2. LITERATURE REVIEW

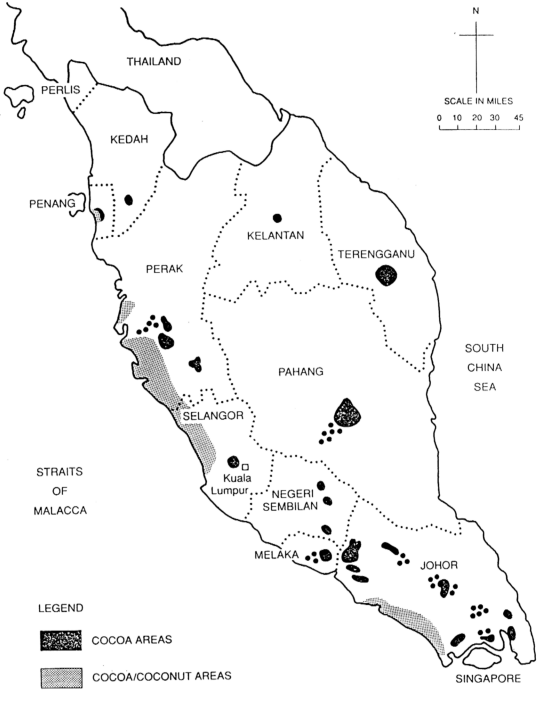
2.1 Introduction and Cultivation of Cocoa in Malaysia

Cocoa (*Theobroma cacao*), which has its origin in the lower storey of the tropical rainforest of the Amazon, was probably first introduced into Malaya (now known as Peninsular Malaysia) by Dutch in the 1700s (Purseglove, 1977), about 100 years earlier than oil palm and rubber. Inspite of its early introduction, the potential of cocoa as a plantation crop in Malaysia was recognised only after the second World War. However, large scale cultivation of monocrop cocoa in Malaysia only accelerated from late 1960 when the superior Upper Amazon hybrid planting materials became commercially available.

In Peninsular Malaysia, cocoa is generally cultivated as an intercrop or mixed crop on coastal soils along the West coast, though considerable monocrop cocoa has been planted on inland soils in the Central and Southern Region of the country (Fig. 2.01).

2.2 The Switch from Seedling to Budded Cocoa

Until the 1980s, commercial cocoa planting had traditionally been established with Upper Amazonian hybrid planting materials characterised by exceptional vigour and precocity. However, the very considerable variability within individual progenies in terms of pod yield, diseases susceptibility, tree growth, bean quality and characteristics, gave rise to ample scope for developing clones from outstanding



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individuals. The scourge of Vascular Streak Dieback (VSD) disease caused by *Oncobasidium theobromae* coupled with the declining cocoa prices in the 1980s further catalysed the switch to the more VSD tolerant and higher yielding clonal materials which are vegetatively propagated mainly by budgrafting method.

As the multi-stem growth habit of fan-budded clonal tree differs considerably from that of a hybrid seedling tree with typical single-stem "chupon" characteristics, the establishment and management of the former will entail a different agronomic approach, specifically on aspects of pruning, shade, nutrient and spacing requirements.

2.3 Spacing of Cocoa

Of all the agronomic factors affecting the yield of cocoa per unit area of land, spacing has the greatest and most immediate impact. The choice of spacing, in turn, is influenced by the planting material, shade, soil and climatic conditions and by the future management of the mature cocoa trees. The optimum spacing between cocoa trees is defined as the distance which will give the greatest economic return of cocoa per unit area and this takes into account planting costs and a discount on returns which in turn depends on the trends of yields with age and environment. The agronomic optimum, on the other hand is often the maximum cumulative yields over a given period.

Different cocoa growing countries have adopted a certain spacing which has become traditional. This generally varies from the wide spacing of 5.0 x 5.0 m in Papua New Guinea, Sri Lanka and Samoa to the very close spacing of less than 2.0 m in West Africa. Most of the experimental evidence point to close spacing as giving higher yields (Wood, 1985) in the early years, but once a canopy forms and the soil becomes fully exploited, the difference between close and wide spacing would narrow.

In Trinidad, very close spacing (2.0 x 2.0 m) has been advocated for planting clones. The difficulty of access at this spacing could be overcome by training to allow only basal chupon to take over (Wood, 1985).

In the Amelonado spacing trial at Tafo in Ghana (established in 1947) which tested eight spacings from 1.2 x 1.2 m up to 4.6 x 4.6 m, the closer spacing from 3.0 x 3.0 to 1.2 x 1.2 m gave similar aggregate yields for ten seasons. The wider spacing - 3.7 x 3.7 m and 4.6 x 4.6 m - gave lower yields (Wood, 1985).

In another Amazon materials trial at the same locality comparing three spacing viz. 2.4 x 2.4 m, 3.0 x 3.0 m and 3.7 x 3.7 m, the closer spacing gave slightly greater yields in the early years, but from eight years on the wider spacings yielded higher. Another example of high yields with close spacing has been reported from Columbia where cocoa planted at 2500 trees/ha (2.0 x 2.0 m) yielded nearly three times higher than cocoa at 1250 trees/ha after three years (Gutierrez, 1981).

2.3.1 Cocoa spacing in Malaysia

Traditionally, cocoa has been grown under varying degree of living shade (Chan et al, 1989) and spaced at square or rectangular patterns at an average of 1000 trees/ha. In conventional plantings with seedling materials, spacings generally used are 3.05 x 3.05 m (1076 trees/ha), 3.66 x 2.44 m (1121 trees/ha) or 3.05 x 2.44 m (1345 trees/ha) with the aim of achieving a stand of at least 1000 trees/ha during a major part of its productive years.

Most of the early research work on precocious and vigorous high yielding Upper Amazon hybrid crosses also showed clear advantage for spacings closer than 3.0 x 3.0 m (Blencowe & Hubbard, 1972, Armstrong, 1976, Wyrley-Birch, 1977). Lim & Chan (1984) confirmed that highest early and cumulative yields were obtained from the close-spaced (4.0 x 1.8 m) hybrid seedling planting established on deep young basaltic soil, with and without stand thinning. They also concluded that wider spacings (4.0 x 3.7 m and 4.0 x 5.5 m) produced more pods per tree but less yield per hectare. No significant difference between yields of single and multi-stem treatment in a given spacing was noted. Progressive systematic thinning based on vigour resulted in the final selection of trees yielding better and being more manageable than trees in the no thinning treatment. In the trial established on inland soil in Malacca, Peninsular Malaysia, Lam (1989) further confirmed that close spacing (3.0 x 1.5 m, 3.0 x 1.8 m and 3.0 x 2.1 m) Amazon hybrid seedling gave significantly higher early and cumulative yield per ha than 3.0 x 3.0 m and wider spacings (3.0 x 3.7 m and 3.0

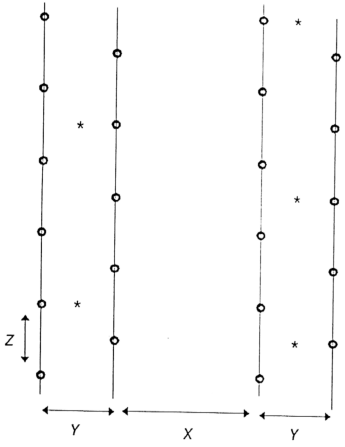
x 4.3 m) inspite of producing significantly lower pods per tree. The effect of inter-tree competition on yield was already evident from the onset of first cropping.

An approach of planting close and thinned later had also been advocated (Blencowe & Hubbard, 1972). The objective is to achieve an early yield or to reduce maintenance in the early years. Armstrong (1976) reported in a trial where a close planted cocoa treatment (4.26 x 1.97 m) was thinned to half its original stand (1378 trees/ha) after five years with no apparent effect on subsequent yields. The additional capital costs in close planting are considerable and there is no evidence to show whether they are equalled by extra yield or lower costs.

Although sufficient information and trial evidence on the optimum spacings for cocoa of seedling origin had been documented, relatively little has been reported on the spacing requirement of fan-budded clonal cocoa in general and Malaysia, in particular.

2.3.2 Novel double hedgerow high density planting system

Work in the Philippines since late 1970s has indicated that the use of fan-budded clonal cocoa planted at much higher density of up to 3 - 5 times conventional density (ca 1000 trees/ha) was economically viable, with yield of 1.1 t/ha in the first year of bearing and up to 3.5 t/ha during full maturity. In the Philippines, fan-budded cocoa were planted in double hedgerows (Fig. 2.02) up to 5000 trees per ha with shade



$X \geqslant Y \geqslant Z$
X = Wide interrow
Y = Close Interrow
Z = Within row
* = Gliricidia shade

only at planting and during establishment. An adequate supply of moisture and nutrients through a drip irrigation system helped to support the trees. This method of intensive cocoa cultivation was pioneered in the Southern Philippines where it has evolved from the experience with bananas cultivation. The system incorporated a combination of management resources, technology and desirable attributes of the different cultivars to maximise profits by the following means:

1. minimising the non-productive fallow period,
2. rapid achievement of a high and stable plateau yield per unit land area and
3. minimising production costs per unit value of yield (Lim & Pang, 1989).

2.3.3 Hedgerow HDP experiences in Malaysia

In Malaysia, the early experience of Borneo Abacca Limited (BAL) in Tawau, Sabah since the mid-1980s with hedgerow high density planting (HDP) of clones at 3333 trees/ha (Lim & Pang, 1989, Lim et al, 1991) on the relatively fertile young basaltic soil have generally been disappointing inspite of an encouraging start. However, it is remarked that such system can be successful provided only suitable clones (in terms of growth habit), preferably of the non-congested type eg. Na 33 and PBC 159, are used. Drip irrigation gave only a 10% gain in yield which is not economically viable. Minimum pruning of the lower branches resulted in higher early yields, but this gain is offset by long term effect of easy access for P & D control and clean harvesting. Trees that retained a closed canopy continue to give higher yields indicating that canopy spread as well as depth of canopy are important for maximum photosynthesis.

Golden Hope's earliest experience of clonal hedgerow HDP at density up to 2500 trees/ha in Sitiawan, Perak since mid-1980s , and Industrial Oxygen Incorporated (IOI), Kumpulan Guthrie's trial planting in Central Johor have also indicated better performance by the less vigorous clones PBC 123 and PBC 159 in the high density (1667 to 2500 trees/ha) plots. The more vigorous clones PBC 130 and PBC 140, on the other hand, only recorded marginal yield increase over the normal density as performance of these clones at higher densities were suppressed by the self-shading of the over-crowded canopy (Chong, 1994, Lim, 1994, Yew, 1993).

Kahar et al (1991) of MARDI reported from three locations in Peninsular Malaysia that high density planting could increase the early yield significantly. However, they found that any increase in density above 3333 trees/ha did not give significant increase in yield. Soil and environmental conditions exerted more profound effects which explain the great differences in yield between the localities. Consistent with BAL, Golden Hope and Guthrie's findings, less vigorous clones yielded better and showed an increasing trend over the year. The high yield from HDP was attributed to high pod production per unit area.

Denamany (1995), in addressing the fertiliser requirement for HDP cocoa planting, reported that higher fertiliser application corresponded with higher yields for cocoa HDP at 4 times the normal density under coconut on coastal alluvial (Typic Tropaquept). Although fertiliser application rate 3 times the conventional rate gave

the highest yield (ca 2.0 kg dry bean/tree/yr), treatment doses higher than 2 times the conventional rate were not significantly different in yields.

The importance of light interception and distribution within the canopy in limiting productivity in cocoa germplasm was highlighted by Yapp and Hadley (1991). They contented that for mature cocoa planted at high density (3333 trees/ha), yield was not related to fractional intercepted radiation (f) but to light distribution through the canopy quantified as light extinction coefficient, K which becomes an important attribute in limiting productivity. It was contented that greater efficiency in productivity could be enhanced through the selection for more efficient 'dwarf' cocoa genotypes which require minimum pruning input; thus allowing the yield component of "tree number per unit land area" to be exploited by allowing rapid canopy closure. This will entail exploitation of different planting systems in terms of their light interception and distribution.