UNIVERSITI PUTRA MALAYSIA

MORPHOLOGICAL CHARACTERIZATION OF FOUR LOCAL CHILI CULTIVARS IN BINTULU SARAWAK

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MORPHOLOGICAL CHARACTERIZATION OF FOUR LOCAL CHILI CULTIVARS IN BINTULU SARAWAK

By

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A Project Report Submitted in Partial Fulfilment of the Requirement
for the Degree of Bachelor of Bioindustry Science in the
Faculty of Agriculture and Food Sciences
Universiti Putra Malaysia Bintulu Sarawak Campus

2008

DEDICATION

To my brothers and sisters; chili get boring, but my family continues to enlighten my life more and more, each and everyday.

ABSTRACT

This study was to evaluate the morphological characteristics and the commercial potential of four different cultivars of local chili (*Capsicum sp.*) commonly found in Bintulu, Sarawak. The four cultivars are locally known as Gerunung Merah, Gerunung Kuning, Cili Besar and Cili Putih making up the four treatments. Each treatment consisted of 30 plants grown in white polybags of size 17" high by 14" wide containing coco pith in three replications. The experiment was conducted under rain shelter netting structure in Completely Randomize Design (CRD). Data were collected based on morphological characteristics and statistically analyzed. The Cili Besar cultivar had the shortest production period followed by Gerunung Kuning, Gerunung Merah, and Cili Putih. Both Gerunung Merah and Gerunung Kuning exhibited good plant architecture with constant first branch angle and larger leaf producing unique fruit shape and color. However, Gerunung Kuning gave the highest fresh to dry-weight conversion ratio, followed by Gerunung Merah, Cili Besar and Cili Putih.

ABSTRAK

Kajian ini adalah untuk menilai ciri-ciri morphologi dan potensi komersil empat kultivar cili yang berbeza (*Capsicum sp.*) yang terdapat di Bintulu, Sarawak. Empat kultivar tersebut dikenali sebagai Gerunung Kuning, Gerunung Merah, Cili Besar dan Cili Putih yang dijadikan sebagai rawatan. Setiap rawatan mengandungi 30 polibeg yang berukuran 17" tinggi x 14" lebar yang menggunakan sabut kelapa sebagai media penanaman dalam 3 replikasi setiap rawatan. Experimen ini dilakukan di bawah struktur jaring pelindung hujan menggunakan rekabentuk eksperimen "Completely Randomized Design" atau (CRD). Data yang telah dikumpul adalah berdasarkan ciri-ciri morphologi dan analisis statistik. Cili Besar menunjukkan jangka masa pengeluaran yang singkat diikuti oleh Gerunung Kuning, Gerunung Merah and Cili Putih. Kedua-dua Gerunung Merah dan Gerunung Kuning mempamerkan nilai hiasan yang tinggi kerana mempunyai sudut dahan pertama yang konstan dan daun yang sangat besar mengeluarkan bentuk buah dan warna yang unik. Walau bagaimanapun Gerunung Kuning mempunyai nilai yang tinggi kadar pertukaran dari basah ke kering diikuti Gerunung Merah, Cili Besar dan Cili Putih.

ACKNOWLEDGMENTS

First of all, I would like to thank God who makes all things possible in this life. I wish to thank the best possible supervisor, Mr. Michael, for all his warm encouragement, kind help and wise words. He stays both broadened my knowledge and gave rise to ideas for this research. It is an honor to know you, Mr. Michael.

Also, I would like to extend thanks to Mr. Make Jiwan, header of Crop Science Department and his staffs. Their help was immeasurable and indispensable for the work completed. This department was friendly, generous, and enlighten in my pursuit for knowledge.

To Mr. Abdul Rahman, Mr. Razak and Madam Jenny, thank you for your support and encouragement and for all your time spent helping me. It was truly appreciated. I will be forever in debt for all your advices, encouragement and friendship. Without your help, guidance and constant motivation this degree would not have been possible.

I would also like to thank the rest of my family, my sisters, Jemmy and Nora, my brothers, Weldrin, Welbin and Teddo, who each in their own way, from the time we were all little kids until now have helped shape and affect the person I am today. They will always be in my heart. I am truly blessed to have them in my life.

My deepest appreciation to all my friends who have lent their helping hands and valuable support in various ways, especially Ms. Faizah, Mr. Aziz, Ms.

Susanna, Mr. Kevin, Mr. Syahalizul, Mr. Arnold, Mr. Eric, Mr. Nazri, Mr. Henky, Mr. Fahmi, Mr. Calvin and Mr. Jelson.

APPROVAL SHEET

I certify that this research project report entitled "**Morphological Characterization of Four Local Chili Cultivars in Bintulu Sarawak**" has been examined and approved as a partial fulfillment of the requirement for the degree of Bachelor of Bioindustry Science in the Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Campus.

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Date: 24-09-2008

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LIST OF ABBREVIATIONS AND TERMS

1. MARDI – Malaysian Agricultural Research and Development Institute
2. NAP – National Agricultural Policy
3. SHU – Scoville Heat Unit
4. HPLC – High-Performance Liquid Chromatography
5. CRD – Completely Randomized Design
6. OECD – Organization for Economic Cooperation and Development
7. PPKC – Pelan Pemasaran Komoditi
8. N – Nitrogen
9. P – Phosphorus
10. K – Potassium
11. GRIN - Germplasm Resources Information Network
12. ITC – International Trade Centre
13. SAS – Statistical Analysis System

CHAPTER 1

INTRODUCTION

Capsicum chili is a genus of plants from the Solanaceae family, native from Mexico, and now cultivated worldwide. Some of the members of *Capsicum* are used as spices, vegetables, beverages and medicines. Bosland (1996) described that *Capsicum* plants have a variety of names depending on place and type. They are commonly called cili, lada or cabai in Malaysia, chili pepper, red or green pepper, or just pepper in Britain and the US, capsicum in Australia and paprika in some other countries, although paprika can also refer to the powdered spice made from various capsicum fruit.

Morphological characters of *Capsicum* peppers are agronomically very important to breeders and farmers. For example, bigger fruits may be more valued as vegetables or condiments, while small and cute fruits may be useful as ornaments. The consumer may prefer a vivid fruit color. Like other crops, plant height and plant type are also important morphological characters when peppers are cultivated (OECD, 2006).

Earlier, a numerical taxonomic analysis carried out of the genus *Capsicum*, but it was pointed out that method produced less than satisfactory results, partly because of a large number of size characters might have mislead the numerical taxonomic analysis at the genus level (Eiji, 2004). *Capsicum* peppers show much parallel variation within the genus, such as gigantism of fruits or other organs, and some domesticated forms

clustering with domesticated forms of other species, rather than their presumed wild ancestor. However, Yamamoto and Eiji (2004) described that at the species level, especially at accessions obtained from limited regional levels, quantitative and qualitative characters are considered to be useful tools to study morphological relationships among accessions.

MARDI (2003) described that chili is utilized as 'garnishing', colorant and in pharmaceutical industry as immunization medicine. The chili plant is a white flowered, dark green or purple leaved plant that grows 1.5 meters in height. The part of the fruit that generates the pungent flavour in the fruit is its membrane and the seeds. Chili powder is obtained from the crushing process of the dried chili. According to Halimathul (2003), the 'pungency' due to alkaloid substance called Capsaicin (8-methyl-N-vanillyl-6-nonenamide) that causes the heat of chili and peppers is a flavourless, odourless chemical concentrated in the veins of chili and peppers.

Chili has several essential elements such as vitamin A, C and E (Rubatzky and Mas, 1999). Zainun Noor (1998) describes that this fruit also contain vitamin B, carotene, carbohydrate and protein, young leaves are edible and they are steamed as a potherb or added to soups and stews and these leaves contain about 4 - 6% protein.

According to Bosland (1996), Chili is antihaemorrhoidal when taken in small amounts, antirheumatic, antiseptic, diaphoretic, digestive, irritant, rubefacient,

sialagogue and tonic. It is taken internally in the treatment of the cold stage of fevers, debility in convalescence or old age, varicose veins, asthma and digestive problems. Externally it is used in the treatment of sprains, unbroken chilblains, neuralgia and pleurisy. It is an effective sea-sickness preventative.

There are different size and shape of chili fruits. The "red chili" with long shaped fruit is highest economic value. This chili is sold in wet condition, while in another country it is sold in dry form. Red chili also used in sauce production (Eshbaugh, 1993). The smallest chili fruits are categorized as *cili burung*, *cili padi* and *cili api*. All of those small chilies are derived from *Capsicum frutescens* except *cili padi* which derived from *Capsicum annum*. All of these small chilies are always used as "sambal" and "jeruk" while the bigger chilies are used as vegetables (MARDI, 2003).

Table 1: Classification of *Capsicum sp.*

Taxonomic placement	**Scientific name**
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Solanales
Family	Solanaceae
Genus	*Capsicum*
Species	*annuum, frutescens, chinense*
Botanical varieties	var. *glabriusculum* (synonym var. *aviculare*) var. *Annuum*

Source: US Department of Agriculture, Agricultural Research Service, Germplasm Resources Information Network (GRIN) 2002.

According to Dewitt and Bosland (1996), the genus Capsicum consists of approximately 22 wild species and five domesticated species:

I. *C. Annuum*, also known Red Chili Pepper and Paprika
II. *C. Baccatum*, Oldest archeological evidence 4500 years ago in Europe
III. *C. Chinese*, also known The Habanero
IV. *C. Frutescens*, also called The Tabasco
V. *C. Pubescens*, also called Rocto or Locoto

In Sarawak, chili is cultivated mainly in home gardens or small fields, and weed forms of this chili are also seen on forest edges, in orchards and along roadsides. This is no doubt the result of dispersal by birds who are attracted to the small and vivid red fruits of some species of that chili. However there are some varieties have been commercialized especially *C. annum* in Miri, Sarawak.

1.1 Problem Statement

Chilies as they are commonly called belong to Genus *Capsicum* of family Solanaceae. While most of them are assigned to species *Capsicum annuum*, some cultivars of *C. frutescens* and *C. pubescens* are also included with them. Chili is commonly found for sale in Bintulu wet market. A great deal of morphological variation in terms of tree

shape, leaf character, fruit size, flower, colour and pungency exist among them which make it difficult to identify.

Base on personal observation at Bintulu Wet Market, different types of chili cultivars are being displayed and given various names by the local people although the may look alike. In some cases, they are given the same name even though they have different fruit sizes, shapes and colours. Commercial values, product quality and perishability remained largely unknown. It was a problem how to identify these cultivars and their agronomic performance was almost non-existence (Personal observations).

The existence of numerous cultivars can be a source of improved germplasms for collection and evaluation which is the first step toward improving the value of this important crop species.

1.2 Objective

The objectives of this study were:

a) To characterize the morphological characteristics of four different cultivars of local chili in Bintulu

b) To evaluate their commercial value as well as the germplasms potential for crop improvement.

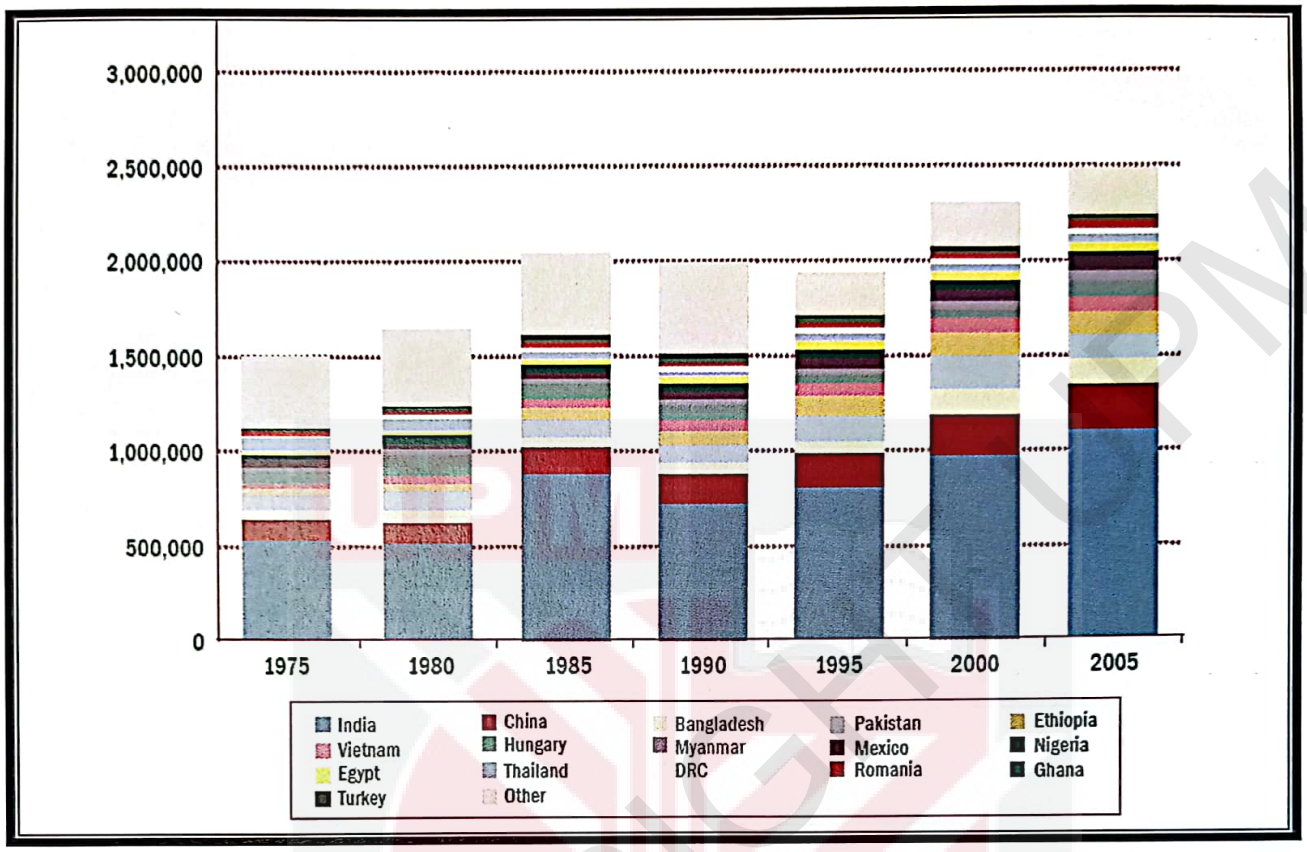
CHAPTER 2

LITERATURE REVIEW

2.1 Overview of World's Chili Production

Till recently, international trade in chilies was dominated by India (Figure 1). However, during the last few years, there has been a change in the situation. According to Perinbam and Ayyappan (2005), export from the country has come down considerably. The total export of chilies from India is on an average only 4% of total production. This is mainly because of the high domestic consumption.

According to Ayyappan (2007), China has emerged as a principal exporter of chilies and is serious competitor in international market. China has success fully penetrated the large Malaysian and Indonesia market. The United States of America has also been purchasing larger quantities of chilies from China. Japan is producing special type of chilies like Bird's Eye, Santaka and Hontaka types of chilies, but export from Japan is decreasing mainly on account of local demand, which has not been matched by local production.



*(Source: World Markets in the Spice Trade 2000-2004 Geneva: ITC, 2006, vi, 111p. (Technical Paper)

Figure 1: World production of Capsicum by country, 1975 to 2005

2.2 Overview of Malaysia's Chilli Production

Chili is one of the most popular annual fruit vegetables in Malaysia and given priority by MARDI. *Capsicum annum* (sweet pepper) and *C. frutescens* (hot pepper) are the two main types of chili cultivated. Among the two, *C. annum* is more important in term of economic and cultivated area. About 90% of locally produced chili is for fresh

consumption. It is not economical to use the existing varieties for processing purposes because of the low conversion rate of fresh to dry which is less than 15% (Melor, 1998).

Base on the requirement of chili annually, import rate is estimated about RM 90 million. In accordance to National Agricultural Policy (NAP3) objective, the reduction of imported of dry chili (estimated RM 60 million per year) and chili padi (about RM 37 million per year) and to boost local production (MARDI, 2003). However, the volume produced locally is insufficient to meet the demand and we are still depending on the imported chili from other countries. According to ITC (2006) Malaysia is the second largest chili importer in the world after US (Table 2).

Most of the cultivated chili in Malaysia is planted in lowland fields, even some of them planted through other method as fertigation system like at Cameron Highland in Malaysia Peninsular. Perak, Johor and Kelantan are the main areas chili producer in Malaysia. Pests and diseases are the main constraints for chili production. The main pests are mites and whitefly, birds and other. Although the use of pesticides and insecticides, provides good control chili varieties which are resistant from diseases is most important. Research about the abundant of local chili varieties especially in Sarawak need to be developed with the objective of improving and boosting local chili production.

Table 2: The import value of various spice commodities and the leading importers of those spices, 2004

Spice categories	Import value (US$'000)	First	%	Second	%	Third	%
Pepper	494,096	US	23.1	Germany	10.9	Netherlands	5.3
Capsicum	590,420	US	23.6	Malaysia	7.6	Germany	7.1
Vanilla	394,928	US	51.9	France	11.3	Germany	9.3
Cinnamon	128,174	Mexico	21.0	US	16.9	India	6.0
Cloves	115,869	Singapore	46.3	India	23.7	Malaysia	7.1
Nutmeg/mace/cardamom	204,383	Saudi Arabia	25.0	India	8.0	Netherlands	8.0
Spice seeds	207,526	US	11.1	Germany	8.4	Malaysia	6.5
Ginger (except preserved)	305,321	Japan	41.2	US	12.1	Pakistan	6.2
Thyme/saffron/bay leaves	105,896	Spain	20.2	US	13.9	Italy	8.0
Spices n.e.s., mixtures	427,266	US	13.0	Belgium	7.8	Germany	6.8

Source: ITC, 2006

The latest chili hybrids are MC11 and MC12 released by MARDI. These are obtained from the hybridization of selected varieties. The shortage of suitable varieties is one of the constraints for production of local chili. The local available varieties such as langkap, kulai and cilibangi are still low of solid material (MARDI, 2003). Therefore, chili germplasm collection is important to assist in developing chili varieties with the desired commercial value. The germplasm can then evaluate with selection and crosses made to begin the improvement program. Those varieties must have

characteristics for commercial values such as superior performance and accepted in specific markets.

According to Melor (1998) the characteristics of good chili variety include:

a) High yield

b) High pungency

c) Short productive period

d) Easy to harvest

e) Simultaneously ripening

f) High conversion of more than 20% for dry chilli

g) Diseases resistance

h) Good plant architecture

2.3 Adaptation Pattern

This species can survive on different soil types and several climatic conditions that widely grown throughout the world, but especially in warm temperate to tropical climates. Chili may be planted on the several of soil types as long as have a well-drained soil. But the most suitable is on the lowland range, temperature between 28 to 29°C and 1500 to 2000 mm/year of rainfall (Sreelathakumary, 2002).

To conserve yield and pungency at optimum level, the best agro zone-climate is in range of 28 to 29°C. If water can be supplied, planting in drought season also guarantee the satisfy yield. Chili suitable planted in most types of soil including peat, light sandy soils (BRIS and left mine) and slightly acid. Chili can better grow at pH 5.5 to 6.8. The best output of this crop is obtained when it is grown on deep, loamy, fertile soil with appropriate moisture content. The soil is ploughed properly at the time of planting of the crop. It has a short duration period of 3 to 4 months (Manju and Sreelathakumary, 2002).

The watering and harvesting of this crop are of utmost importance for the proper growth of the crop. Regular and appropriate watering is required when the chili plant is at its sprouting stage. Harvesting of the green chili crop is done when the pods are green and matured. For the harvesting of red chili crop, the crop has to be harvested late when the green pods dry up and 80% of those become red.

2.4 Morphological Characters for Identification

The five domesticated species are differentiated by using morphological characters that rely primarily on colour and morphology of flowers and seeds, as shown in Table 3. However, identifying some plants in the diverse *C. annuum* complex can be problematic. Capsaicinoid profiles are not reliable as unique indicators for identification, though the profile may be useful as a supplementary character. In one

study (7-58 accessions per species), the accuracy of identification based solely on capsaicinoid profiles, in the *C. annuum* complex was 82% of the *C. chinense* accessions, 57% for *C. annuum* and just 20% for *C. frutescens* (but its sample was only 10 accessions); and similarly was 59% for *C. baccatum*, and 86% for the distinctive *C. pubescens* (OECD, 2006).

Cultivated *Capsicum annuum* var. *annuum* is very diverse regionally and worldwide, having a wealth of innumerable strains, landraces and varieties that defy both facile description and clustering into an inclusive and practicable classification. Sometimes typical characteristics (fruit shape, size, and pungency) have been featured and organized, recognizing the Cerasiforme Group (cherry peppers), Conoides Group (conical peppers), Longum Group (Cayenne peppers) and Grossum Group (blocky sweet or bell peppers), but as more plants are considered the array of variations and combinations of notable traits increases (fruit sizes and shapes can be intermediate, and fruits can be erect or pendent), and the groups become less distinct and meaningful (OECD, 2006).

Table 3: Morpholgical characters that generally differentiate the domesticated species of Capsicum

Species	Flowers per node	Calyx	Corolla colour	Corolla-lobe basal spots	Anther colour	Seed colour
C. annuum **var. *Annuum***	1 (-5)	no ring; often teeth	white to dingy white (rarely purple)	none	blue-purple	straw (tan)
C. frutescens	usually 2-4 (1-6)	no ring; usually no teeth	greenish white or greenish	none	blue-purple	straw (tan)
C. chinense	(1-) 2 (-5)	annular ring; no teeth	greenish white or white	none	Blue	straw (tan)
C. baccatum **var. *Pendulum***	1 (-2)	no ring; teeth	white (cream) or greenish-white	yellow-green	white to yellowish	straw (tan)
C. pubescens	1	no ring; teeth	purple or purple-white	none	purple (purple-white)	black (brown/ black)

**Source:* OECD 2006, *Consensus Document on the Biology of the Capsicum spp.*

2.4.1 Leaves

Eshbaugh (1993) described that leaves are simple, alternate, exstipulate, elliptic, lanceolate, and glabrous with unequal margin. Leaf area per plant varies from 1000 to 3000 cm2. Leaves are shed either due to foliar diseases especially due to powdery mildew infestation, moisture stress or due to senescence. According to Bosland and Votava (2000) chili plants infested by mites have long petiole and leaves curl downward. Thrips infested leaves have cup shaped appearance. Leaf thickness has bearing on pest tolerance especially thrips. Chili leaves contain nitrogen 3 to 5 per cent, phosphorus 0.5 to 0.6 per cent, potash 3 to 5 percent, calcium 0.9 to 1.3 per cent magnesium 1 to 1.5 percent on dry weight basis (OECD, 2006).

2.4.2 Branching

Chili plant is a highly branched herbaceous plant having height ranging from 50-100 cm, branching mainly depends on cultivar, soil fertility, soil moisture and season. High branching is preferred in chili for easy picking of fruits and for effective inter cultivation and to prevent rotting of fruits (Ikisan, 2000)

2.4.3 Flower

According to Ahmet (2000), *Capsicum annuum* starts flowering at the axil of the first branching node, with subsequent flowers forming at each additional node. Usually *C. annuum* has a solitary flower at the axil, although some accessions have a few clustered flowers between which there are short internodes (Table 3). Flower differentiation is not affected by daylength. The most important factor determining differentiation is air temperature, especially at night.The *Capsicum* flower is bisexual, hypogynous and usually pentamerous (OECD, 2006).

The flowers are complete, with calyx, corolla, and male and female sex organs. The diameter of a *C. annuum* flower is 9-15 mm. The *Capsicum* calyx is broadly campanulate, ribbed; about 2 mm long, and truncate or undulate to weakly or prominently dentate with 5-7 teeth. The short-tubed corolla is rotate in most *Capsicum* species, with usually 5 but sometimes 6-7 (-8) petals in some species. The number of corolla lobes and stamens is equal (OECD, 2006). Typically the flowers have 5 stamens; the filaments are white or violet depending on the species (or variety), with the usually connivent to free anthers are varying from bluish-purplish to yellow and white depending on the species (*e.g.* Table 3) (OECD, 2006).

The pistil comprises an ovary of 2-4 carpels that is 2-5 mm long and 1.5-5 mm in diameter, a style 3.5-6.5 mm long, and a capitate papillate stigma slightly wider than

the style. The style extends well beyond to just beyond the anthers or may be even with them, or it may be slightly exceeded by the anthers (Armstrong, 1997).

2.4.4 Fruit

According to Bosland and Votava (2000) there are five basic forms of fruits, each form having various varieties. These forms are:

i. Cerasiforme. These have small cherry-shaped pungent fruits.

ii. Conioides. These fruits are cone-shaped and up to 5cm long. Many of them are grown as ornamentals, but some are also cultivated for food..

iii. Fasciculatum. Also cone-shaped, but with pungent red fruits up to 7.5cm long.

iv. Grossum. These are the sweet peppers with large bell-shaped fruits and thick flesh.

v. Longum. These are the cultivated hot cayenne and chilli peppers with long thin fruits up to 30cm long.

There is extensive diversity in fruit shape, size, wall thickness and fleshiness, colour and pungency, determined by genetic and environmental factors. Among the innumerable varieties of *C. annuum*, the diversification of shapes of the pod (fruit) is striking — *e.g.* blocky (or lantern- or bell-shaped), globose, oblong (sausage-shaped), ovoid, conical, cylindrical, banana-like (curved); and smooth, grooved, lumpy or

wrinkled. The length of the pod varies from less than 1 to 32.5 cm. The pedicel length also varies in different pod types (over several cm), and the fruit may be erect to pendent (deflexed). Fruit colours range from green, yellow, orange and red to purple, brown, black, and white as well. Some of the genetics of fruit colour and shape are becoming well understood (OECD, 2006).

Morphologically the *Capsicum* fruit is a berry, sometimes with a few stone cells (sclerified inclusions in the fleshy portion). The pericarp consists of epidermal cells in regular order with a thick-grooved cuticle. Several rows of collenchymatously thickened beaded cells constitute the hypodermis. The mesocarp is formed by thick-walled beaded cells; the inner mesophyll cells are thin-walled ground parenchyma and fibrovascular bundles. Giant cells (perhaps unique to *Capsicum*) occur on the inner wall of the endocarp.

The vascular bundles consist of xylem tissue with spiral vessels and phloem tissue. The pod has two, three or four locules, with each corresponding wall of the axile placenta having vesicles for production of capsaicinoids. Usually there are many more flowers than fruits. The most obvious sign of assimilate competition or dominance among the organs is abscission of flowers and small fruits during the most active fruit-growth period, resulting in a cycling of flowering and fruit set. The most actively growing organ of a chili pepper plant after flowering is the fruit. Fruit growth is dependent on ovule growth (whether fertilized).

The fruit is ordinarily seeded, but parthenocarpic forms exist. The seed set affects development and subsequent growth of the fruit; on average there is a direct linear relationship between the number of seeds per fruit and final fruit size, until saturation at perhaps over 200 seeds per fruit. The number of seeds per fruit ranged from 1 to 34 in wild northwestern Mexico populations of *C. annuum*. A low of 50-100 seeds per cultivated fruit (20-30% of maximum) is sufficient for maximal fruit set; blocky sweet pepper (bell pepper) may average 150-300 seeds per fruit (OECD, 2006).

The time from anthesis to a fully grown fruit varies considerably among different pod types (Bosland and Votava, 2000). Typically cultivated fruit reaches the mature green stage in 35-50 days after the flower is pollinated. This stage is horticulturally ripe for some uses, but still physiologically immature. Fruit maturity depends on the cultivar and the environmental conditions before and during maturation. The fruits are characterized as non-climacteric in ripening, apparently lacking the typical increase in CO_2 and ethylene production as they ripen (OECD, 2006).

The fruits of most *Capsicum* are pungent, because the placenta accumulates capsaicinoids (*e.g.* capsaicin), except in domesticated non-pungent (sweet) varieties which are mostly developed in *C. annuum* (Bosland and Votava, 2000). The pungency trait is controlled at a single locus on chromosome 2; when the pungency gene *Pun1* (also called *C*) is homozygous recessive (*i.e.* present as *pun1/pun1* or *cc*), the capacity

to make capsaicinoids is lost. In the pungent chili peppers, other genes variously affect the synthesis of capsaicinoids, and production is also affected by physiological interactions and the environment. The individual fruit's pungency (content of capsaicinoids) is affected by its node position on the plant, whereas its capsaicinoid profile remains fairly constant. Capsaicinoids increase with fruit growth to a maximum (*e.g.* 40-50 days after fruit set), then decline. Capsaicinoids can be transported within the plant, with different capsaicinoid profiles found in stems and leaves (OECD, 2006).

The red fruits of wild *C. annuum* var. *glabriusculum* attract birds, which eat them and disperse viable seeds, but their pungency discourages consumption by wild mammals. Rats experimentally fed hot chili peppers for 2-11 months became desensitized to aversion, but indifferent rather than developing a preference for this spicy food. Nonetheless, the widespread and common little yellow-shouldered bat (*Sturnira lilium*), which sometimes favours solanaceous fruits, has been reported to consume pungent *Capsicum* in northwestern Argentina and disperse the seeds — which is favoured by local people who recognize this increases the number of wild plants, as they gather the fruits for home seasoning and village marketing (OECD, 2006).

2.4.5 Seeds

The seed develops from a campylotropous ovule. Within a pod, the many seeds are attached to the placenta walls in close rows, mainly near the calyx end. The seeds are

disk-like with a deep chalazal depression. The embryo is surrounded by a well-defined endosperm which makes up the bulk of food reserves for the embryo and young seedling. The endosperm lies directly in front of the radicle and consists of seven to nine thick cells. *Capsicum annuum* seeds have mainly protein and lipids as storage reserves. The seed is covered by a parchment-like seed coat, which does not cause a mechanical restriction to germination. Seed colour inheritance involves at minimum about three genes. Seed size is somewhat dependent on the variety and growing conditions. Seed mass maturity may occur about 50 days after anthesis, with 10-12 more days required for maximum potential longevity but 17-21 days for maximal seedling dry weight (based on variation in time from sowing to emergence). An average *C. annuum* seed is about 5.3 mm long, 4.3 mm wide and 1 mm thick, with a surface area of 33 mm^2 (OECD, 2006).

Freshly harvested seeds of certain wild *Capsicum* species can exhibit dormancy. An after-ripening period at room temperature may be required to remove dormancy. As *C. annuum* seeds age and lose viability they may become brown. Seeds of cultivated *C. annuum* can be cry preserved at –196°C and moisture content of 4.7-11.5%, and subjected to rapid or slow freezing and thawing. *Capsicum* species seeds germinate well in a constant temperature range between 15°C and 30°C, and do not germinate when exposed to temperatures below 8°C or above 40°C. No special light requirements are necessary for germination of domesticated chili pepper seeds, whereas

seeds of wild *C. annuum* var. *glabriusculum* do not germinate in constant darkness (OECD, 2006).

2.4.6 Root

Root system of chili plant is restricted to upper soil layer of 30 cm depth. Application of organic manures and fertilizers enhances root activity. Root system of chili crop is highly branched with a tap root at centre. Root system resembles that of grasses. Chili plants withstand drought better than excess soil moisture. It is observed that chili crop is more drought hardy than sorghum. Moreover, chili crop picks up its growth after receipt of rains. Water stagnation or saturated condition of soil for more than 24 hours is highly detrimental to the chili crop at any stage of its growth (Ikisan, 2000).

2.5 Sexual Reproduction

Capsicum species are usually self-compatible, and *C. annuum* is a partially self-pollinating crop, wind or similar mechanical disturbance may enhance self-pollination. Out crossing is associated with insect pollinators, less with wind. The proportion of plants cross-pollinated depends on several factors and can range from 2 to 90%; in many localities, cross-pollination is predominant. In field research *Capsicum* should be considered facultative cross-pollinating species. Breeders and seed producers thus need

to undertake precautionary measures to prevent uncontrolled cross-pollination (Bosland, 1996).

2.6 Asexual Reproduction

The chili pepper plant can be propagated asexually by means of cuttings and grafting. Young cut shoots form whole independent plants with roots *in vitro* as well as in the field. Scions from chili pepper plants graft successfully on stocks of chili pepper as well as tomato. The grafted plants can set flowers and fruits. *Capsicum* grafting can induce genetic changes, which may provide variations of breeding value.

2.7 Pungency

Chili pungency due to Capsaicin substance inside the veins of chili which is the most pungent of the group of compounds called capsaicinoids that can be isolated from Chili. It is sparingly soluble in water, but very soluble in fats, oils and alcohol.

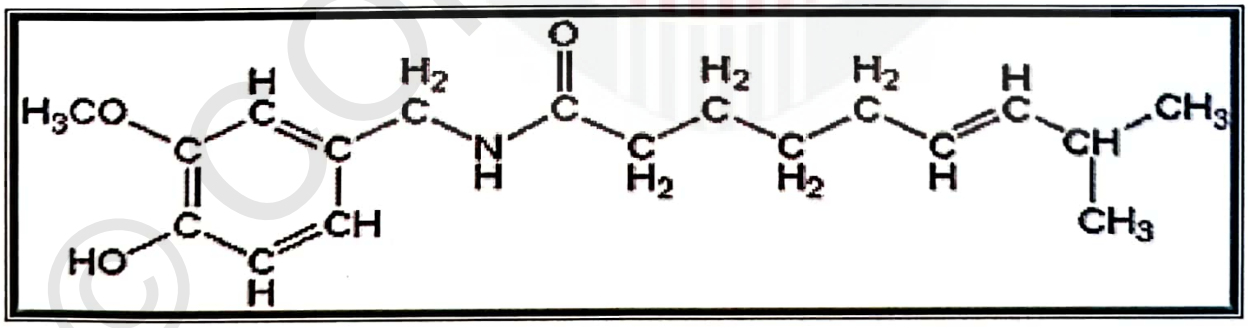


Figure 2: Molecular structure of capsaicin (8-methyl-N-vanillyl-6-nonenamide)

Chili pungency levels are the results of two factors, the plant's genetics and the environment in which it grows. Although plant breeders can produce a chili with a certain amount of relative heat, genetic control is not yet fully understood (George and Robert, 2006).

Methods to Determine Pungency

The most common way to test chili pungency is to taste the pod, this method, although quick and cost effective, may leave the tester in some pain. There are two other ways of testing pungency as well, the Scoville organoleptic test and high performance liquid chromatography.

Scoville Organoleptic Test (SHU)

The Scoville test is a refined, systematic approach. It was the first laboratory approach used to measure pungency in chilies. In this method, human subjects taste a chili sample and record the heat level. The samples are diluted in the laboratory until heat can no longer be detected by the tasters. This dilution is called the Scoville Heat Unit. This procedure can be appropriate in many circumstances, as it is more accurate than the taste test ("bite the chili") technique. This test is also less expensive than more advanced laboratory techniques, but this method has limitations. Measuring pungency with this technique is still subjective and depends on the taster's palate and sensitivity to

the chemicals that are responsible for pungency. In addition, there are serious limits on how many samples a taster can handle within a reasonable time.

High-Performance Liquid Chromatography (HPLC)

The most accurate method for measuring pungency in chilies is a High performance liquid chromatography (HPLC). In this procedure, chili pods are dried, and then ground. Next, the chemicals responsible for the pungency are extracted, and the extract is injected into the HPLC device for analysis. This method is more costly than the Scoville test or the Taste test but much more accurate. This method measures the total heat present as well as the individual capsaicinoids present (Oksana, 2005)

CHAPTER 3

MATERIAL AND METHOD

3.1 Study Location

This study was conducted under rain shelter netting structure at the Horticulture and Production Unit at Universiti Putra Malaysia, Bintulu Campus.

3.2 Growing Media

Chili plants were raised in white polybags of size 17" high by 14" wide using coco pith as planting medium (Figure 3 and 4)

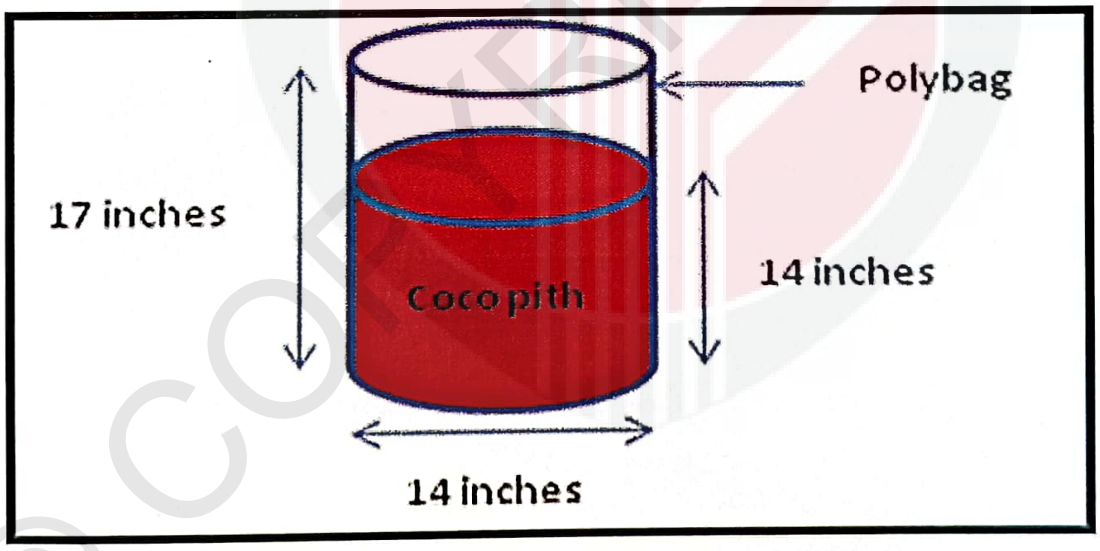


Figure 3: The size of polybag filled with coco pith

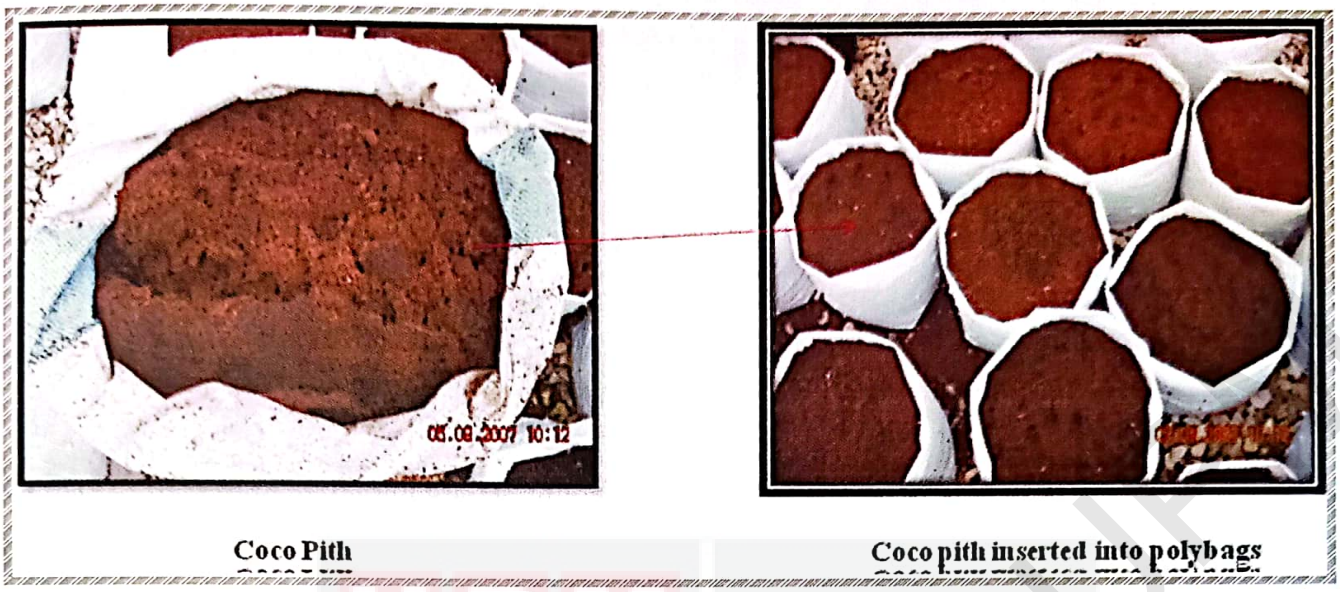


Figure 4: Coco pith as growing media

3.3 Site Preparation

The rain shelter netting structure was equipped with fertigation system, nutrient solution tank with complete delivery lines including control valves system for fertigation (Figure 5). The choice of using the rain shelter structure was to facilitate management and prevent direct impact of rain and other extreme environmental condition. Before setting the experiment, the site was cleared of all vegetation and undesirable debris. Fertigation was installed and all polybags filled with coco pith.

Figure 5: Site preparation

3.4 Treatment

The treatments for this study were four different local chili cultivars locally known as Gerunung Merah, Gerunung Kuning, Cili Besar and Cili Putih selected from among those found in Bintulu market (Figure 6). The selection was mainly based on the differences of their morphology. Seeds were removed and dried under sunlight for

three days from each of these selected cultivars for production of seedlings for this study.

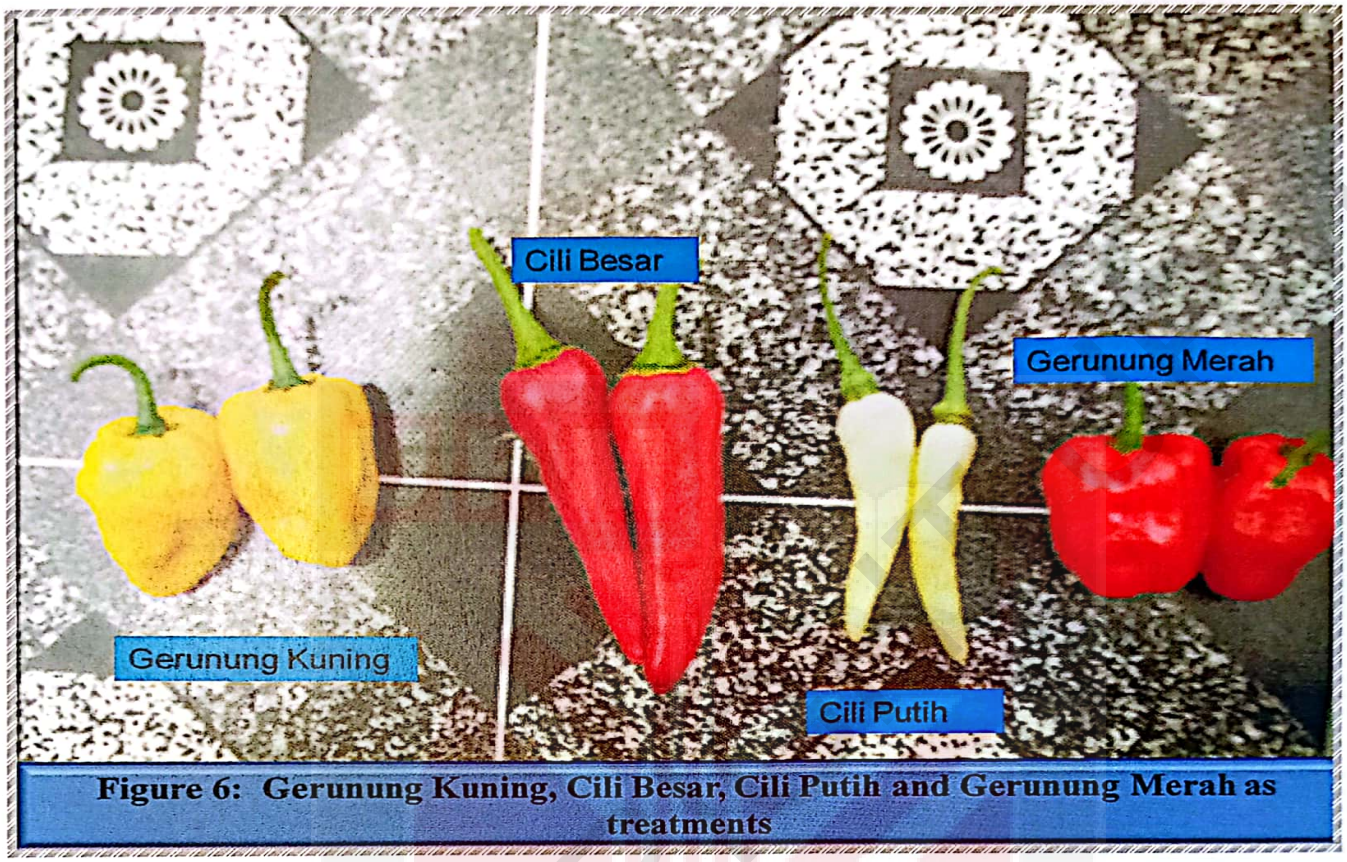


Figure 6: Gerunung Kuning, Cili Besar, Cili Putih and Gerunung Merah as treatments

3.5 Treatment Arrangement

Each of the four treatments was replicated three times with one replication containing 30 experimental units giving a total 360 experimental units overall. Each replication was arranged in two rows at 15 polybags per row with one foot spacing in between polybags and kept under rain shelter structure (Figure 7). Drip irrigation system was placed in between the rows of each replication to supply NPK nutrient solution from the tank for those crops. A space of two feet in between replication was provided to

facilitate movement and work activities. This spacing was also considered appropriate in providing sufficient space to accommodate fully grown chili plants. Figure 7 shows the arrangement of a replication representing the 30 experimental units.

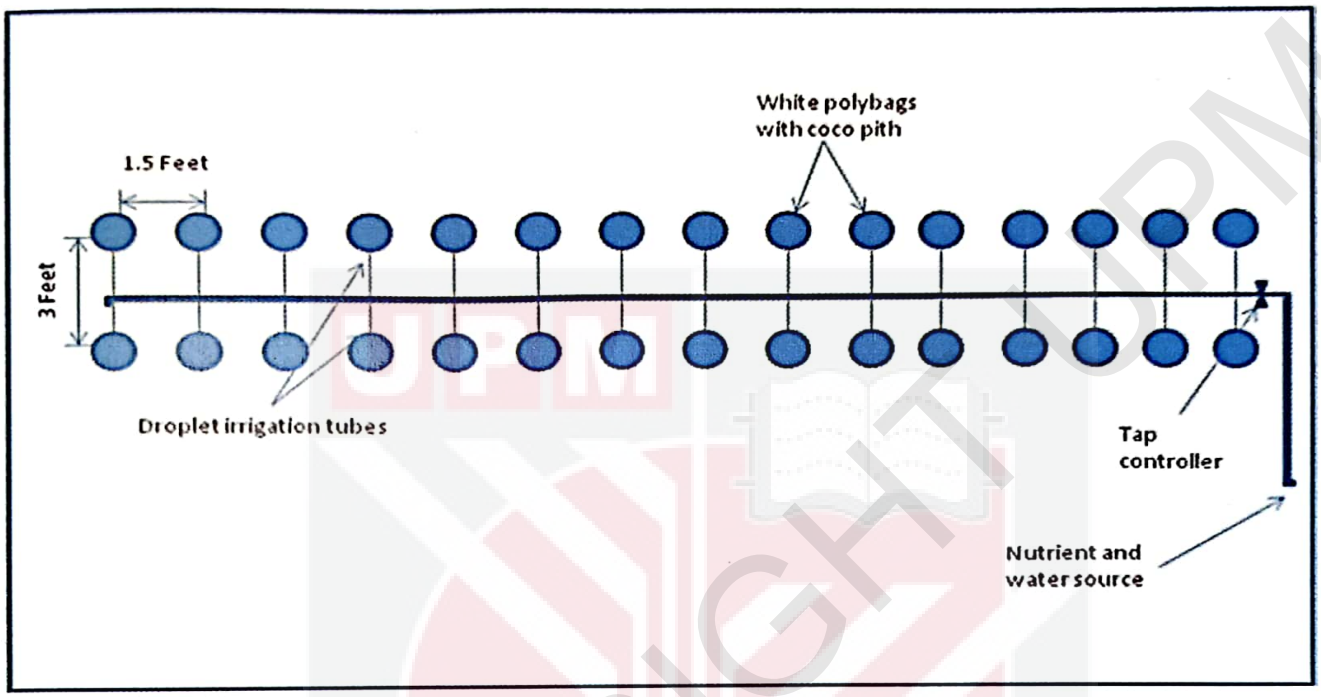


Figure 7: Treatment arrangement in a replication

3.6 Experimental Design

The entire experiment was conducted under rain shelter netting structure using Completely Randomized Design (CRD). All experimental units were laid at random. Plants were managed using the fertigation system inside the rain shelter netting structure (Figure 8).

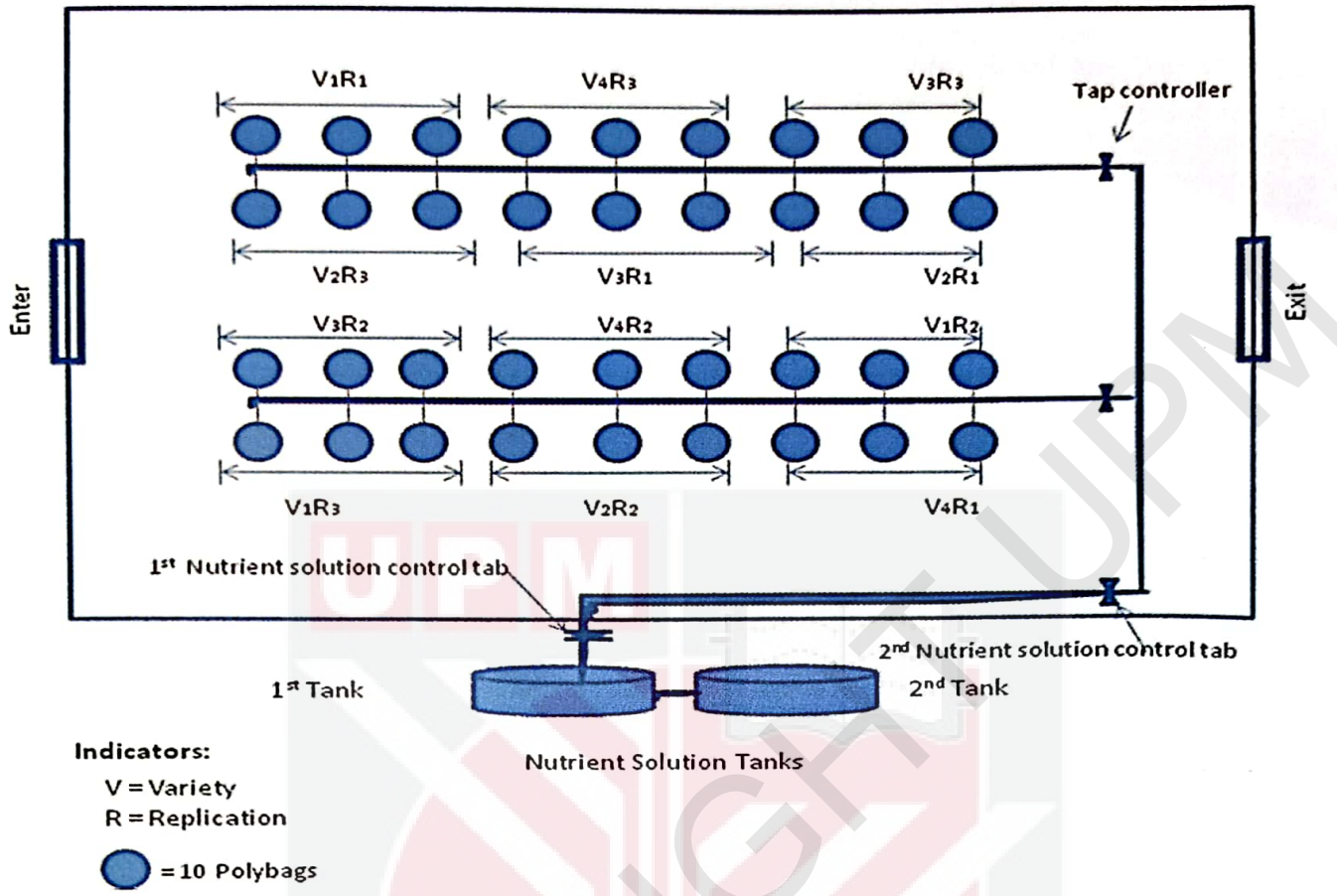


Figure 8: Treatments arrangement in CRD inside rain shelter

3.7 Germination of Chilli Seeds

The seeds of each variety were extracted out from fully riped fruits and dried under sunlight for three days before germination. After 3 days, seeds were treated with benlate to prevent attack of fungi and then sown into Jiffy pellets placed in germination trays with different germination trays for each cultivar. Before sowing the seeds, all Jiffy pellets were soaked in water for 20 minutes to obtain full expansion. Trays were used

for holding the Jiffy pellets (Figure 9) sown with the seeds and kept under rain shelter structure and watered twice daily, morning around 7.00 am to 10.00 am and evening around 4.00 pm to 6.00 pm.

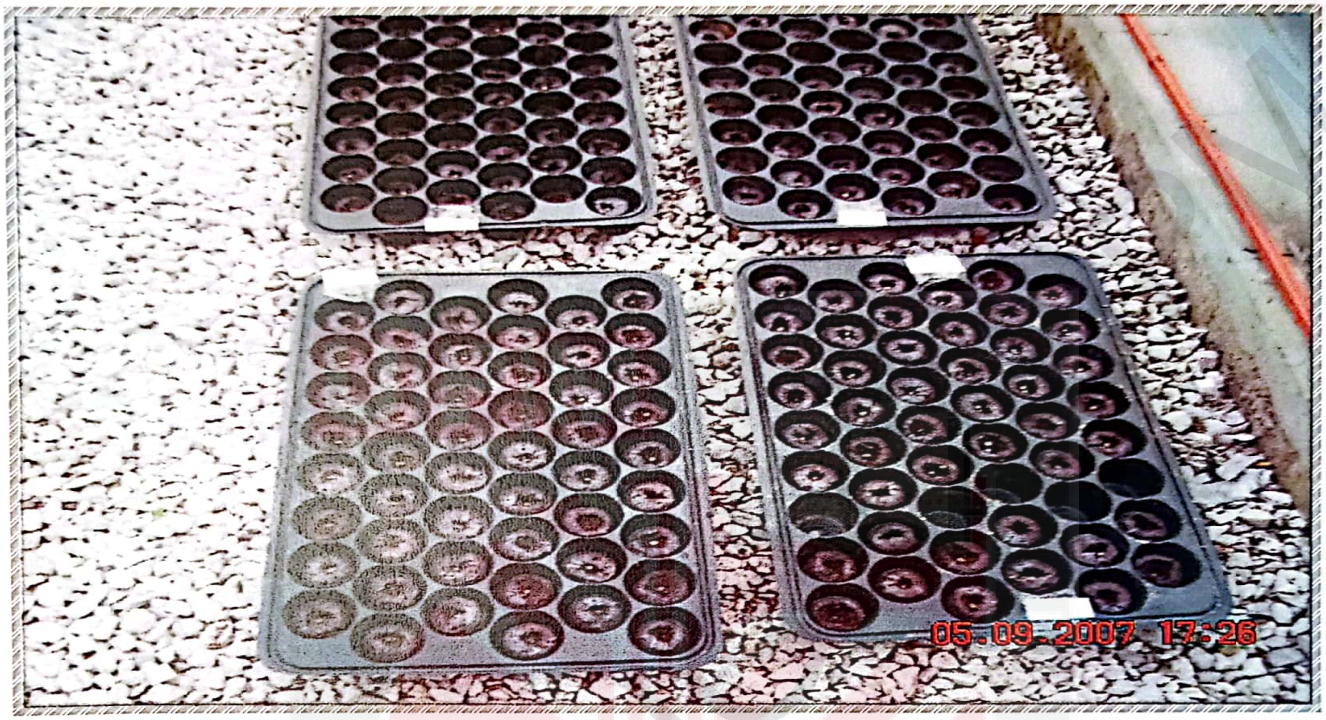


Figure 9: Chili seeds germination using Jiffy pellets inside germination tray

3.8 Transplanting of Chili Seedlings

The chili seedlings were transplanted into growing media after attaining 20 days of growth. Transplanting was done together with the Jiffy pellets containing the seedling into the white plastic polybags containing coco pith medium (Figure 10). Each variety and replication was properly labelled to facilitate experimental management and data collection. Adequate nutrient NPK solutions were supplied immediately after the

transplanting process. The progress of growth performance of the chilli plants was observed and recorded on regular daily basis.

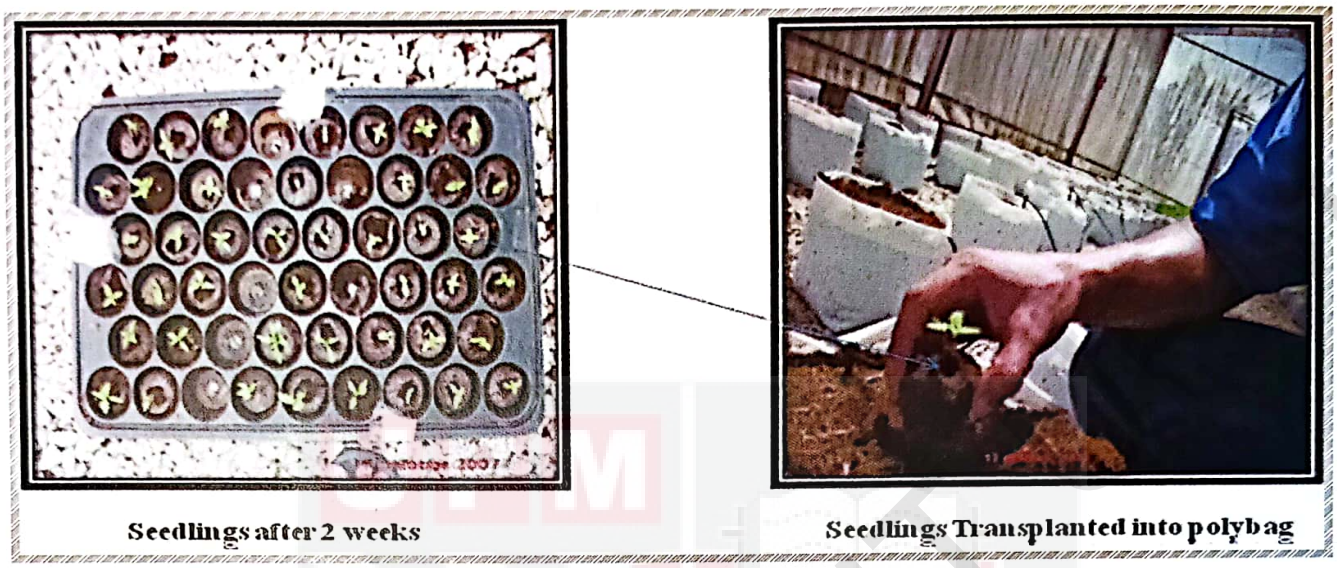


Figure 10: Transplanting of chili seedlings into polybags

3.9 Crop Management and Maintenance

3.9.1 Nutrient and Water Supplement

The fertigation system enables nutrient solution and water to be supplied simultaneously which was done twice daily around 8.00 am in the morning and 5.00 pm in the evening. Each session of supplement application was scheduled from 15 to 20 minutes.

3.9.2 Weeding

Weeding was done manually by pulling out the weeds surround the growing media and also inside the rain shelter. This was only done whenever necessary. No Chemical herbicide was applied.

3.10 Data Collection

Morphological characters of these four varieties were investigated, and they were used for numerical taxonomic analysis including qualitative and quantitative characters. All values of represent the average from 15 samples for each replication. Digital Calliper, Ruler, Leaf Area Meter and Plant Canopy Analyzer were used for measuring the various characters required by this study. Data collection was done during the appearance of the characters under study in according to the techniques of Yamamoto and Eiji (2004) and OECD, (2006). Detail description of these follows.

3.10.1 Plant Morphology

The purpose was to identify the plant architecture which has importance in garnishing and ornamental value and also for estimating the yield potential.

Table 4: Data collection method for plant morphology

Character	Measurement method
Shape	Compare with conned, rectangular (T or Y shaped) form
Stem diameter	Measure 5 cm from the ground
Height	Measure as distance between the ground and end of the canopy
Branch characteristic	Total of the 1st , 2nd and 3rd branch
Branch angle	Measure with clinometers tool
Canopy length	Measure from tip to tip of canopy height
Canopy diameter	Measure as width of the canopy

Note: Measurement is done simultaneously after the entire trees produced yield.

3.10.2 Leaf Morphology

The purpose was to identify the ornamental value, flowering habits, yield potential and effectiveness in term of photosynthesis.

Table 5: Data collection method for leaf morphology

Character	**Measurement method**
Shape/type	Comparison with simple, alternate, exstipulate, elliptic, lanceolate, or glabrous form
Venation	Compare with parallel or net venation
Colour	Compare with fair greenish, dark greenish or yellow greenish
Texture	Compare with smooth, waverous or globulrous texture
Length of petiole	Measure as distance from the branch it attached, to the leaf stalk
Length of leaf	Measure as distance from the end of the stalk to the end of the leaf
Diameter of petiole	Measure as petiole width
Width of leaf	The wider part of the leaf
Area (cm^2)	Use simple grid technique

Note: measurement is done simultaneously on fully expanded leaf.

3.10.3 Fruit Morphology

The purpose was to evaluate the fruit characteristics relating to commercial properties and garnishing potential.

Table 6: Data collection method for fruit morphology

Character	Measurement method
Shape	Compare with cerasiforme, conioides, fasciculatum, grossum or longum of most of the chilli form
Type	Compare with pepo, pome, and drupe or berry that relevant to chilli form.
length	Measure with distance tip to tip of fruit
Width/diameter	Measure with the longest width of the fruit
Colour before ripening	Own observation: dark green, fair green, purple or white as most of the chilli species
Colour after ripening	Own observation: dark red, fair red, purple or yellow as most of the chilli species
Thick of pericarp	Using calliper after fruit is splitted
Seed type	Compare with linear, miniature, rudimentary or peripheral embryo as most of the solanaceae family
Total seed per fruit	Manually counted and mean from 20 fruit per variety

Note: Measurement is done simultaneously as the fruit begins to ripen.

3.10.4 Flower Morphology

The purpose was to identify the production/yield potential and ornamental values.

Table 7: Data collection method for flower morphology

Character	Measurement method
Colour	Compare with white, purple, red or blue colour
Shape/Type	Compare with solitary, auxiliary, pairs, actinomorphic, pedicellate, bisexual or hypogynious type
Petal total	Compare with *C. annum* and *C. frutescens* that usually 4-6 petals
Sepal total	Compare with *C. annum* and *C. frutescens* that usually 5 sepal
Length of pedicel	Measure as distance between receptacle and tip of the flower stalk
Diameter of pedicel	Measure as width of pedicel
Length of receptacle	Measure as distance between pedicel tip and start of the sepal
Diameter of receptacle	Measure as width of receptacle
Filament colour	Compare with green, light purple, or purple colour of *C. annum* and *C. frutescens*
Anther colour	Compare with blue, yellowish-blue or blue of *C. annum*
Stigma character	Compare with subcapitate or faintly bifid *C. annum* and *C. frutescens*
Style character	Compare with slender, terminal or linear of *C. frutescens*
Calyx shape	Compare with *C. annum* and *C. frutescens* that usually capanulate
Corolla shape	Compare with *C. annum* and *C. frutescens* that rotate 5 to 6 lobed twisted in bud
Corolla total	Compare with *C. annum* and *C. frutescens* that usually bell shaped
Ovary	Compare with *C. annum* and *C. frutescens* that superior 2 or 4 celled with numerous ovules in each locule on swollen axile placentation

Note: Measurement is done simultaneously on fully expanded flower.

3.10.5 Total Yield

The purpose is to determine the conversion rate (%) from fresh weight to dry weight which is an important commercial characteristic. Method of measurement is indicated in Table 8.

Table 8: Data collection method for total yield

Character	Measurement method
Fresh weight	Mean of 1 kg fresh fruit from each replication
Dry weight	Weight from 1 kg fresh weight and above after drying in oven for 24 hours at 90°C.

3.10.6 Production Period

The purpose was to determine the period of production for each cultivar.

i. Time period from sowing to fruiting

ii. Time period from transplanting to flowering

ii. Time period from sowing to harvesting

iv. Ripening time period after fruiting

v. Ripening character: simultaneously or not.

CHAPTER 4

RESULT

4.1 Plant Morphology

HSD Test shows that Gerunung Merah and Gerunung Kuning cultivars showed similar plant height, canopy height, stem diameter and first branch angle characters (Table 9). However there were differences in canopy diameter among these cultivars. Meanwhile, both of the Cili Putih and Cili Besar exhibited differences for all characters. This was evident where Cili Putih had the highest means for tree height and canopy height measurements, followed by Gerunung Merah, Gerunung Kuning and Cili Putih being the shortest plant of all the cultivars. Gerunung Merah had the widest canopy diameter followed by Cili Putih, Gerunung Kuning and Cili Besar. Only Cili Putih and Cili Besar showed significant differences for stem diameter size (Figure 11).

Table 9 shows that Cili Putih, Gerunung Merah and Gerunung Kuning showed similarity for total number of main branch but different compared with Cili Putih. Gerunung Merah and Gerunung Kuning showed similar first branch angle but both of them differed from Cili Putih and Cili Besar. Cili Putih however showed to be highly branched cultivar followed by Gerunung Merah, Gerunung Kuning and the least branched being Cili Besar. Gerunung Kuning and Gerunung Merah had the largest first branch angle, followed by Cili Putih and Cili Besar.

Table 9: Plant morphology comparison by Tukey's Studentized Range (HSD) Test

Plant Character	Cili Putih	Gerunung Merah	Gerunung Kuning	Cili Besar
Plant Height (cm)	58.7727 a*	50.2400 b	48.2260 b	33.0980 c
Canopy Height (cm)	49.6880 a	44.8307 b	43.7940 b	30.3940 c
Canopy Diameter (cm)	34.4953 bc	39.9480 a	36.7113 b	32.4853 c
Stem Diameter (cm)	1.34800 a	1.16800 ab	1.13667 ab	1.20067 b
Main branch Total	8.33330 a	7.06670 ab	6.53330 b	3.73330 c
First branch Angle (°)	44.4670 a	48.8000 b	48.8000 b	39.0670 c

* Means with different alphabets within a row indicate significant difference between plant characters at $P \geq 0.05$

Figure 11: Chili plant canopy variation among cultivars

4.2 Leaf Morphology

HSD Test shows that Gerunung Merah and Gerunung Kuning exhibited similarity for petiole length character but both of them showed significantly different for petiole diameter, leaf length and leaf diameter (Table 10). Gerunung Merah had the longest

petiole length, leaf length and the widest leaf diameter followed by Gerunung Kuning, Cili Putih and Cili Besar (Figure 12).

Table 10 shows that all cultivars exhibited significant different for leaf area character as indicated by the different in leaf length and leaf width of each cultivar. The largest leaf was exhibited by Gerunung Merah followed by Gerunung Kuning, Cili Putih and Cili Besar. Cili Putih had the most total number of leaf followed by Gerunung Kuning, Gerunung Merah and then Cili Besar.

Table 10: Leaf morphology comparison by Tukey's Studentized Range (HSD) Test

Leaf Character	Cili Putih	Gerunung Merah	Gerunung Kuning	Cili Besar
Petiole Length (cm)	3.9520 **a***	4.9867 **b**	4.8687 **b**	6.5667 **c**
Petiole Diameter (cm)	0.38533 **a**	0.54867 **b**	0.63000 **c**	0.39667 **a**
Leaf Length (cm)	17.0287 **a**	23.5887 **b**	22.0293 **c**	13.8167 **d**
Leaf Diameter (cm)	10.7940 **a**	13.8787 **b**	12.8380 **c**	7.2720 **d**
Leaf Area (cm^2)	75.674 **a**	104.087 **b**	94.375 **c**	55.628 **d**
Leaf Total	389.467 **a**	199.867 **b**	212.867 **b**	157.333 **c**

* Means with different alphabets within a row indicate significant difference between leaf characters at $P \geq 0.05$

Figure 12: Leaf morphology variation among chili cultivars

As shown on Table 11, qualitative analysis on chili leaf morphology exhibits that there were no difference between Gerunung Merah and Gerunung Kuning for shape, venation, texture, leaf arrangement and leaf margin. Only the leaf colour showed slight difference among them. All cultivars showed alternate leaf arrangement. Cili Putih and Cili Besar however showed differences for shape, venation, colour and margin of leaf but similar in leaf texture and leaf arrangement.

Table 11: Qualitative analysis on chili leaf morphology

Leaf character	Cili Putih	Gerunung Merah	Gerunung Kuning	Cili Besar
Shape/form	Aristate	Elliptic	Elliptic	Lanceolate
Venation	Cross-venulate	Reticulate	Reticulate	Reticulate
Color	Fair green	Green darkish	Fair green	Green darkish
Texture	Smooth	Crinkled	Crinkled	Smooth
Leaf arrangement	Alternate	Alternate	Alternate	Alternate
Margin	Ciliate	Crenate	Crenate	Entire

4.3 Flower Morphology

Gerunung Merah and Gerunung Kuning exhibited similar pedicel length, petal length, petal diameter, sepal length and sepal diameter of flower both of which differ from Cili Besar and Cili Putih. All cultivars showed significant different for pedicel diameter, receptacle length and receptacle diameter (Table 12).

Cili Besar had the largest measurement for every character evaluated except the pedicel length by being the shortest among the cultivars. Gerunung Merah, Gerunung Kuning and Cili Putih did not show significant difference for the characters evaluated.

Table 12: Flower morphology comparison by Tukey's Studentized Range (HSD) Test

Flower Character	Cili Putih	Gerunung Merah	Gerunung Kuning	Cili Besar
Pedicel Length (cm)	2.20267 **a***	2.08133 **b**	2.09000 **ab**	1.37267 **c**
Pedicel Diameter (cm)	0.118000 **a**	0.232667 **b**	0.131333 **a**	0.163333 **c**
Receptacle Length (cm)	0.406000 **a**	0.297333 **b**	0.206000 **c**	0.489333 **d**
Receptacle Diameter (cm)	0.300667 **a**	0.205333 **b**	0.239333 **c**	0.410667 **d**
Petal Length (cm)	0.66133 **a**	0.75800 **b**	0.78333 **b**	0.95200 **c**
Petal Diameter (cm)	0.39467 **a**	0.44400 **b**	0.45600 **b**	0.56600 **c**
Sepal Length (cm)	0.269333 **a**	0.246000 **b**	0.246000 **b**	0.294000 **c**
Sepal Diameter (cm)	0.137333 **a**	0.114000 **b**	0.116000 **b**	0.188667 **c**

* Means with different alphabets within a row indicate significant difference between flower characters at $P \geq 0.05$

As shown on Table 13, all chilli cultivars exhibits similar flower shape, type, sepal colour, stigma colour, corolla shape, and calyx shape morphology. Only the flowers of Gerunung Kuning and Gerunung Merah had five to six petals per flower while the flowers of the other cultivars had five petals per flower. Gerunung Merah and Gerunung Kuning exhibit white-greenish petal colour while Cili Putih and Cili Besar showed white-darkish and pure-white petal color, respectively. Gerunung Merah and Gerunung Kuning both had yellow filament colour which differed from Cili Putih and Cili Besar which showed light-purplish and white-darkish filament color, respectively. Anther colour for Gerunung Kuning, Gerunung Merah and Cili Putih was yellow-blue while Cili Besar had purple-color anther. Calyx teeth was absent from the flower of Cili Putih cultivar.

Stamen was longer than pistil for Gerunung Merah and Cili Besar, whereas Gerunung Kuning and Cili Putih had shorter stamen than pistil (Table 13). The total number of stamen for Gerunung Kuning was six but the other three cultivars only had five stamens. Flower length and diameter for Gerunung Merah, Gerunung Kuning and Cili Putih were similar ranging from 1.0-1.3 cm for length and 0.7-1.1 cm for diameter. However, Cili Besar had the largest flower with size ranging from 1.2-1.7 cm in length and 0.9-1.2 cm diameter.

Table 13: Qualitative analysis for chili flower morphology

Flower Character	Cili Putih	Gerunung Merah	Gerunung Kuning	Cili Besar
Shape	Actinomorphic	Actinomorphic	Actinomorphic	Actinomorphic
Type	Bisexual	Bisexual	Bisexual	Bisexual
Petal total	5	5-6	5-6	5
Petal color	White-darkish	White-greenish	White-greenish	pure white
Sepal total	5	5-6	5-6	5
Sepal color	Green	green	green	green
Filament color	Light purplish	yellow	yellow	Dark-white
Anther color	Yellowish-blue	Purple	Purplish blue	Yellow
Stamen and pistil character	Stamen shorter than pistil	Stamen taller than pistil	Stamen bigger but shorter than pistil	Stamen taller than pistil
Stigma color	yellow	yellow	yellow	yellow
Stamen total	5	5-6	5-6	5
Calyx shape	Capanulate	Capanulate	Capanulate	Capanulate
Calyx teeth	Absent	Present	Present	Present
Flower length	1.0-1.3 cm	1.0-1.3 cm	1.0-1.3 cm	1.2-1.7 cm
Flower diameter	0.8-1.1 cm	0.7-1.1 cm	0.8-1.1ccm	0.9-1.2 cm

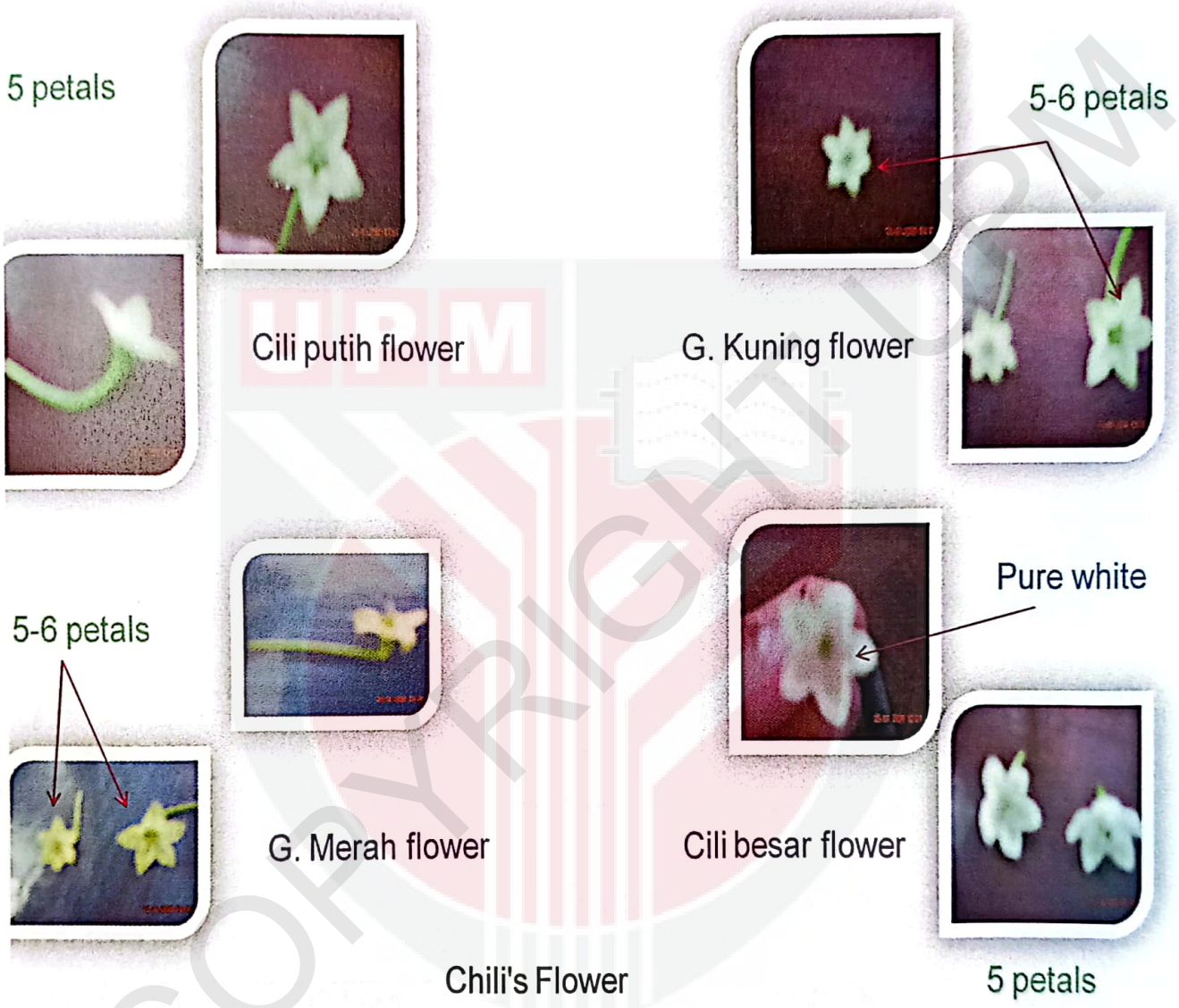


Figure 13: Chili flower morphology variation among cultivars

4.4 Fruit Morphology

No significant difference was shown between Gerunung Merah and Gerunung Kuning for fruit characters but both differed from Cili Putih and Cili Besar (Table 14). Cili Besar had longest fruit stalk length, fruit length, thickest fruit pericarp and had the most seed per fruit even though the fruits diameters are smaller compared to the fruits of Gerunung Merah and Gerunung Kuning. Cili Putih however had the shortest fruit stalk, fruit diameter, with the thinnest fruit pericarp and the least number of seed per fruit.

Table 14: Fruit morphology comparison by Tukey's Studentized Range (HSD) Test

Fruit Character	Cili Putih	Gerunung Merah	Gerunung Kuning	Cili Besar
Stalk Length (cm)	2.7800 **a***	3.1933 **b**	3.1400 **b**	3.6133 **c**
Fruit Length (cm)	4.7200 **a**	3.1000 **b**	3.1330 **b**	8.4930 **c**
Fruit diameter (cm)	1.3333 **a**	2.9266 **b**	2.9333 **b**	2.6800 **c**
Pericarp Thick (cm)	0.1526 **a**	0.2426 **b**	0.2440 **b**	0.3466 **c**
Seed Total	32.333 **a**	47.267 **b**	45.267 **b**	107.86 **c**

* Means with different alphabets within a row indicate significant difference between fruit characters at $P \geq 0.05$

In term of qualitative values, Gerunung Merah and Gerunung Kuning fruits were cerasiforme while Cili Putih and Cili Besar were conoides shape (Table 15). Gerunung Merah and Gerunung Kuning produced one to four fruit per node while Cili Putih and Cili Besar produced only one fruit per node. Fruit colour of Gerunung Merah and Cili Besar was green before ripening which changes to red on ripening. Gerunung Kuning fruits showed light green color before ripening which turns to red on ripening. Cili Putih cultivars produced white color fruits before ripening which turns to orange upon ripening (Figure 14). The fruits of Cili Putih were borne erect upward while the fruits of the other three cultivars were borne hanging downwards. Fruits of all cultivars exhibited straw (tan) seed color when fully ripe.

Table 15: Qualitative Analysis for Chili Fruit Morphology

Fruit Character	**Cili Putih**	**Gerunung Merah**	**Gerunung Kuning**	**Cili Besar**
Fruit shape	Conoides	Cerasiforme	Cerasiforme	Conoides
Fruit per node	1	1 to 4	1 to 4	1
Fruit color before ripening	White	Green	Fair green	Green
Fruit color After ripening	Orange	Red	Yellow	Red
Seed color	Straw (tan)	Straw (tan)	Straw (tan)	Straw (tan)
Fruit attachment on branch	Erect upward	Erect downward	Erect downward	Erect downward

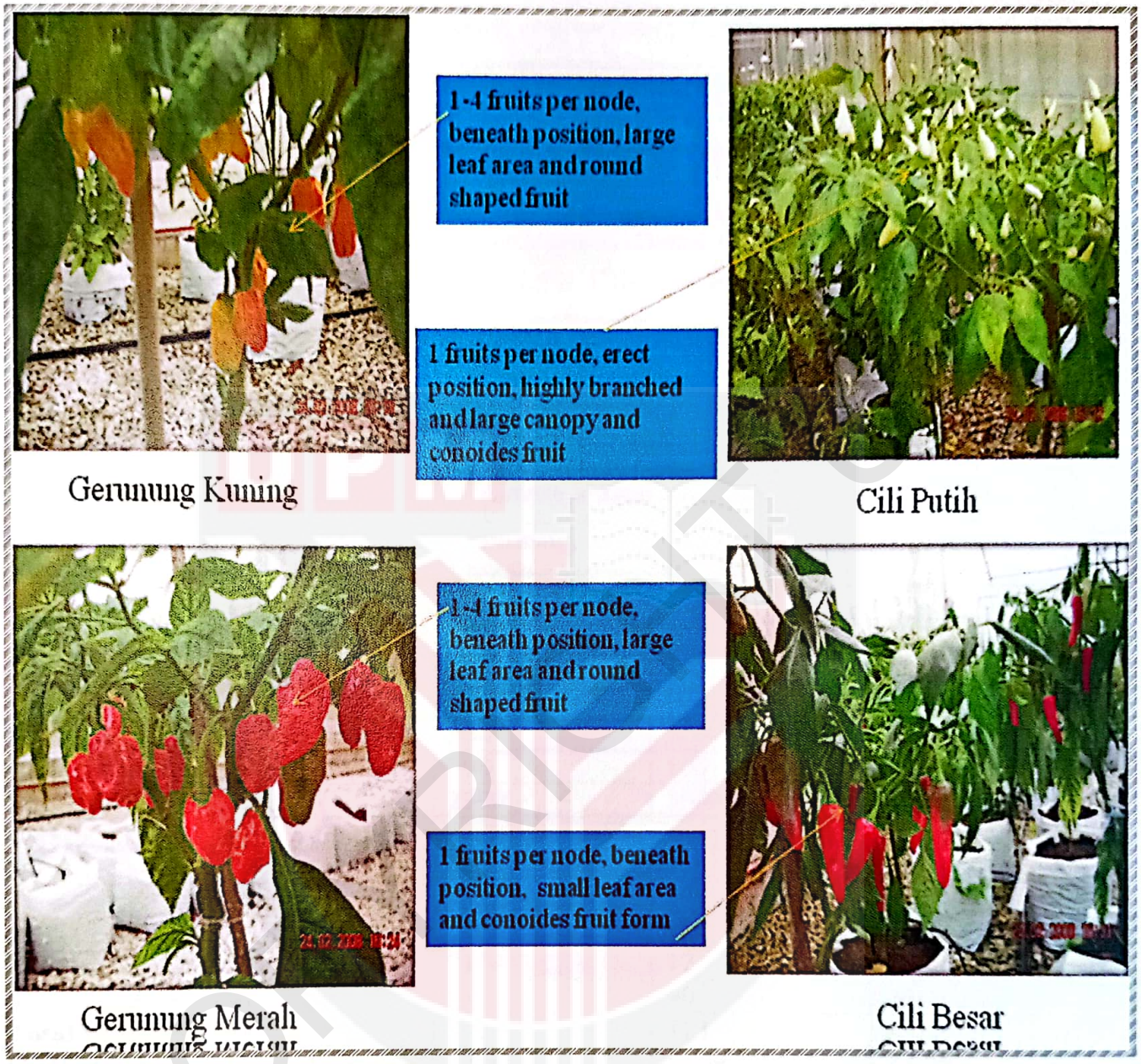


Figure 14: Fruits variations among the chili cultivars

4.5 Fresh and Dry Weight

Five samples 500 g fresh fruit from each cultivar were weighed. The fruits packed with aluminium foil and inserted into the oven with 90°C for 24 hours. After 24 hours all of the samples taken out and weighed again to take the dry weight reading. Table 16 below shows that Gerunung Kuning had the highest conversion rate which about 16.56% conversion from fresh to dry weight. This was followed by Gerunung Merah (14.48%), Cili Besar (14.08%) and then Cili Putih (11.48%).

Table 16: Analysis on fresh and dry weight of chili cultivars

n	Cili Putih	Gerunung Merah	Gerunung Kuning	Cili Besar
	Fresh Weight (g)			
1	500	500	500	500
2	500	500	500	500
3	500	500	500	500
4	500	500	500	500
5	500	500	500	500
Total	**2500**	**2500**	**2500**	**2500**
	Dry weight (g)			
1	73	82	81	81
2	51	68	101	69
3	63	70	65	65
4	53	91	77	63
5	47	51	90	74
Total	**287**	**362**	**414**	**352**
Conversion Rate (%)	**11.48**	**14.48**	**16.56**	**14.08**

Figure 15: Dried Chili after oven drying for 24 hrs at 90°C

4.6 Production Period

Table 17 below shows that there were some differences among the cultivars production period. Gerunung Merah and Cili Putih were flowering seven weeks after transplanted and then followed by appearance of first fruit bud two weeks later. However, fully expanded fruit for Gerunung Merah took about five weeks after appearance of first bud fruit which different from Cili Putih that took seven weeks. Gerunung Merah and Cili Putih can be harvested two weeks after fully expanded fruit at the 18^{th} week and 19^{th} weeks respectively when the fruit ripened.

Gerunung Kuning and Cili Besar were flowering six weeks after transplanted and then followed by appearance of first fruit bud two weeks later. The fully expanded fruit both of these cultivars achieved after five weeks from first bud. These cultivars fruits can be harvested about two weeks after fully expanded at 18^{th} week and 17^{th} week respectively.

Table 17: Production period of Chili's cultivars

Cultivar	Germination period	Flowering	First fruit bud	Fully expanded fruit	Fully ripened	Production period
Gerunung Merah	2 weeks and then transplanted	7 weeks after transplanted	2 weeks after flowering	5 weeks after first bud	2 weeks after fully expanded	18 weeks (4 months and 2 weeks)
Gerunung Kuning	2 weeks and then transplanted	6 weeks after transplanted	2 weeks after flowering	5 weeks after first bud	3 weeks after fully expanded	18 weeks (4 months 2 weeks)
Cili Putih	2 weeks and then transplanted	7 weeks after transplanted	2 weeks after flowering	6 weeks after first bud	2 weeks after fully expanded	19 weeks (4 months and 3 weeks)
Cili Besar	2 weeks and then transplanted	6 weeks after transplanted	2 weeks after flowering	5 weeks after first bud	2 weeks after fully expanded	17 weeks (4 months and 1 weeks)

CHAPTER 5

DISCUSSION

Morphological differences and similarity were observed among the cultivars studied as indicated in Table 18. Morphological characters of commercial and agronomic importance were also noted and details of these follows.

Table 18: Morphological character of the cultivars

Character	Mean Measurement			
	Gerunung Merah	Gerunung Kuning	Cili Putih	Cili Besar
Leaf area ($cm^{2)}$	104.087	94.375	75.674	55.628
Branch Total	7.0667	6.5333	8.3333	3.7333
Plant Height (cm)	50.2400	48.2260	58.7727	33.0980
Canopy Height (cm)	44.8307	43.794	49.6880	30.3940
Canopy Diameter (cm)	39.9480	36.7113	34.4953	32.4853
Fruit Length (cm)	3.1000	3.1330	4.7200	8.4930
Fruit Diameter (cm)	2.9266 cm	2.9333	1.3333	2.6800
Fruit Attachment on branch	Erect downward	Erect downward	Erect upward	Erect downward
Petal Total	5-6	5-6	5	5
Sepal Total	5-6	5-6	5	5
Anther Color	Purple	Purple	Yellowish-blue	Yellow
Total Fruit per node	1-4	1-4	1	1
Leaf Structure	Crinkled	Crinkled	Smooth	Smooth
Conversion Rate	14.48%	16.56%	11.48%	14.08%

5.1 Gerunung Merah

This plant had the largest leaf area reaching up to 105 cm^2 and significantly different from the other three other cultivars (Table 18). However this cultivar had fewer branches with intermediate height of 44.83 cm and canopy width of 33.95 cm. The size of its fruit by mean 3.100 lengths and 2.927 cm diameter visualizes that this The fruit was cerasiforme or round shape (Bosland and Votava, 2000) and coloured red when ripe which makes the fruit rather unique in nature.

The flowers had five or six petals and sepals borne on the same tree. The stamen bearing the purplish anther was longer than the pistil and producing one to two fruits per node which differentiates this cultivar from the other cultivars (Manju and Sreelathakumary, 2002). The elliptic leaf form with crinkled leaf structure and reticulate leaf venation makes this cultivar interesting (Dewitt, 1994). However the conversion rate from fresh fruit weight to dry weight was only 14.48% and this is below the 20% standard requirement for good dry chili market (MARDI, 2003). The pericarp thickness of the fruit was 0.24 cm which was an important factor that contributed to the low conversion rate. The production period of this cultivar took about 18 weeks from sowing to harvesting and this is rather long period to harvest. The red fruits appeared similar to the red habanero (*C. chinense*) fruits which is a commonly cultivated species in China and India.

5.2 Gerunung Kuning

The unique character of this cultivar was in having light yellowish fruit colour with strong pungent flavour. This unique colour of the fruit differentiates this cultivar from other chilli cultivars found in Malaysia. The plant of this cultivar had few branches producing leaves of up to 100 cm^2 size which is smaller than Gerunung Merah (Table 18). The elliptic leaf form with proper reticulation of venation and crinkled structure makes this cultivar unique (Sreelathakumary, 2002).

Each flower may have five to six petals and sepals borne on the same tree with pistil shorter than the stamen bearing the purplish anther. One to four strongly pungent fruits may be produced per node and this makes it distinctly different from the other cultivars (Dewitt, 1994). The yellow fruit colour with cerasiforme shape with fruit size of 3.13 cm long and 2.93 cm diameter together with its large leaf morphology makes this cultivar quite suitable for ornamental plant (Bosland and Votava, 2000). The conversion rate of fruit from fresh to dry weight was 16.56% which is higher than Gerunung Merah cultivar and closer to the 20% required for commercial dry chilli production. The production period to from sowing to harvest was 18 weeks similar to that of Gerunung Merah cultivar and considered to be too long.

5.3 Cili Putih

The plant of this cultivar was the tallest and the largest canopy among the four cultivars studied (Table 18). The plant had more branches and bearing dense leaves which is a good morphology for efficient photosynthesis process for high yield potential (Eiji Nawata, 2004). In general the floral size and colour resembled the commonly cultivated chilli cultivars.

The unique morphology associated with this cultivar was the colour of the fruits during the ripening process which changed from whitish to orange upon ripening and the fact that the fruits were borne erects upward which is in concurrence to that reported by Yamamoto and Eiji (2004). However, the fruits conversion rate from fresh weight to dry weight was very low at 11.48 %. The low conversion rate was due to the fact that the fruit produced fewer seed with mean of 32 seeds per fruit and the thin pericarp of the fruits which was 0.157 cm. This cultivar also had the longest production period, from sowing to harvesting, of 19 weeks as opposed to 18 weeks for the other cultivars.

5.4 Cili Besar

This cultivar had the smallest plant canopy size of all the four cultivars studied (Table 18). Although it had fewer branches, the branch arrangement was opposite of one another which is considered good plant architecture (Bosland, 1996). The lanceolate leaf with smooth surface makes it a potentially suitable ornamental plant. The conoides long fruit form with less pungent taste and thick pericarp of this cultivar, with out the seeds, makes it potentially suitable for use as fresh vegetable (Ikisan, 2000).

Another potential use of this cultivar is that the brilliant red colour ripe fruits produced high amount of seeds per fruit which makes it a good source for seed production. Also the pure white colour and large size flowers, ranging from 1.2-1.7 cm in length makes this cultivar potentially useful for use as ornamental plants (Bosland and Votava, 2000). The production period from sowing to harvest of 17 weeks is the shortest of the four cultivars studied. However, the plant produced fewer branches and leaf and this indicates low photosynthetic efficiency low yield potential. The fresh fruit to dry conversion rate was 14.08% indicating that this cultivar has a moderate potential for marketing in dry form.

5.5 Problem during Research Project Activities

The main problem was caused by the damaged plastic roofing of the netting structure (Figure 16) which exposed the plants to direct rain and also insects and birds. The long production period from sowing to harvest was mainly attributed to the heavy rainy season occurring at this time from November 2007 to January 2008. Many chilli seedlings became retarded in growth and even plant death as the consequence of the heavy raindrops that tended to flood the floor inside the netting structure (Figure 16).

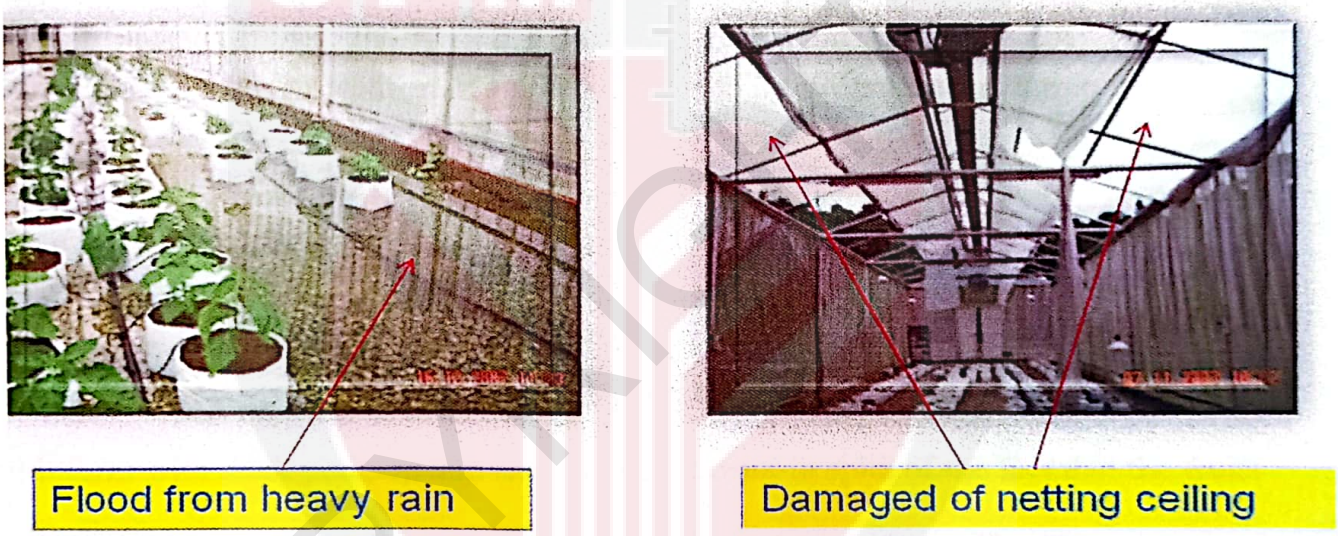


Figure 16: A note on some research constraints

The irregular supply of nutrient solution for the crop was another factor that affected the growth of the plants during the study. With properly constructed roofing and regular fertigation schedule, the production period of the chilli crops could be reduced to less than 15 weeks from sowing to harvesting.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

The Gerunung Kuning cultivar has most commercial potential of the four cultivars evaluated on the basis that it has the highest fresh to dry weight of fruit conversion rate at 16.56 %. This rate is reasonably close to the 20% rate recommended by MARDI for commercial dry chilli production. The cerasiforme yellow fruit colour with its strongly pungent flavour in addition to the large leaf area makes this cultivar also potentially suitable for ornamental use. The crinkled leaf surface structure and large leaf area together with the floral morphology in having five to six petals per flower with purplish anther in addition to the strongly pungent cerasiforme fruit form and the number of fruits produced at one to four fruits per node are common characteristics displayed by the *Capsicum chinense* group.

Cili Besar is most suitable for fresh consumption by nature of its long conoides fruit form with thick pericarp and less pungent flavour in spite of the fact that the fruits had the most seeds which need to be removed before cooking. The lanceolate leaf (pointed at both ends) with its smooth surface in addition to the large pure white flower and red brilliant fruit colour makes this cultivar a potential specimens for ornamental purpose. The fresh to dry fruits conversion rate at 14 % is considered moderate among the four cultivars. Most of the morphological characters displayed by the Cili Besar cultivar namely, the smooth leaf surface, longer stamens than the pistils, flowers

consistently having five petals and sepals, large conoides fruits and the present of calyx teeth are common characteristics of *Capsicum annum* group.

The special character of Gerunung Merah is its leaf area up to 105 cm^2 which is the largest of all the four cultivars, the red cerasiforme fruit with elliptic leaf form and regular reticulate venation are desirable morphological characteristics for ornamental plants. This cultivar has moderate production period of 18 weeks and fruit conversion rate at 14% of fresh to dry fruit weight. The large leaf with crinkled surface structure and flowers having five to six petals per flower bearing purplish anther that produced one to four cerasiforme fruits per node characterized this cultivar akin to *Capsicum chinense* group.

The unique characteristic of Cili Putih is the fruit colour that changes from white to orange upon ripening. The plant is densely branched with large and bushy canopy which can be an attractive plant specimen for ornamental use. This cultivar produced the most fruits per plant basis and had the lowest fresh to dry weight of fruit conversion rate at 11 % among all the four cultivars and this probably makes it most suitable for fresh consumption and flavouring use. The bushy canopy of the plant producing flowers with yellowish-blue anther on stamen that is shorter than the pistil, together with the fruits borne in erect upward position and the absent of calyx teeth from the flowers are characteristics common to the *Capsicum frustencens* group.

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Appendix A

Raw Data of Chili Plant Morphology

Plant Height Data of The Four Cultivars

Observation	G. Merah (cm)	G. Kuning (cm)	C. Putih (cm)	C. Besar (cm)
1	52.25	47.62	61.24	34.56
2	49.38	51.09	57.08	29.55
3	49.62	50.08	58.05	33.49
4	48.10	48.70	58.60	34.44
5	49.11	48.04	59.23	35.58
6	47.07	47.26	56.08	31.21
7	49.09	46.07	61.30	32.70
8	50.22	49.28	60.19	28.32
9	48.24	48.33	54.30	30.83
10	51.35	45.28	57.98	37.38
11	47.66	51.05	60.20	34.41
12	48.63	49.10	62.66	36.65
13	52.67	44.62	59.62	29.44
14	57.79	50.58	62.81	32.37
15	52.42	46.29	52.25	35.54

Primary Branch Total Per plant

Observation	G. Merah	G. Kuning	C. Putih	C. Besar
1	8	8	9	3
2	7	4	10	2
3	9	5	8	4
4	10	7	12	2
5	8	9	7	4
6	6	6	8	3
7	6	5	8	5
8	5	5	7	4
9	7	6	8	5
10	6	9	10	4
11	8	7	56	3
12	7	6	7	2
13	8	8	8	6
14	6	5	9	5
15	5	8	8	4

Plant Canopy Height

Observation	G. Merah (cm)	G. Kuning (cm)	C. Putih (cm)	C. Besar (cm)
1	46.45	47.65	49.59	29.24
2	40.52	45.55	48.45	28.55
3	45.35	46.90	50.63	30.30
4	47.67	44.25	47.75	28.53
5	42.62	39.45	53.28	31.75
6	43.27	41.70	49.07	32.18
7	45.25	47.58	47.85	30.47
8	43.79	42.20	51.27	28.65
9	42.54	38.69	52.60	32.60
10	48.20	45.50	48.32	29.34
11	44.27	45.65	51.50	32.03
12	45.35	36.83	49.13	33.05
13	47.56	43.40	47.35	29.19
14	43.17	45.25	50.43	31.55
15	46.45	46.31	48.10	28.48

Plant Canopy Diameter

Observation	G. Merah (cm)	G. Kuning (cm)	C. Putih (cm)	C. Besar (cm)
1	41.28	39.25	34.50	29.30
2	38.62	32.82	30.24	31.46
3	36.51	36.50	38.70	28.15
4	39.10	35.95	31.56	32.47
5	41.47	34.08	35.17	35.53
6	40.25	38.35	33.29	29.20
7	42.10	33.59	37.23	32.48
8	39.43	32.45	37.44	33.97
9	41.17	38.83	32.12	31.30
10	40.59	40.00	34.58	34.25
11	42.30	35.19	31.15	35.50
12	39.42	37.56	38.28	33.71
13	41.55	39.37	36.65	31.60
14	34.78	37.61	34.22	36.23
15	40.65	39.12	32.30	32.13

Main Stem Diameter

Observation	G. Merah (cm)	G. Kuning (cm)	C. Putih (cm)	C. Besar (cm)
1	1.24	1.13	1.43	1.19
2	1.57	0.92	1.22	1.34
3	1.05	1.46	1.31	0.99
4	0.96	1.27	1.33	0.87
5	1.30	1.59	1.34	1.17
6	1.26	1.25	1.29	0.90
7	0.99	0.98	1.39	1.29
8	1.33	0.93	1.41	1.34
9	0.97	1.22	1.39	1.36
10	1.29	0.97	1.42	1.44
11	1.05	1.06	1.26	0.61
12	0.93	0.92	1.33	1.36
13	1.21	1.21	1.43	1.15
14	1.43	0.99	1.39	1.51
15	0.94	1.15	1.28	1.49

First Branch Angle

Observation	G. Merah (˚)	G. Kuning (˚)	C. Putih (˚)	C. Besar (˚)
1	51	45	44	38
2	49	51	39	32
3	52	50	47	39
4	44	47	42	35
5	39	49	38	39
6	55	50	47	42
7	46	48	45	38
8	46	48	42	45
9	49	47	44	44
10	52	52	48	39
11	50	45	40	40
12	48	53	47	37
13	52	49	49	42
14	51	51	47	36
15	48	47	48	40

Appendix B

Raw Data of Leaf Morphology

Petiole length

Observation	G. Merah (cm)	G. Kuning (cm)	C. Putih (cm)	C. Besar (cm)
1	4.51	4.85	3.33	6.05
2	4.33	43.35	4.18	7.16
3	5.26	5.17	3.92	7.12
4	5.19	4.58	4.24	6.17
5	5.33	5.07	3.13	5.83
6	5.65	5.05	4.05	6.38
7	4.67	4.36	4.18	7.24
8	4.95	4.50	4.39	6.99
9	4.97	4.79	4.01	6.45
10	5.03	4.98	3.73	6.50
11	4.95	5.12	4.21	7.29
12	5.12	5.33	3.96	6.31
13	5.05	4.83	4.17	6.36
14	4.89	5.06	3.87	6.21
15	4.90	4.99	3.91	6.44

Petiole Diameter

Observation	G. Merah (cm)	G. Kuning (cm)	C. Putih (cm)	C. Besar (cm)
1	0.52	0.73	0.32	0.41
2	0.45	0.54	0.41	0.39
3	0.61	0.59	0.33	0.42
4	0.55	0.66	0.42	0.37
5	0.41	0.73	0.39	0.38
6	0.64	0.65	0.41	0.40
7	0.63	0.54	0.42	0.40
8	0.55	0.75	0.34	0.37
9	0.52	0.64	0.35	0.43
10	0.56	0.66	0.40	0.39
11	0.61	0.72	0.37	0.39
12	0.47	0.63	0.39	0.41
13	0.44	0.58	0.41	0.40
14	0.58	0.52	0.43	0.37
15	0.69	0.51	0.39	0.42

Leaf Length

Observation	G. Merah (cm)	G. Kuning (cm)	C. Putih (cm)	C. Besar (cm)
1	22.23	19.13	16.91	14.30
2	23.47	20.43	17.86	13.61
3	25.79	23.30	17.15	12.98
4	26.31	19.55	17.85	13.42
5	20.24	19.04	16.84	13.44
6	24.25	20.67	16.70	14.21
7	25.53	23.56	18.06	13.35
8	23.64	24.12	16.32	14.20
9	23.41	26.26	17.46	12.87
10	24.67	25.34	17.23	14.20
11	23.32	19.94	15.90	14.32
12	24.56	22.64	16.35	14.14
13	22.24	21.71	17.11	13.68
14	23.75	23.22	17.65	14.00
15	20.42	21.53	16.04	14.53

Leaf Width

Observation	G. Merah (cm)	G. Kuning (cm)	C. Putih (cm)	C. Besar (cm)
1	12.51	12.35	9.59	6.72
2	14.16	13.60	10.54	7.54
3	13.32	11.34	11.13	7.28
4	15.15	11.71	10.21	6.93
5	14.13	13.76	9.62	7.45
6	15.34	12.34	11.36	7.73
7	13.61	13.62	10.64	6.94
8	15.63	13.06	10.75	6.98
9	14.85	13.10	10.96	7.16
10	14.72	13.98	11.37	8.29
11	12.36	13.17	11.64	7.61
12	13.31	12.15	12.07	7.13
13	12.17	12.40	10.20	6.97
14	12.49	12.05	12.21	7.35
15	14.43	13.94	9.62	7.00

Leaf Area

Observation	G. Merah (cm^2)	G. Kuning(cm^2)	C. Putih (cm^2)	C. Besar (cm^2)
1	108.04	88.21	83.41	57.27
2	110.21	99.32	70.34	67.29
3	111.37	89.24	68.22	49.35
4	97.23	99.33	81.34	52.47
5	112.42	99.64	69.09	47.33
6	109.21	82.23	75.34	59.08
7	99.65	87.59	74.90	47.73
8	102.64	93.23	82.07	53.69
9	97.15	95.37	84.60	56.95
10	103.64	96.60	73.57	54.37
11	98.23	98.12	69.34	50.34
12	105.65	102.52	81.77	59.28
13	103.06	90.24	74.34	60.56
14	98.55	97.97	77.03	62.07
15	104.25	96.02	69.75	56.64

Total number of leaf per plant

Observation	G. Merah	G. Kuning	C. Putih	C. Besar
1	183	199	391	149
2	233	251	427	145
3	192	187	417	163
4	246	193	374	181
5	191	229	383	155
6	164	235	348	173
7	232	205	401	145
8	201	209	395	139
9	119	231	427	160
10	197	177	413	137
11	221	189	421	159
12	237	218	351	171
13	209	241	340	169
14	194	193	388	171
15	179	236	366	143

Appendix C

Raw Data of Flower Morphology

Flower Pedicel Length

Observation	G. Merah	G. Kuning	C. Putih	C. Besar
1	2.10	2.00	2.10	1.10
2	2.00	1.99	2.10	1.15
3	1.98	2.10	2.15	1.17
4	2.20	2.22	2.20	1.21
5	2.15	2.05	2.16	1.32
6	2.12	2.13	2.21	1.54
7	1.97	2.11	2.32	1.42
8	2.00	2.18	2.28	1.34
9	2.17	2.17	2.32	1.65
10	2.11	2.18	2.27	1.80
11	2.10	2.00	2.18	1.35
12	1.88	1.95	2.18	1.40
13	2.13	2.11	2.05	1.55
14	2.21	2.05	2.25	1.25
15	2.10	2.11	2.27	1.34

Flower Pedicel Diameter

Observation	G. Merah	G. Kuning	C. Putih	C. Besar
1	0.20	0.13	0.11	0.15
2	0.25	0.14	0.10	0.15
3	0.25	0.12	0.13	0.17
4	0.35	0.10	0.15	0.14
5	0.18	0.15	0.12	0.12
6	0.26	0.11	0.10	0.13
7	0.24	0.16	0.15	0.16
8	0.19	0.10	0.11	0.18
9	0.22	0.15	0.10	0.17
10	0.24	0.13	0.10	0.19
11	0.25	0.16	0.13	0.16
12	0.22	0.15	0.12	0.18
13	0.23	0.14	0.14	0.19
14	0.20	0.10	0.10	0.17
15	0.21	0.13	0.11	0.19

Flower Receptacle Length

Observation	G. Merah	G. Kuning	C. Putih	C. Besar
1	0.31	0.22	0.40	0.50
2	0.32	0.19	0.42	0.46
3	0.29	0.21	0.46	0.51
4	0.31	0.18	0.41	0.50
5	0.28	0.23	0.39	0.47
6	0.29	0.20	0.42	0.52
7	0.32	0.18	0.39	0.48
8	0.27	0.21	0.40	0.47
9	0.29	0.23	0.39	0.50
10	0.30	0.19	0.43	0.49
11	0.28	0.22	0.38	0.51
12	0.31	0.20	0.41	0.47
13	0.27	0.22	0.42	0.47
14	0.32	0.20	0.37	0.49
15	0.30	0.21	0.40	0.50

Flower Receptacle Diameter

Observation	G. Merah	G. Kuning	C. Putih	C. Besar
1	0.22	0.25	0.30	0.41
2	0.20	0.22	0.33	0.45
3	0.19	0.26	0.27	0.40
4	0.21	0.27	0.31	0.44
5	0.21	0.24	0.29	0.37
6	0.22	0.25	0.30	0.46
7	0.19	0.21	0.31	0.40
8	0.20	0.23	0.28	0.39
9	0.20	0.24	0.33	0.43
10	0.22	0.22	0.31	0.37
11	0.21	0.24	0.28	0.41
12	0.18	0.25	0.29	0.44
13	0.23	0.23	0.31	0.38
14	0.21	0.26	0.30	0.41
15	0.19	0.22	0.30	0.40

Flower Petal Length

observation	G. Merah	G. Kuning	C. Putih	C. Besar
1	0.75	0.88	0.63	0.83
2	0.71	0.75	0.55	0.88
3	0.72	0.81	0.60	0.91
4	0.80	0.69	0.71	0.93
5	0.74	0.74	0.66	1.05
6	0.71	0.79	0.69	0.94
7	0.79	0.73	0.71	0.98
8	0.67	0.79	0.67	0.94
9	0.72	0.81	0.65	0.99
10	0.75	0.76	0.69	1.00
11	0.87	0.83	0.64	1.20
12	0.82	0.75	0.72	0.81
13	0.74	0.80	0.70	0.88
14	0.78	0.80	0.66	0.96
15	0.80	0.82	0.64	0.98

Flower Petal Width

Observation	G. Merah	G. Kuning	C. Putih	C. Besar
1	0.41	0.47	0.38	0.55
2	0.44	0.45	0.41	0.59
3	0.49	0.44	0.44	0.60
4	0.44	0.46	0.37	0.50
5	0.46	0.48	0.37	0.53
6	0.40	0.48	0.43	0.56
7	0.42	0.49	0.39	0.59
8	0.41	0.43	0.36	0.61
9	0.48	0.42	0.40	0.53
10	0.42	0.44	0.41	0.57
11	0.44	0.45	0.38	0.62
12	0.45	0.43	0.41	0.55
13	0.46	0.48	0.42	0.53
14	0.46	0.47	0.36	0.59
15	0.48	0.45	0.39	0.57

Flower Sepal Length

Observation	G. Merah	G. Kuning	C. Putih	C. Besar
1	0.25	0.22	0.26	0.29
2	0.23	0.23	0.28	0.32
3	0.22	0.25	0.29	0.35
4	0.29	0.24	0.24	0.29
5	0.27	0.27	0.28	0.28
6	0.24	0.25	0.26	0.31
7	0.26	0.20	0.29	0.30
8	0.30	0.23	0.27	0.30
9	0.21	0.25	0.29	0.29
10	0.24	0.25	0.25	0.24
11	0.20	0.27	0.28	0.31
12	0.24	0.23	0.26	0.27
13	0.23	0.26	0.23	0.29
14	0.26	0.26	0.27	0.27
15	0.25	0.28	0.29	0.30

Flower Sepal Width

Observation	G. Merah	G. Kuning	C. Putih	C. Besar
1	0.10	0.12	0.12	0.19
2	0.12	0.13	0.13	0.18
3	0.13	0.14	0.14	0.20
4	0.13	0.13	0.13	0.21
5	0.10	0.10	0.15	0.19
6	0.09	0.11	0.13	0.17
7	0.12	0.13	0.16	0.20
8	0.10	0.10	0.10	0.20
9	0.12	0.10	0.14	0.18
10	0.11	0.12	0.14	0.16
11	0.11	0.10	0.16	0.19
12	0.10	0.11	0.13	0.18
13	0.12	0.11	0.15	0.17
14	0.13	0.13	0.14	0.21
15	0.13	0.11	0.14	0.20

Appendix D

Raw Data of Fruit Morphology

Fruit length

Observation	G. Merah (cm)	G. Kuning (cm)	C. Putih (cm)	C. Besar (cm)
1	3.1	3.2	4.5	8.5
2	3.2	3.1	4.9	8.3
3	3.2	3.3	4.8	8.2
4	2.9	3.2	4.7	8.5
5	3.1	3.1	4.7	8.4
6	3.2	3.2	4.8	8.4
7	3.0	3.3	4.9	8.2
8	3.1	3.2	4.6	8.3
9	2.9	3.1	4.4	8.6
10	3.1	2.9	4.6	8.8
11	3.2	3.0	4.3	8.5
12	3.2	2.8	4.7	8.6
13	2.8	3.2	4.9	8.7
14	3.3	3.1	5.1	8.8
15	3.2	3.3	4.9	8.6

Fruit diameter

Observation	G. Merah (cm)	G. Kuning (cm)	C. Putih (cm)	C. Besar (cm)
1	2.8	3.1	1.3	2.6
2	3.0	3.1	1.5	2.4
3	2.9	3.0	1.1	2.7
4	3.1	2.9	1.4	2.6
5	2.9	2.8	1.5	2.6
6	3.0	2.9	1.2	2.8
7	2.7	3.0	1.3	2.5
8	2.9	3.1	1.4	2.7
9	3.1	2.6	1.2	2.4
10	3.1	2.9	1.4	2.7
11	3.0	2.7	1.2	2.9
12	3.2	2.9	1.5	2.7
13	2.8	3.1	1.3	2.9
14	2.7	3.0	1.4	2.8
15	2.7	2.9	1.3	2.9

Fruit Stalk Length

Observation	G. Merah (cm)	G. Kuning (cm)	C. Putih (cm)	C. Besar (cm)
1	3.2	3.1	2.9	3.5
2	3.3	3.2	2.7	3.7
3	3.1	3.2	2.9	3.6
4	3.2	3.3	2.6	3.7
5	3.0	3.1	2.8	3.5
6	3.2	3.2	2.5	3.6
7	3.3	3.3	3.0	3.4
8	3.1	3.2	2.8	3.8
9	3.4	3.1	2.9	3.7
10	3.2	3.0	2.6	3.5
11	3.1	2.9	2.8	3.6
12	3.4	3.1	3.0	3.8
13	3.2	3.4	2.7	3.6
14	3.2	3.1	2.9	3.5
15	3.0	2.9	2.6	3.7

Pericarp Thickness of Fruits

Observation	G. Merah (cm)	G. Kuning(cm)	C. Putih(cm)	C. Besar(cm)
1	0.29	0.25	0.13	0.30
2	0.22	0.21	0.12	0.38
3	0.20	0.25	0.17	0.33
4	0.27	0.20	0.15	0.31
5	0.21	0.21	0.17	0.37
6	0.27	0.21	0.14	0.39
7	0.29	0.22	0.15	0.37
8	0.22	0.26	0.18	0.30
9	0.20	0.26	0.14	0.34
10	0.25	0.29	0.17	0.31
11	0.25	0.28	0.18	0.39
12	0.24	0.20	0.17	0.31
13	0.26	0.27	0.12	0.37
14	0.21	0.27	0.16	0.34
15	0.26	0.28	0.14	0.39

Total seed per fruit

Observation	G. Merah	G. Kuning	C. Putih	C. Besar
1	46	41	27	121
2	52	39	31	119
3	39	52	34	89
4	44	48	29	101
5	47	63	33	109
6	35	47	31	97
7	43	34	29	126
8	51	42	23	105
9	48	38	30	115
10	50	39	34	127
11	61	51	43	82
12	49	38	37	111
13	56	46	33	117
14	41	57	42	93
15	47	44	29	106

Fruit Fresh weight 500 g base for dry weight conversion

Observation	G. Merah (g)	G. Kuning (g)	C. Putih (g)	C. Besar (g)
1	500	500	500	500
2	500	500	500	500
3	500	500	500	500
4	500	500	500	500
5	500	500	500	500
Total	2500	2500	2500	2500

Dry weight after drying the 500 g fresh weight at 90°C in oven for 24 hours

Observation	G. Merah (g)	G. Kuning (g)	C. Putih (g)	C. Besar (g)
1	82	81	73	81
2	68	101	51	69
3	70	65	63	65
4	91	77	53	63
5	51	90	47	74
Total	362	414	287	352
Conversion Rate (%)	14.48	16.56	11.48	14.08

PUBLICATION OF THE PROJECT UNDERTAKING

This is to certify that I have no objection to publish the project entitled "**Morphological characterization of four local chili cultivars in Bintulu Sarawak**" by the supervisor in a joint authorship. However, it has to be evaluated by the Faculty of Agriculture and Food Sciences, University Putra Malaysia Bintulu Campus and published in form approved by the Faculty.

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Arlden Johnny

Date: 28 APRIL 2008