbarium Bogorience, Bogor Indonesia in 1981. Kostermans (1992) reported that in July 1991, the 8 meter high plant grown in Dr Kostermans' private garden in Gadok, Bogor, commenced flowering and proved to be an undescribed species of durian. The tree produced about 40 fruit each measuring 14cm x 21 cm. Fallen fruit started splitting after two days. Kostermans (1992) states: "The importance of the discovery is that it is one of the smaller trees with *Durio* fruit like *D. zibethinus*. Instead of spacing 10 meter as when planting the common durian, this species only needs 5 meter. Its small size makes it easier to maintain in comparison with the tall, 20 – 30 metre high common durian, and the flowers and fruit are easy to manipulate.”

In 1996, Dr Kostermans contacted CSIRO requesting information on how to send seed of this species to Australia to assist with the survival of the species. CSIRO passed on his request to the project researchers who contacted John Marshall, an Australian Durian collector, by coincidence on holiday in Bali, Indonesia. John kindly agreed to travel to Bogor to met Dr Kostermans and hand carried budwood and a fruit back to Australia for introduction into the quarantine facilities at Kamerunga, Cairns. The fruit was consumed inside the quarantine area and reported by all that tasted it, to be excellent.

Dr Vasanthe Vithanage, Plant Industries, CSIRO Brisbane also visited Dr Kostermans a few weeks after John Marshall and hand carried more budwood back to Australia. Both shipments of budwood were grafted onto *D. zibethinus* seedlings and only one tree out of the 16 plantings showed signs of incompatibility.

The researchers’ observations of the 16 plantings have verified Dr Kostermans’ research. This species is compact and has a strong horizontal branching habit. First fruiting has occurred on Hill observation site (Table 36).

Dr Kostermans’s wish to prevent this species from extinction has been fulfilled.

**D 175. (Red Prawn)**
10 Project Tree original numbers: 124, 124, 163 – 165, 374, 375, 521 –523.
This tree originated in Penang, an island off the west coast of peninsular Malaysia renowned for producing excellent durian fruit. Personal observations and tasting in Penang by the researchers indicate that this clone is a winner.

*“D 175 is a high yielding clone with trees reported to commence flowering in the sixth year after field planting. Percentage of fruit set to flowers is very high. Flesh texture is fine and smooth and soft. Taste is sweet and slightly bitter. Colour is yellowish pink with approximately 24% flesh recovery. Keeping quality is also good rated at 2 to 3 days. The fruit is very attractive with a fruit size ranging from 1.5 to 3kg* (Voon, B. H. personal communications, 1995).

This is the most cold tolerant clone evaluated in the project. Leaf abscission failed to occur even with temperatures as low as 5°for short periods. The oldest tree (no. 375) has an excellent structure and required no pruning. Knowing the fruit quality and attractiveness of the fruit, this clone will be an important resource to our industry development. DNA results locate this clone between KK 11 and Jacky in Figure 16.

**DPI Mon Thong**
11 Project Tree original numbers: 74, 75, 153 – 155, 420, 544 – 547.

This clone was supplied to DPI from the Department of Agriculture and Extension, Thailand following requests by Brian Watson OIC DPI Kamerunga Research Station, Cairns. Following the closure of this research station and the relocation of the DPI research to Wet Tropics, Dr John Mansfield arranged for the original clone to be used in this research project. Plants have been grafted for DPI and several plants are under evaluation at Wet Tropics.

This is the major clone used by Thailand in their export markets. In 1992, this clone represented 40.6% planted area both of bearing and non-bearing trees in Thailand. It was the most successful clone grown in southern Thailand (Anon, 1992b cited by Jumat, A. *et al.*, 1994). From observations in Thailand, fruit set is good although *Phytophthora palmivora* is a problem with this clone. Mon Thong is more susceptible to durian pests and diseases than Chanee (Siripanich and Jarimopas, 1993 cited by Nanthachai, S. *et al.*, 1994). Grafting has proved to be more difficult with this clone. Field results have been favourable although this clone does defoliate at low temperatures. DNA results have closely linked this clone to Luang, Gumpun and Ng Mon Thong.

**Hawaiian Mon Thong**
13 Project Tree original numbers: 305, 309, 311, 313, 315, 317, 319, 323, 479, 481, 482, 484 and 486.

This clone was introduced into Australia by Brian Watson from Hawaii. Brian passed it on to the researchers and the Hall site trees (No's 305, 309, 311, 313, 315, 317, 319, and 323) were planted in 1992. This clone has fruited well during the project. Tree 305 produced 18 fruit (totalled 45kg of fruit) in the 1999 season. Other trees also produced fruit and are currently fruiting heavily with No 315 producing 140kg this season (Table 36). This fruit was excellent quality with highly coloured yellow flesh. The taste was sweet, creamy with a strong flavour. All fruit characteristics were identical to Chanee. DNA testing has this clone very closely related to Chanee.

This clone is highly recommended for planting.

**D 190**
15 Project Tree original numbers: 126, 127, 184, 319, 322, 366, 367, 393, 429, 561, 598, 601 –604.

This is a hybrid developed by Dr. Zainal Abidin Mohamed, MARDI, from a cross between D 24 and D 10 and released for distribution in June 1992. Zainal *et al.*, (1992) states that at year 12, D 190 yielded 104 kg from 58 fruit compared to D 24 of 111 kg from 60 to 80 fruit. Flesh recovery is 26% compared to 21% for D 24. D 190 has excellent keeping qualities of 78 to 86 hours. The flesh is very thick and slightly dry while the colour is golden yellow. The taste is sweet and nutty. Results of field observations of 10-year old trees (subject to natural infection *of Phytophthora*) at MARDI Serdang showed that D 190 and D 189 were relatively tolerant to trunk and root rot (Lee, 1999).

Project observations did indicate that leaf drop did occur at low temperatures. Survival rates were good and as this clone comes into fruit at year 6, it is one to consider. DNA results in Chapter 6 clearly group D 190 with its parents D 10 and D 24 therefore this is the correct clone.

**Kradum Thong**
18 Project Tree original numbers: 72, 73, 238, 240, 316, 353, 413 – 418, 574, 576, 578, 580, 582 and 605.

*"This clone is an early maturing variety with fruit ripe 90-100 days after flowering. This clone crops very well and regular. Leaves are dark green, leathery and dark bronze on the underside. It is very adaptable to poor environmental conditions. Fruit is 1 to 1.5 kg with a round lobbed shape. Flesh is golden yellow with many shrivelled seeds. Taste is sweet, but lacks the strong durian flavour. Flesh can be a bit fibrous. Fruit quality is acceptable but not as good as D 2 or D 24. It is a good pollinator clone for D 24."* (Chan. Y. K. personal communications, 1995).

"Flesh recovery is more than 24% and the fruit keeps for 2 days. 12-year-old trees can produce 100 –130 fruit per tree with yields of 12.5 tonnes per hectare reported. Kradum Thong also grows well on 10° to 20° sloping land." (Voon. B. H. personal communications, 1995).

It is pictured in Figure 2.26 page 26, Durian ASEAN Food Handling Bureau (1994).

Australian observations of this clone have supported the overseas data. Survival has been good (Table 12) with even light flowering occurring on tree No. 416 in 2000 (Table 36). This clone has coped well with the cyclones and is recommended for planting. DNA results locate this clone between Kan Yaow and Gob Yaow.

## 7.3 Australian and overseas Clonal Observations for Group 2 for ZTR-1A Phase 2

Projects results have identified another 13 clones, all of these clones achieved a greater than 50% survival from the original plantings for the 5-year period. These are called Group 2 and include one of the major Thai clone used for export Chanee, and the Malaysian clones D 24, D 99, D 99X, D 118, D 144, D 168, D 178, D 179, Hew 7, KK 11, P 21 and Sahom. These clones are listed in this order.

**Chanee**
11 Project Tree original number: 16, 17, 20, 21, 239, 412, 428, 471, 472, 536 and 537.

This is one of the best Thai clones with 32.9% of Thailand's area under cultivation to durian being planted to Chanee in 1991, with Monthong 40.6%, Kan Yao with 6% and Kradum Thong with 2.3%. However in terms of tonnage Chanee is the leading clone with 36% followed by Monthong with 31.8% (Anon 1992d). Chanee fruit ripens 100-115 days after anthesis (Sangchote, 1988). It is pictured in Figure 2.22 page 26, Durian ASEAN Food Handling Bureau 1994).

Thai production for 15-year-old Chanee trees is listed at 50 to 100 fruits (Yaacob and Subhadrabandhu Table 6.2, 1995). Fruit size is from 2 to 3 kg with broad-based thorns and a flat fruit base. Seed from Chanee is used for rootstock in Thailand for tolerance to *P. palmivora*. (Sangchote, 2000)

Australian observations have shown these trees are very strong with small leaves. Chanee was introduced into Australia in the 1970's but turned out to be Kop (Watson, 1991). This clone withstands winter temperatures and would be in Group 1 but for the loss of additional data from the replicates in the Hall site (Rows 1 and 2).

**D 24**
48 Project Tree original numbers: 3, 5, 7, 15, 90, 91, 138, 140, 142, 144, 146, 148, 150, 192, 194, 196, 201, 207, 209, 215, 217, 246, 250, 255, 257, 258, 260, 264, 396 to 400, 402, 403, 406, 407, 425, 272, 573, 575, 577, 579, 581, 583, 585, 587 and 589.

This is Malaysia's best clone but has not performed to expectations in the 5-year project. Its spreading growth habit has suffered from the extreme weather conditions with splitting of branches a regular occurrence. This tree has weak branch structure. Flowering has occurred on trees but no fruit has been harvested to date. D 24 is pictured in page 13 of Penanaman Durian (1991) MARDI. In 1983, D 24 was one of 13 clones studied in Serdang for Phytophthora tolerance. D 24 was rated as one of the worst performers (Tai, 1983).

"*Best and most widely grown clone in Malaysia. It is a good regular cropper with 12 - 15 year old trees producing 100 fruit annually. The leaves are light green, droopy when young and characterised by a light silvery sheen on the underside. The tree is very susceptible to trunk canker. It lacks vigour and is weak especially at the young stage causing this clone to be difficult to establish. Fruit is medium size (1.8 kg) with fine thorns and a greenish to yellow shell. Flesh quality is excellent with thick, smooth, creamy, soft yellow pulp with excellent aroma and flavour. The fruit also has good keeping qualities*." (Chan. Y. K., personal communications, 1995).

*Flesh texture is dry and sticky with a slight wrinkle appearance. Seeds can be large with recovery usually 21%. The sweet taste also has a hint of bitterness. Harvest is 105 to 115 days from fruit set. It has a low resistance to diseases*. (Voon B. H. , personal communications, 1995).

The researchers believe that this clone could have a place in protected areas of far north Queensland. The original tree was grown in a wet, cool, misty environment near a reservoir in Bukit Merah, Perak, west Malaysia. Its registration dated back to 1937 and is still used in Malaysia as the quality standard for new clones to achieve. Its unique flavour and texture would make it ideal for any future minimal processing as the arils remain firm and intact after removal from the ripe fruit.

**D 99**
10 Project Tree original number: 18, 19, 156 to 158, 351, 352, 430, 519 and 520.

D 99 is pictured in page 14 of Penanaman Durian (1991) MARDI. From discussions with Malaysian growers and their own experience, the researchers believe that this clone is the Thai clone, Kradum Thong. The description of this clone beside the picture in Penanaman Durian (1991) even mentions its Thai origin.

Serudin *et al.*, (1994) states that: *"The tree is medium sized, low in branching, often with a loose canopy. It flowers and fruits regularly with a tendency towards biannual bearing fruiting as has a very high fruit bearing ability of up to 100- 130 fruit per year per season at 10-15 years of age. The clone is tolerant to Phytophthora stem-canker as well as to dry environments. A good pollinator clone, it is cross-compatible to most other clones. Fruits are borne mainly on the lower branches. The fruit is small to medium in size weighing 1.0-1.5 kg each and almost round in shape with slight depressions at the apical end. It is easily split revealing its thin skin. Each locule contains 1-4 pulp units, medium to large in size. The aril is thick, bright yellow in colour, of fine texture, slightly wet and has a sweet and nutty taste with good aroma. This clone is an early dropper."*

Australian observations indicate it is very similar to Kradum Thong. When future DNA analysis is carried out, this clone will be sampled to finalise this issue.

**D 99X**
15 Project Tree original number: 9, 11, 78, 79, 160 to 162, 394, 524 to 527, 584, 586 and 588.

This clone is vigorous but the fruit size observed in Malaysia is large. It is similar to a Kop style Thai fruit pictured in Figure 2.21, page 26, Durian ASEAN Food Handling Bureau (1994). This clone was placed in Quartile 2 in both the Hall and House sites (Table 15 and 18). Further data will be available from this clone's performance in a few years.

**D 118 (Tembaga)**
10 Project Tree original number: 34, 35, 130, 131, 186, 420, 509 to 511 and 564.

Australian observations indicate this is a strong tree similar to D 2 in shape and structure. It has orange coloured flesh as suggested by its name which translates to "flaming." Unfortunately no's 34 and 35 were lost due to the deletion of Rows 1 and 2 from the Hall site. The remaining clones performed well with Quartile 3 rankings in Table 15 and 18. First flowering did occur on the No 511 in 2001. Further data will be available from this clone's performance in a few years.

**D 144**
12 Project Tree original numbers: 31, 32, 98, 99, 173, 388, 389, 464, 467, 497, 548 and 565.

"*This is a cross between D 24 and D 2. This tree resembles D 2 in growth habit and is easy to grow. Malaysian data indicates that mature trees bear 100 fruit annually. Fruits are large with up to 50% shrivelled seeds. The texture is fine, dry and smooth with a sweet fragrant flavour and bitter. Flesh colour is golden yellow. Recovery is very high as 50% of the seeds are collapsed. Mature trees produce 100 fruit per season with the 15-year-old mother tree bearing 70 fruit per season. This clone is easy to grow and resistant to disease."* (Voon B. H. , personal communications, 1995)

Australian growth observations support the above Malaysian data. This clone has two of the best parents available. It rated in Quartile 3 at the Hall site (Table 15) and Quartile 2 at the House site

(Table 18). First flowering did occur on the No 497 in 2000 and 2001. Further data will be available from this clone's performance in a few years.

**D168 (Mas Muar)**
12 Project Tree original number: 8, 100, 101, 177 to 179, 390, 391, 469, 552 to 554.

*"This is a good regular cropper. Fruit size is medium, rounded and easily split to open. Sometimes 6 carpels (sections) are obtained from 1 fruit. The flesh is not that thick but is orange in colour with many shrivelled seeds. Taste is excellent as it is very sweet, creamy and bitter with a smooth firm texture."* (Chan. Y. K., personal communications, 1995).

*"The clone originated from Johor, Malaysia. Flesh texture is firm and smooth, very sweet and creamy with a slight bitter taste. Flesh colour is orange, yellow. Flesh is thick with an excellent recovery ratio."* (Voon B. H. personal communications, 1995).

D 168 is pictured in page 15 of Penanaman Durian (1991) MARDI.

Australian observations indicate that this tree has small leaves. Survival has been fair with a Quartile 3 ranking in Table 18 but a Quartile 1 ranking in Table 15. Further data will be available from this clone's performance in a few years.

**D 178 (P 88)**
11 Project Tree original number: 29, 30, 82, 83, 169, 380 to 385.

This clone has an erect habit in Australia. It has fruited on some small branches. Fruit was small, about 1kg, with pinkish to yellow coloured flesh, which was creamy, sweet and excellent. D 178 has shown tolerance to cold temperatures. It gained a Quartile 4 rating in Table 18 but only a Quartile 1 rating in Table 15. This clone would need structural training to encourage horizontal branching at an early stage after establishment. Growers will be shown this clone during the field day in July 2002.

**D179 (P 99)**
12 Project Tree original number: 84, 85, 170 to 172, 376, 377, 549 to 551, 570 and 571.

*"This Penang clone is describes as having a smooth, sticky flesh texture, with a sweet, fragrant and slightly bitter taste. Flesh is a yellowish pink in colour and the fruit is up to 2 kg in size. Yield is moderate and the fruit has a 2 – 3 day keeping qualities"* (Voon B. H. personal communications, 1995).

Australian observations indicate that this clones has a good shape and structure, although slightly more sensitive to cold damage than some of the clones in Group 1. It has a Quartile 3 rating in Table 18 but only a Quartile 1 rating in Table 15. Further data will be available from this clone's performance in a few years.

**Hew 7**
10 Project Tree original numbers: 61, 62, 136, 137, 245, 355, 357, 359, 538 and 539.

This clone has fruited in NT and reported to be an orange fleshed clone (Tropical Primary Products, personal communications, 2000). Project trees have shown a high degree of vigour. Flowering is still to occur. It rated in Quartile 4 in Table 18 and Quartile 2 in Table 15. Further data will be available from this clone's performance in a few years.

**KK 11**
10 Project Tree original numbers: 44, 45, 106, 107, 112, 259, 360, 362, 531 to 533.

*This clone is reported to yield 30 – 60 fruit from 13-year-old trees. Fruit is 1.8 to 2.3kg in size and has a pointed base. The taste is sweet but lacks bitterness. It is reputed to be tolerant of P. palmivora in Malaysia* (Burhan, T. Mr., personal communications, 1995).

This clone is has performed well at the House site with a Quartile 3 rating (Table 18) but only a Quartile 1 rating was recorded on the Hall site (Table 15). Further data will be available from this clone's performance in a few years.

**P 21 (Baby Red Flesh)**
11 Project Tree original numbers: 1, 80, 81, 166 to 168, 370 to 373, 566.

This clone has shown good growth gains especially as it was a late addition to the project. 7 trees survived for growth data and results placed this clone in the lower section of Quartile3, Hall site (Table 15) and again in the lower section of Quartile 2, House site (Table 18). This is a seedling of D 166 and is a smaller fruit than D 166.

**Sahom**
10 Project Tree original numbers: 33, 108, 109, 182, 262, 361, 363, 365, 529 and 530.

This is an old clone from the Kuala Kangsar region of Malaysia. Sahom has rated highly in Quartile 4 of the Hall site (Table 15) but this result relates to only one tree. It rated in Quartile 3 of the House site (Table 18). It appears to be a strong grower once established. The researchers have not tasted this fruit. Fruiting should occur within the next year from the original introduction in Hall site.

## 7.4 Australian and Overseas Clonal Observations for Group 3. Deleted from future evaluation (7)

These clones with the exception of Permasuri, D 120 and Sukun performed poorly under the weather conditions (Table 19), while Hew 6, Sukun and D 120 lack tolerance to cool temperatures. Ampung and D 16 were the worst performers in this group received lowest rankings in Table 15 and 18. Ampung did manage a high survival rate (Table 12) but failed to impress with the trunk growth increases.

**Ampung**
10 Project Tree original numbers: 110, 111, 185, 263, 321, 404, 487, 512 to 514.

Australian experience is that this is a weak tree. 8 project trees survived but growth rates were poor (Table 12). This clone was rated in Quartile 1 at the House site (Table 18) and Quartile 2 at the Hall site (Table 15).

**D 16**
10 Project Tree original numbers: 53 to 55, 92, 93, 405, 460, 555 to 557.

D 16 was one of the worst performers and received lowest Quartile ranking in Table 15 and 18. It was also affected by cold weather and is not recommended for further evaluation.

**D 120 (KK5, Manong)**
10 Project Tree original number: 38 to 40, 132, 133, 364, 490, 491, 562 and 563.
This clone lacks tolerance to cool temperatures and severe winds. Tree no's 132 and 133 were destroyed by cyclones during the project.

**Hew 6**
10 Project Tree original numbers: 58 – 60, 134, 135, 356, 357, 358, 534 and 535.
This clone lacks tolerance to cool temperatures. It has an untidy habit and is not recommended.

**Permasuri**
10 Project Tree original numbers: 56, 57, 65, 66, 261, 426, 461, 463, 515 and 516.
Australian observations indicate that this clone has an excellent structure with horizontal branching occurring naturally. The parent tree (number 261) has grown well but other trees have failed to perform in our conditions.

**Sukun**
12 Project Tree original numbers: 13, 36, 37, 41 to 43, 213, 340, 342, 344, 346 and 348.

Subhadrabandhu and Ketsa (2001) report that "*the fruit is long and round with quite a thick yellow rind and small spines which are close together. The fruit are easily split and weigh 2.5 to 3.0kg. Each fruit has five locules with 5 to 15 pulp units with flattened seeds and yellowish - white flesh. Each full grown tree produces 100 – 300 fruit per year. This cultivar was released in 1984 as a cultivar resistant to root-rot disease and fruit boring insects.*"

Winter badly affected this clone; with severe leaf drop occurring. It has demonstrated an erect narrow habit as recorded in Indonesia (Setiadi, 1993 cited by Yaacob, O. and Subhadrabandhu, S. 1995). This clone would therefore be suited to close plantings but only in a warm site.

## 7.5 Australian and overseas Clonal Observations for Group 4 for ZTR-1A Phase 2

This group contains 4 clones that require further evaluation through an extension of ZTR-1A, Phase 2.

**Chin**
10 Project Tree original numbers: 46, 47, 69 to 71, 594 to 597, 619.

Due to the limited budwood supply propagation has been difficult. This tree requires further evaluation as the entire Hall site trees were located in rows 1 and 2, which were deleted from growth measurements due to cyclone damage. At the House site 3 of the 5 original trees survived and were placed in Quartile 4. More information is therefore required before a decision can be made on this Malaysian clone.

**D 2**
21 Project Tree original numbers: 6, 88, 89, 180, 181, 191, 203,218, 227, 308, 395, 401, 489, 504 to 506.

D 2 was one of 13 clones studied in Serdang for Phytophthora tolerance. D 2 was rated with D 10 as some of the best performers compared to D 24 (Tai, 1983). Australian observations have shown that this is a very strong tree. This is in line with Malaysian observations listed below. "*Trees are vigorous with leathery dark green leaves. The tree structure is upright which makes it easy to maintain. It is a shy bearer although it usually flowers prolifically. The fruit is 1.5 to 2 kg in size with a dark green shell, elongated shape, with short fine thorns. Sometimes the fruit shape is irregular and twisted due to poor pollination and seed development. The flesh is deep orange to light crimson with an excellent flavour. Flesh is thick as most seeds are shrivelled. The texture is creamy*." (Dr Chan. Y. K. and Voon B. H. , personal communications, 1995).

D 2 is pictured in page 13 of *Penanaman Durian* (1991) MARDI.

Other reports indicate that yield is high in different locations of Malaysia (Tamen Eden Sdn Bhd, personal communications, 2002). Therefore further evaluation is required to determine if fruit set is acceptable in Australia.

**D 163 (Hor Lor)**
10 Project Tree original numbers: 25 to 28, 159, 427, 488, 567 to 569.

Once again results were affected by deletion of rows 1 and 2 in the Hall site. The researchers have tasted this clone in Singapore. The low yields are a concern but further evaluation is recommended.

"*This Penang clone has low yields with trees over 10 years producing 30 – 40 fruit. The fruit shape is similar to a lantern. Texture is dry, sticky, fine and smooth. The flesh is yellow and is very sweet and fragrant*. "(Voon B. H. personal communications, 1995).

**D 164 (Red Flesh)**

10 Project Tree original numbers: 48 to 50, 67, 68, 378,379, 468, 517 and 518.

This is another Penang clone regularly place highly in their competitions. Unfortunately this clone need more evaluation, as no evaluation was possible at the Hall site due to the deletion of Rows 1 and 2. The researchers have tasted this clone in Penang and compared its fruit quality with D 175.

## 7.6 Australian and overseas Clonal Observations for Group 5

A further 19 clones were also observed but unfortunately these clones were not replicated by 5 at both sites replicates to ensure a thorough analysis. Their evaluation was restricted by the lack of planting material, as some of these were late introductions. These are listed in Group 5. This includes 20 new clonal introductions and 3 "standards" with insufficient numbers of replicates for evaluation.

**Capri**
1 Project Tree original numbers:114 (died).

Due to the limited budwood supply propagation has been difficult. This tree requires further evaluation. It is popular in Penang, Malaysia with high placing in their durian competitions. The fruit is a small, up to a kilo, which would suit our market. The flesh is whitish. The researchers tasted this clone in 1993.

**D 7**
5 Project Tree original numbers: 306, 310, 312, 314 and 386.

This tree is very weak and susceptible to cold temperatures. D 7 was only planted at the Hall site but is severely affected by cold weather and would have been consigned to Group 3 except that no plantings were available for observations at the House site.

**D10**
6 Project Tree original numbers: 117, 236, 269, 270,294, 431.

Project observations indicate this clone is a strong growing tree. As it is clone is more Phythophthora tolerant than D 24 (Tai, 1983), it was used in the MARDI breeding program as a parent of D 188, D 189 and D 190. D 10 is pictured in page 13 of Penanaman Durian (1991) MARDI.

"*The fruit is 1.5 to 2 kg in weight, elongated shape with light green to yellow shell. Thorns are broad at the base. The fruit splits easily and does not keep well. Flesh has good eating qualities, yellow flesh, thick, creamy with a good flavour. It is a good regular cropper*." (Chan. Y. K., personal communications, 1995).

Further comments from growers in other areas in west Malaysia indicate that their experience is that this clone is not a regular cropper. Tamen Eden Sdn Bhd (personal communications (2002).

**D 24 Serawak**
2 Project Tree original numbers: 616 and 618.

This fruit was tasted in Serawak state, east Malaysia. It is similar to D 24 but has a pointed base on the fruit. Fruit quality is not as good as D 24 though the tree seems stronger under Australian conditions.

**D 96**
9 Project Tree original numbers: 51, 52, 63, 64, 446 to 449 and 451. This clone is similar to D 2.

**D 123**
10 Project Tree original numbers: 22 to 24, 241, 268, 474 to 476 and 478.

D 123 is pictured in page 13 of Penanaman Durian (1991) MARDI. It is believed to be Chanee and the DNA tests (Figure 16) locate this clone near the Chanee group. The surviving trees are strong but results were affected by the deletion of 3 trees in Rows 1 and 2 in the Hall site. Therefore further observations will be undertaken.

**D140**
4 Project Tree original numbers: 94, 95, 387, 620.

This is described as a rogue D 24 (Anon, 1992) and Lim (1997).

**D 143**
3 Project Tree original numbers: 96, 97 and 424.

This is a hybrid from the crossing of D 2 and D 7 (Anon, 1992). Due to limited of tree numbers further evaluation is required.

**D 145**
3 Project Tree original numbers: 613, 615 and 617.

"*This is a dark green skinned durian. The tree is medium – large and is rather sensitive to drier conditions. It fruits rather less regularly, but shows average to high yielding ability. Fruits are borne all over the tree. Fruit is round, medium size (1.3 – 1.5 kg) and are quite easy to open. Flesh is thick, bright yellow in colour, with a fine texture and a sweet nutty taste. This clone is quite sensitive to Phytophthora stem-canker.*" (Serudin *et al.,* 1994). D 145 is pictured in page 14 of Penanaman Durian (1991) MARDI.

This was another clone to be introduced late into the project. It is a recent selection from Pahang state, west Malaysia. Further evaluation is required before a final decision is made.

**D 160**
5 Project Tree original numbers: 115, 599, 600, 607 and 609.

"*Malaysian information indicates this clone has average yield with fine smooth yellowish pink flesh. Taste is sweet, creamy fragrant flavour and bitter. Keeping qualities are 72 hours.*" (Voon B. H. , personal communications, 1995).

D 160 rated in Quartile 2 at the House site (Table 18) and tree number 115 failed to survive at the Hall site. Further evaluation is recommended.

**D 188 (MDUR 78)**
9 Project Tree original numbers: 116, 174 to 176, 392, 500 to 503.

*"D 188 formally called MDUR 78 was a hybrid produced by MARDI and released in September 1991. D 188 is a large vigorous tree that has a height of 20 metres at year 10. It produces first fruit at 6 to 7 years and has a medium to heavy but consistent fruiting behaviour. It averaged 99 fruit per year at year 12 (over a period from 1981 to 1990). The fruit is 1,5 to 1.8kg with a greenish yellow skin colour. Recovery is 20% with medium seeds. The flesh is thick and a yellow orange colour. Taste is sweet and nutty with a fine texture. Natural storage life is 70 hours*." (Zainal *et al.*, 1992). D 188 is pictured in page 13 of Penanaman Durian (1991) MARDI.

This clone was placed in Quartile 2 at the Hall site (Table 15) and Quartile 1 at the House site (Table 18). It has been slow to establish but from the above descriptions deserves more observations, especially as survival rates have been reasonable (Table 12).

**D 197 (Raja Kunyit)**
6 Project Tree original numbers: 423, 606, 608, 610, 612 and 614.

*"This is one of the latest clones to be registered in Malaysia. 20-year-old trees produce more than 100 fruit per season. The fruit is 1.8kg on average, with golden yellow flesh. Texture is fine with a sweet, fragrant flavour and slightly bitter. Flesh recovery is 26%. The tree is resistant to disease and the quality of fruit from this clone is not influenced by rain* (Voon B. H., personal communications 1995)."

This clone was a late addition to the project. It was first introduced in 1992 as a single tree. The researchers then collected additional budwood in July 1996 in Malaysia. The House site survival has been excellent (Table 12). Further evaluation needs to be undertaken for this selection from Kelantan State, west Malaysia.

**Gob Yaow**
13 Project Tree original numbers: 272, 275, 279, 282, 286, 289, 297, 300, 470, 477, 480, and 473.

Brian Watson introduced this clone in the 1970's. It is similar to Chanee in fruit shape, quality and tree habit. The DNA analysis (Figure 16.) located this clone next to D 123 and Kradum Thong, in the Chanee grouping. This clone will be used as a standard in any future evaluation observations.

**Gumpum**
11 Project Tree original numbers: 198, 206, 443 – 445, 450, 452, 456, 462, 465 and 466.

This clone was introduced into Australia by Brian Watson, OIC, DPI Kamerunga Horticultural Research Station in the 1970's. In the 1987/88 season Kamerunga yield results for Gumpum (formally called Monthong), from tree number 115, list that 20 fruit were produced weighing 47.2kg. This tree was then 8 years of age. Observations of the fruit characteristics for Gumpun were described as the mean fruit being 2.36kg, mean pericarp weight expressed as a percentage 58.9%, mean seed weight expressed as a percentage4.5% and mean aril weight expressed as a percentage 36.6%. The aril was described as a deep yellow colour with very firm texture. Gumpun will also carry to markets without odour if picked outside two days before normal drop (Watson, 1988).

Project observations have supported these research results. Gumpun is already on the recommended list for planting in Australia. It is included in this section only because there were insufficient replications in the Hall site. Survival rates have been excellent (Appendix 1.) This clone also achieved Quartile 4 ranking across both sites (Table 19). DNA results (Figure 16) clearly show this clone to be located in the Monthong group.

**Hew 1**
15 Project Tree original numbers: 210, 211, 234, 327, 329, 331, 333, 335, 337, 339, 341, 343, 345, 347 and 349.

This is an introduction from Tropical Primary Products, Lambell's Lagoon, NT. This clone is vigorous with a distinct Christmas tree shape. First fruiting is due in May 2002. (Table 36). Fruiting has occurred in NT. Fruit yield and quality has been excellent with even five-year-old trees commencing to fruit (Tropical Primary Products, personal communications, 2000). This clone is now listed on the recommended planting list for NT. Hew 1 was rated in Quartile 3, House site (Table 18) and in Quartile 4, Hall site (Table 15). It achieved an overall ranking of 4 in Table 20. Most of the observations were from the House site with only 1 tree surviving at the Hall site from the 3 originally plantings (Table 12).

**Hew 2**
7 Project Tree original numbers: 326, 328, 330, 332, 334, 336 and 338.

This is another introduction from Tropical Primary Products, Lambell's Lagoon, NT. This clone is similar to Hew 1. The DNA analysis (Figure 16) places this clone next to D 144. This is surprising as the clone bears a closer resemblance to Chanee. This clone was not planted at the Hall site and observations were only conducted at the House site. Hew 2 was rated in Quartile 2 (Table 18). Tree no 334 is currently fruiting (Table 36).

**NG Monthong**
1 Project Tree original numbers: 411.

This single tree has performed well. It was not planted out across both sites as the researchers had difficulty in multiplying enough grafted plants in time. Later plantings (outside this project) have performed well with excellent survival. This clone has flowered only lightly in both 1999 and 2000 but is yet to produce fruit. The researchers have tasted this clone in Malaysia and found it to be of excellent quality. The fruit was large, over 5kg but this could have been due to the numbers of fruit on the tree. Watson (1988) reports that yield results from Kamerunga over several years from various clones indicates that "*fruit size/weight is correlated inversely to fruit numbers.*" This clone will be further evaluated over the coming seasons.

**P 601**
7 Project Tree original numbers: 86, 87, 369, 419, 459, 507 and 508.

This is a Penang selection rated in Quartile 2, Hall site (Table 15) and Quartile 1, House site (Table 18). The researchers have tasted this fruit in Penang and rate it highly. The flesh is highly coloured and is excellent quality. Further evaluation will monitor this clone.

**Petruk**
1 Project Tree original numbers: 199.

This Indonesian clone has a fruit size reported to be 1 to 1.5kg and the shape of an egg. Flesh is yellow and sweet with 10 to 12 year old trees producing 50 to 150 fruit (AARD, 1993a). Fruits are not easily opened (Setiadi, 1993 cited by Yaacob, O. and Subhadrabandhu, S. 1995). Petruk is pictured in Figure 2.14 page 15, Durian ASEAN Food Handling Bureau (1994)

Australian observations have shown that this clone is slow to establish as it has a very bushy habit up to year 3. It did eventually develop a leader and was placed in Quartile 3 at the Hall site (Table 15).

The fruit size, production and other characteristics if reproduced in Australia could make this clone important in the future. Therefore further evaluation will be undertaken.

**Sunan**
5 Project Tree original numbers: 453 to 458.

Sunan produces an attractive 1.5 to 2.5kg fruit with a thick skin. Flesh is cream- coloured with flattened seeds. Sunan is pictured in Figure 2.13 page 15, Durian ASEAN Food Handling Bureau (1994). Each tree can yield 200 to 800 fruit per year (Setiadi 1993 cited by Yaacob, O. and Subhadrabandhu, S. 1995) and (Serudin, T. *et al.*, 1994)

This clone has an excellent compact growth habit. It has suffered slight defoliation in winter (Table 34). Sunan has fruited in Australia for Colin and Dawn Gray for several years. This is a strong flavoured fruit and has potential. Unfortunately not enough data was available to place this in either group 1 or 2. This clone will be evaluated further and used as a standard in any future observations.

**Taiping 1**
1 Project Tree original numbers: 421.

*"In Kuala Kangsar this clone is produces from 80 to 120 fruit from 13 year old trees. The fruit is 1.5 to 2 kg in size. It is sweet, creamy, slightly bitter but is a poor keeper splitting 2 to 6 hours after dropping."* (Mr Burhan Taib, personal communications, 1995).

The single project tree has struggled with the weather conditions over the past 5 years. No propagation of this clone has occurred due to the lack of vigour in the original tree. As soon as propagation can occur, this clone will be further evaluated. As minimal processing will become more important in future marketing strategy, this clone could be of assistance to our industry.

**TLK/YEAO**
4 Project Tree original numbers: 119 to 121 and 408.

This is a selection from Tamen Eden Sdn Bhd. The trees are very strong and will be observed in the future.

**XA**
6 Project Tree original numbers: 2, 409, 590 to 593.

This is another selection from Tamen Eden Sdn Bhd. The trees are very strong and will be observed in the future.

## 7.7 Recommendations

The 37 clones identified in Groups 2, 4 and 5 clearly need further investigations before any final recommendations on their future are made. As many of these clones have excellent qualities, research should be undertaken through ZTR-1A Phase 2, or a similar project to achieve their full evaluation.

## 7.8 References

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# Appendix 1. Original Planting Survival Table for 23 clones without 5 replicates at each site.

| Name | Origin and Alternative Name | Number Planted House Site | Number Planted Hall Site | Numbers Surviving House Site June 2001 | Numbers Surviving Hall Site June 2001 | % Survival House Site | % Survival Hall Site | Comments |
|---|---|---|---|---|---|---|---|---|
| Capri | Malaysia | 0 | 1 | N/A | 0 | 0 | N/A | Small fruit, Penang, pale flesh colour, Lack of budwood |
| D7 | Malaysia | 1 | 4 | 1 | 4 | 100 | 100 | Very weak tree, defoliates in winter. |
| D10 | Malaysia<br><br>Durian Hijau | 1 | 5 | 0 | 4 | 0 | 80 | Parent used for D190 as is noted for phytophthora tolerance. |
| D24 Serawak | Malaysia | 2 | 0 | 1 | N/A | 50 | N/A | Serawak version of D24. Slightly more pointed fruit than D 24. |
| D96 | Malaysia<br><br>Bangkok A | 5 | 4 | 4 | 0 | 80 | 0 | Hall results severely affected by deletion of 4 replicate trees in rows 1 and 2. |
| D123 | Malaysia<br><br>Chanee | 4 | 5 | 2 | 2 | 50 | 40 | Budwood from MARDI<br>Hall results affected by deletion of 3 replicate trees in rows 1 and 2. |
| D140 | Malaysia<br>DX/Rogue D 24 | 2 | 2 | 1 | 2 | 50 | 100 | Strong tree |
| D143 | Malaysia<br>Hybrid<br>(D 2 X D 7) | 1 | 2 | 1 | 1 | 100 | 50 | Tree lacks vigour |
| D145 | Malaysia<br><br>Beserah | 3 | 2 | 2 | N/A | 66 | N/A | Selection from Pahang, West Malaysia |
| D160 | Malaysia<br>Buluh Bawah | 4 | 1 | 3 | 0 | 75 | 0 | Large fruit up to 3kg |

**Appendix 1. continued**

| Name | Origin and Alternative Name | Number Planted House Site | Number Planted Hall Site | Numbers Surviving House Site June 2001 | Numbers Surviving Hall Site June 2001 | % Survival House Site | % Survival Hall Site | Comments |
|---|---|---|---|---|---|---|---|---|
| D188 | Malaysia MDUR 78 | 5 | 4 | 3 | 2 | 60 | 50 | MARDI crosses |
| D197 | Malaysia Raja Kunyit | 6 | 0 | 6 | N/A | 100 | N/A | Latest Selection from Kelantan, West Malaysia |
| Gob Yaow | | 4 | 9 | 3 | 9 | 75 | 100 | Introduced into Australia by Brian Watson OIC Kamerunga DPI. |
| Gumpun | | 9 | 2 | 8 | 2 | 89 | 100 | Introduced into Australia by Brian Watson OIC Kamerunga DPI. |
| Hew 1 | Malaysia | 12 | 3 | 11 | 1 | 92 | 33 | Introduced into Australia by Tropical Primary Products NT. |
| Hew 2 | Malaysia | 7 | 0 | 6 | N/A | 86 | N/A | Introduced into Australia by Tropical Primary Products NT. |
| Ng Mon Thong | Malaysia D 159 | 1 | 0 | 1 | N/A | 100 | N/A | Only one tree observed. Latest planting on the Hall site looks excellent. |
| P 601 | Malaysia | 5 | 2 | 3 | 2 | 60 | 100 | One of the best Penang selections |
| Petruk | | 0 | 2 | N/A | 1 | N/A | 50 | Introduced into Australia by Bert Jaminon and others in Darwin |
| Sunan | | 5 | 0 | 4 | N/A | 80 | N/A | Introduced into Australia by Colin and Dawn Gray, Cape Tribulation NQ. |
| Taiping 1 | Malaysia | 1 | 0 | 1 | N/A | 100 | N/A | Only one tree observed |
| XA | Malaysia | 5 | 0 | 4 | N/A | 80 | N/A | Strong tree. Selection from Tamen Eden Sdn Bhd, Tapah, Malaysia. |
| Yeoh | Malaysia TLK | 1 | 3 | 1 | 2 | 100 | 66 | Strong tree. Selection from Tamen Eden Sdn Bhd, Tapah, Malaysia. |

# Appendix 2. Hall Planting and House Planting.

| **Original Plantings Hall Site 2** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Row 1 | Row 2 | Row 3 | Row 4 | Row 5 | Row 6 | Row 7 | Row 9 | Row 10 |
| 16 | 46 | 72 | 112 | 153 | 187 | 238 | 270 | 305 |
| 17 | 47 | 73 | 113 | 154 | 188 | 239 | 271 | 306 |
| 18 | 48 | 74 | 114 | 155 | 189 | 240 | 272 | 307 |
| 19 | 49 | 75 | 115 | 156 | 190 | 241 | 273 | 308 |
| 20 | 50 | 76 | 116 | 157 | 191 | 242 | 274 | 309 |
| 21 | 51 | 77 | 117 | 158 | 192 | 243 | 275 | 310 |
| 22 | 52 | 78 | 118 | 159 | 193 | 244 | 276 | 311 |
| 23 | 53 | 79 | 119 | 160 | 194 | 245 | 277 | 312 |
| 24 | 54 | 80 | 120 | 161 | 195 | 246 | 278 | 313 |
| 25 | 55 | 81 | 121 | 162 | 196 | 247 | 279 | 314 |
| 26 | 56 | 82 | 122 | 163 | 197 | 248 | 280 | 315 |
| 27 | 57 | 83 | 123 | 164 | 198 | 249 | 281 | 316 |
| 28 | 58 | 84 | 124 | 165 | 199 | 250 | 282 | 317 |
| 29 | 59 | 85 | 125 | 166 | 200 | 251 | 283 | 318 |
| 30 | 60 | 86 | 126 | 167 | 201 | 252 | 284 | 319 |
| 31 | 61 | 87 | 127 | 168 | 202 | 253 | 285 | 320 |
| 32 | 62 | 88 | 128 | 169 | 203 | 254 | 286 | 321 |
| 33 | 63 | 89 | 129 | 170 | 204 | 255 | 287 | 322 |
| 34 | 64 | 90 | 130 | 171 | 205 | 256 | 288 | 323 |
| 35 | 65 | 91 | 131 | 172 | 206 | 257 | 289 | 324 |
| 36 | 66 | 92 | 132 | 173 | 207 | 258 | 290 | 325 |
| 37 | 67 | 93 | 133 | 174 | 208 | 259 | 291 | |
| 38 | 68 | 94 | 134 | 175 | 209 | 260 | 292 | |
| 39 | 69 | 95 | 135 | 176 | 210 | 261 | 293 | |
| 40 | 70 | 96 | 136 | 177 | 211 | 262 | 294 | |
| 41 | 71 | 97 | 137 | 178 | 212 | 263 | 295 | |
| 42 | | 98 | 138 | 179 | 213 | 264 | 296 | |
| 43 | | 99 | 139 | 180 | 214 | 265 | 297 | |
| 44 | | 100 | 140 | 181 | 215 | 266 | 298 | |
| 45 | | 101 | 141 | 182 | 216 | 267 | 299 | |
| | | 102 | 142 | 183 | 217 | 268 | 300 | |
| | | 103 | 143 | 184 | 218 | 269 | 301 | |
| | | 104 | 144 | 185 | 219 | | 302 | |
| | | 105 | 145 | 186 | 220 | | 303 | |
| | | 106 | 146 | | 221 | | 304 | |
| | | 107 | 147 | | 222 | | | |
| | | 108 | 148 | | 223 | | | |
| | | 109 | 149 | | 224 | | | |
| | | 110 | 150 | | 225 | | | |
| | | 111 | 151 | | 226 | | | |
| | | | 152 | | 227 | | | |
| | | | | | 230 | | | |
| | | | | | 231 | | | |
| | | | | | 232 | | | |
| | | | | | 233 | | | |
| | | | | | 234 | | | |
| | | | | | 235 | | | |
| | | | | | 236 | | | |

237

South House Site North

| Row 1 | Row 2 | Row 3 | Row 4 | Row 5 | Row 6 | Row 7 | Row 8 |
|---|---|---|---|---|---|---|---|
| 443 | 468 | 500 | 534 | 561 | 572 | 590 | 605 |
| 444 | 469 | 501 | 535 | 562 | 573 | 591 | 606 |
| 445 | 470 | 502 | 536 | 563 | 574 | 592 | 607 |
| 446 | 471 | 503 | 537 | 564 | 575 | 593 | 608 |
| 447 | 472 | 504 | 538 | 565 | 576 | 594 | 609 |
| 448 | 473 | 505 | 539 | 566 | 577 | 595 | 610 |
| 449 | 474 | 506 | 540 | 567 | 578 | 596 | 611 |
| 450 | 475 | 507 | 541 | 568 | 579 | 597 | 612 |
| 451 | 476 | 508 | 542 | 569 | 580 | 598 | 613 |
| 452 | 477 | 509 | 543 | 570 | 581 | 599 | 614 |
| 453 | 478 | 510 | 544 | 571 | 582 | 600 | 615 |
| 454 | 479 | 511 | 545 | | 583 | 601 | 616 |
| 455 | 480 | 512 | 546 | | 584 | 602 | 617 |
| 456 | 481 | 513 | 547 | | 585 | 603 | 618 |
| 457 | 482 | 514 | 548 | | 586 | 604 | 619 |
| 458 | 483 | 515 | 549 | | 587 | | 620 |
| 459 | 484 | 516 | 550 | | 588 | | |
| 460 | 485 | 517 | 551 | | 589 | | |
| 461 | 486 | 518 | 552 | | | | |
| 462 | 487 | 519 | 553 | | | | |
| 463 | 488 | 520 | 554 | | | | |
| 464 | 489 | 521 | 555 | | | | |
| 465 | 490 | 522 | 556 | | | | |
| 466 | 491 | 523 | 557 | | | | |
| 467 | 492 | 524 | 558 | | | | |
| | 493 | 525 | 559 | | | | |
| | 494 | 526 | 560 | | | | |
| | 495 | 527 | | | | | |
| | 496 | 528 | | | | | |
| | 497 | 529 | | | | | |
| | 498 | 530 | | | | | |
| | 499 | 531 | | | | | |
| | | 532 | | | | | |
| | | 533 | | | | | |

| Row 1 | Row 2 | Row 3 | Row 4 | Row 5 | Row 6 | Row 7 |
|---|---|---|---|---|---|---|
| 326 | 351 | 369 | 387 | 404 | 419 | 432 |
| 327 | 352 | 370 | 388 | 405 | 420 | 433 |
| 328 | 353 | 371 | 389 | 406 | 421 | 434 |
| 329 | 354 | 372 | 390 | 407 | 422 | 435 |
| 330 | 355 | 373 | 391 | 408 | 423 | 436 |
| 331 | 356 | 374 | 392 | 409 | 424 | 437 |
| 332 | 357 | 375 | 393 | 410 | 425 | 438 |
| 333 | 358 | 376 | 394 | 411 | 426 | 439 |
| 334 | 359 | 377 | 395 | 412 | 427 | 440 |
| 335 | 360 | 378 | 396 | 413 | 428 | 441 |
| 336 | 361 | 379 | 397 | 414 | 429 | 442 |
| 337 | 362 | 380 | 398 | 415 | 430 | |
| 338 | 363 | 381 | 399 | 416 | 431 | |
| 339 | 364 | 382 | 400 | 417 | | |
| 340 | 365 | 383 | 401 | 418 | | |
| 341 | 366 | 384 | 402 | | | |
| 342 | 367 | 385 | 403 | | | |
| 343 | 368 | 386 | | | | |
| 344 | | | | | | |
| 345 | | | | | | |
| 346 | | | | | | |
| 347 | | | | | | |
| 348 | | | | | | |
| 349 | | | | | | |
| 350 | | | | | | |