EFFECTS OF WATER STRESS ON THE GROWTH AND YIELD OF CHILLI (*Capsicum annuum L.*)

CHRISTINA A/P PERUMAL

DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF AGRICULTURAL SCIENCE WITH HONOURS

HORTICULTURE AND LANDSCAPING PROGRAMME
FACULTY OF SUSTAINABLE AGRICULTURE
UNIVERSITI MALAYSIA SABAH

2017

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN TESIS

JUDUL: EFFECTS OF WATER STRESS ON THE GROWTH AND YIELD OF CHILLI (Capsicum annuum L.)

IJAZAH: SARJANA MUDA SAINS PERTANIAN (HORTIKULTUR DAN LANDSKAP)

SAYA: CHRISTINA A/P PERUMAL **SESI PENGAJIAN:** 2013/2014
(HURUF BESAR)

Mengaku membenarkan tesis *(LPSM/Sarjana/Doktor Falsafah) ini disimpan di Perpustakaan Universiti Malaysia Sabah dengan syarat-syarat kegunaan seperti berikut:-

1. Tesis adalah hak milik Universiti Malaysia Sabah.
2. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (/)

[ ]	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di AKTA RAHSIA RASMI 1972)
[ ]	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
[/]	TIDAK TERHAD	

(TANDATANGAN PENULIS)

Alamat Tetap: 1521 JALAN RPR BATU KAWA LORONG 28AG, 93250, KUCHING, SARAWAK.

TARIKH: 10 JANUARI 2017

Disahkan oleh:
NURULAIN BINTI ISMAIL
PUSTAKAWAN KANAN
UNIVERSITI MALAYSIA SABAH

(TANDATANGAN PUSTAKAWAN)

DR. ABDUL PAHIM ANJANG
PENSYARAH KANAN
FAKULTI PERTANIAN LESTARI
UMS KAMPUS SANDAKAN

(NAMA PENYELIA)

TARIKH: 11.01.2017

Catatan:
*Potong yang tidak berkenaan.
*Jika tesis ini SULIT dan TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT dan TERHAD.
*Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana Secara Penyelidikan atau disertai bagi pengajian secara kerja kursus dan Laporan Projek Sarjana Muda (LPSM).

DECLARATION

I hereby declare that this dissertation is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that no part of this dissertation has been previously or concurrently submitted for a degree at this or any other university.

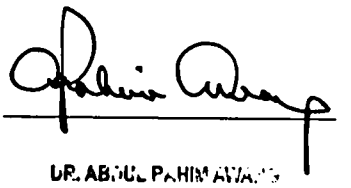
Christina A/P Perumal

BR13110029

13th January 2017

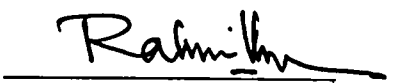
VERIFIED BY

1. Dr. Abdul Rahim Awang
   SUPERVISOR



DR. ABDUL RAHIM AWANG
PENSYARAH KANAN
FAKULTI PERTANIAN LESTARI
UMS KAMPUS SANDAKAN

2. Prof. Dr. Abd. Rahman Milan
   CO-SUPERVISOR



PROF. DR. ABD RAHMAN MILAN
PENSYARAH
FAKULTI PERTANIAN LESTARI
UMS KAMPUS SANDAKAN

ACKNOWLEDGEMENT

First of all, I would like to express my sincere thanks to God because of His blessings I manage to complete this dissertation successfully. I would like to express my special appreciation and thanks to my supervisor, Dr. Abdul Rahim Awang and my co-supervisor, Prof. Dr. Abd. Rahman Milan, both have been a tremendous guider for me. I would like to thank both of you for encouraging my research and guide me from the beginning of this dissertation until this piece of work is successfully completed by giving me many information and support regarding this project.

A special thanks to my family. Words cannot express how grateful I am to both my parents, Mr. Perumal A/L Pakri Manikom and Madam Rita Law Siew Fah for their sacrifices for me. Their prayers for me was what sustained me this far. Also for my siblings, Cecilia A/P Perumal, Christopher A/L Perumal and Charles A/L Perumal whose always had been there for me with their moral supports, love and understanding.

Hereby, this opportunity for me to express my gratitude and appreciation to all the lecturers, colleagues (Nur Aisar Izzati Bt Che Musa, Karistani Amoi ak Elebis, Amelia Nuratikah Bt Amat Dalan, Amalina Izzati Bt Nor Safuan), and other FSA students for the support and help. Nevertheless, my special appreciation to Azlie Sadri Bin Puteh for his kindness to support, encouragement and care until the moment I submit this thesis.

Lastly, I would like to express my regards and thanks to those who helped and supported me either directly or indirectly during the completion of this project and dissertation.

ABSTRACT

This study was carried out at Faculty of Sustainable Agriculture (FSA), Universiti Malaysia Sabah, Sandakan, Sabah (5°55'4" N 118°0'8" E) to know the effects of water stress on the growth and yield of chilli (*Capsicum annuum L.*). The objective of this study is to know the effects of water stress on the growth and yield of chilli (*Capsicum annuum L.*). Besides, it is also to identify the optimum rate of water that should be irrigated to chilli (*Capsicum annuum L.*). This study was conducted from June 2016 until October 2016. Experimental design that was used in this experiment is Completely Randomized Design (CRD). There are 5 treatments involved in this study and each carried different rate of water to be applied where treatment 1 (Control), no watering, treatment 2, watered one week interval, treatment 3, watered four days interval, treatment 4, watered once a day and lastly treatment 5, watered thrice a day. Each treatment has five replications. Data collected was analyzed using one-way ANOVA at 5% significance level. The results shown for vegetative growth and yield of chilli, treatment 4 produced the highest number of leaves, number of fruits, fresh fruit weight, dry fruit weight and fruit length. Thus, treatment 4 is highly recommended practice for farmers since it helps to produce high quantity and quality of chilli fruits compared to other treatments. Furthermore, as food products can be produced in high amount by managing the water application to crops which then helps to strive the goals of food security.

KESAN KADAR PENGAIRAN TERHADAP

PERTUMBUHAN DAN HASIL CILI

(*Capsicum annuum L.*)

ABSTRAK

Kajian ini telah dijalankan di Fakulti Pertanian Lestari (FPL), Universiti Malaysia Sabah, Sandakan, Sabah (5°55'4"N 118°0'8"E) untuk mengetahui kesan kadar pengairan terhadap pertumbuhan dan hasil cili (*Capsicum annuum L.*). Objektif kajian ini dijalankan adalah untuk mengetahui kesan kadar pengairan terhadap pertumbuhan dan hasil cili (*Capsicum annuum L.*). Selain itu, ia juga adalah untuk mengenal pasti kadar optima air yang bersesuaian kepada cili (*Capsicum annuum L.*). Kajian ini dijalankan dari Jun 2016 sehingga Oktober 2016. Analisis eksperimen ini menggunakan reka bentuk eksperimen iaitu reka bentuk secara rawak (CRD). Terdapat 5 rawatan dalam kajian ini dan setiap kadar pengairan berbeza untuk setiap rawatan, di mana rawatan 1 (Kawalan), tiada pengairan, rawatan 2, disiram selang seminggu, rawatan 3, disiram selang empat hari, rawatan 4, disiram sekali setiap hari dan akhir sekali rawatan 5, disiram tiga kali sehari. Setiap rawatan mempunyai lima replikasi. Data yang diperolehi dianalisis dengan menggunakan ANOVA satu hala pada 5% aras keertian. Keputusan yang ditunjukkan untuk pertumbuhan vegetatif dan hasil cili, rawatan 4 mempunyai hasil bilangan daun tertinggi, bilangan buah, berat buah basah, berat buah kering dan panjang buah. Oleh itu, cara pengairan seperti rawatan 4 amat disyorkan untuk petani kerana ia membantu untuk menghasilkan buah cili yang berkuantiti dan berkualiti tinggi berbanding rawatan lain. Tambahan pula, cili sebagai produk makanan yang boleh dihasilkan dalam jumlah yang tinggi dengan mengawasi kadar pengairan kepada tanaman kerana ini boleh membantu untuk mencapai salah satu matlamat keselamatan makanan.

TABLE OF CONTENTS

Content			Page
DECLARATION			ii
VERIFICATION			iii
ACKNOWLEDGEMENT			iv
ABSTRACT			v
ABSTRAK			vi
TABLE OF CONTENTS			vii
LIST OF TABLES			ix
LIST OF FIGURES			x
LIST OF SYMBOLS, UNITS AND ABBREVIATIONS			xii
CHAPTER 1	**INTRODUCTION**		**1**
1.1	Background		1
1.2	Justification		2
1.3	Objectives		2
1.4	Hypothesis		3
CHAPTER 2	**LITERATURE REVIEW**		**4**
2.1	Basic Information on *Capsicum annuum L.*		4
	2.1.1	Centre of Origin	4
	2.1.2	Taxonomy of *Capsicum annuum L.* var. 'Kulai'	5
	2.1.3	Botanical Descriptions of Chilli	5
	2.1.4	Growth and Development of *Capsicum annuum L.* Plant	9
	2.1.5	Maturity Index of *Capsicum annuum L.*	11
	2.1.6	Fertilizer Requirements for *Capsicum annuum L.* Plant	12
	2.1.7	Climate and Soil Requirement for *Capsicum annuum L.* Plant	13
	2.1.8	Planting Distance and Irrigation of *Capsicum annuum L.* Plant	14
2.2	Economic Importance		14
	2.2.1	Annual Change of Chilli Crop in Malaysia	14
	2.2.2	Average Annual Price of Farms in Malaysia	15
2.3	Pest and Diseases		16
	2.3.1	Pest	16
	2.3.2	Diseases	18
2.4	Drying of *Capsicum annuum L.*		20
2.5	Water		20
	2.5.1	The Importance of Water towards Plant	20
2.6	Water Stress		21
	2.6.1	Effects of Water Stress on the Vegetative Growth and Yield Production of *Capsicum annuum L.*	21
CHAPTER 3	**METHODOLOGY**		**24**
3.1	Location of Study		24
3.2	Duration of Study		24
3.3	Materials		24
	3.3.1	Soil Media Preparation	24
	3.3.2	Pot Preparation	25
	3.3.3	Seed Preparation	25

3.3.4 Soil pH Test 25
3.3.5 Transplant Seedling 26
3.3.6 Fertilizer Preparation 26
3.3.7 Water, Weeding and Pest and Diseases Control 26
3.3.8 Harvesting 26
3.4 Water Stress Treatment 27
3.5 Statistical Analysis 27
3.6 Parameters Measured in this Study 27
3.6.1 Vegetative Growth Parameters 28
3.6.2 Yield Parameters 29

CHAPTER 4 RESULTS 30
4.1 Effect of Water Stress on the Growth and Yield of *Capsicum annuum L.* var. 'Kulai' 30
4.1.1 Plant Height (cm) 34
4.1.2 Number of Leaves 36
4.1.3 Leaf Diameter (cm) 38
4.1.4 Stem Circumference (cm) 40
4.1.5 Root Length (cm) 42
4.1.6 Days to Flowering 43
4.1.7 Number of Fruits 44
4.1.8 Fruit Length (cm) 45
4.1.9 Fresh Fruit Weight (g) 46
4.1.10 Fruit Dry Weight (g) 47

CHAPTER 5 DISCUSSION 48
5.1 Effect of Water Stress on the Vegetative Growth of *Capsicum annuum L.* var. 'Kulai' 48
5.1.1 Plant Height (cm) 48
5.1.2 Number of Leaves 49
5.1.3 Leaf Diameter (cm) 50
5.1.4 Stem Circumference (cm) 50
5.1.5 Root Length (cm) 50
5.1.6 Days to Flowering 51
5.2 Effect of Water Stress on the Yield Production of *Capsicum annuum L.* var. 'Kulai' 51
5.2.1 Number of Fruits 51
5.2.2 Fruit Length (cm) 52
5.2.3 Fresh Fruit Weight (g) 52
5.2.4 Fruit Dry Weight (g) 52

CHAPTER 6 CONCLUSION 54
REFERENCES **55**
APPENDICES **59**

LIST OF TABLES

Table		Page
2.1	The Taxonomy of *Capsicum annuum L.* var. 'Kulai'	5
2.2	The Characteristic of *Capsicum anuum L.* Varieties	9
2.3	The Physiological Maturity Index of *Capsicum annuum L.*	11
2.4	The Annual Change of Chilli Crop in Malaysia, 2009-2013	15
2.5	The Average Annual Price of Farms in Malaysia	16
3.1	Water Stress Treatment with Different Rate of Water Supplied	27
4.1	Mean Squares from ANOVA for Growth Traits of 5 Treatments	31
4.2	Mean Squares from ANOVA for Yield Traits of 5 Treatments	31
4.3	Mean of Growth Traits of 5 treatments	32
4.4	Mean of yield traits of 5 treatments	33

LIST OF FIGURES

Figure		Page
2.1	Taproot system of *Capsicum annuum L.* plant	6
2.2	Stem structure of *Capsicum annuum L.* plant	7
2.3	Flower of *Capsicum annuum L.* plant	8
4.1	*Capsicum annuum L.* var. 'Kulai' mean plant height from week 1 to week 10 after transplanting	34
4.2	The effect of water stress on the mean plant height growth of *Capsicum annuum L.* var. 'Kulai' on the tenth week after transplanting	35
4.3	The number of leaves available on *Capsicum annuum L.* var. 'Kulai' from week 1 to week 10 after transplanting	36
4.4	The effect of water stress on the mean number of leaves of *Capsicum annuum L.* var. 'Kulai' on the tenth week after transplanting	37
4.5	The mean leaf diameter on *Capsicum annuum L.* var. 'Kulai' from week 1 to week 10 after transplanting	38
4.6	The effect of water stress on the mean leaf diameter of *Capsicum annuum L.* var. 'Kulai' on the tenth week after transplanting	39
4.7	The mean stem circumference on *Capsicum annuum L.* var. 'Kulai' from week 1 to week 10 after transplanting	40
4.8	The effect of water stress on the mean stem circumference of *Capsicum annuum L.* var. 'Kulai' on the tenth week after transplanting	41
4.9	The effect of water stress on the mean root length of *Capsicum annuum L.* var. 'Kulai' on the tenth week after transplanting	42
4.10	The effect of water stress on the mean days to flowering of *Capsicum annuum L.* var. 'Kulai' on the tenth week after transplanting	43
4.11	The effect of water stress on the mean number of fruits of *Capsicum annuum L.* var. 'Kulai' on the tenth week after transplanting	44
4.12	The effect of water stress on the mean fruit length of *Capsicum annuum L.* var. 'Kulai' on the tenth week after transplanting	45

4.13 The effect of water stress on the mean fresh fruit weight of *Capsicum annuum L.* var. 'Kulai' on the tenth week after transplanting 46

4.14 The effect of water stress on the mean fruit dry weight of *Capsicum annuum L.* var. 'Kulai' on the tenth week after transplanting 47

LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

°C	Degree Celsius
%	Percent
$	Dollar
ANOVA	Analysis of Variance
cm	Centimetre
FAMA	Federal Agricultural Marketing Authority
FAO	Food and Agriculture Organisation
FPL	Fakulti Pertanian Lestari
FSA	Faculty of Sustainable Agriculture
g	Gram
ha	Hectare
ITIS	Integrated Taxonomic Information System
L	Litre
LSD	Least Significance Difference
m	Metre
mm	Millimetre
MARDI	Malaysian Agricultural Research and Development Institute
mg	Milligram
ml	Millilitre
NPK	Nitrogen-Phosphorus-Potassium
RM	Ringgit Malaysia
t	Tonne
UMS	Universiti Malaysia Sabah
USD	US Dollar

CHAPTER 1

INTRODUCTION

1.1 Background

Capsicum is one of the most important vegetables in the world. Most of them are true perennials that have a rapid growing period of 90 to 150 days especially *Capsicum annuum L.* (Akinbile and Yusoff, 2011). Chilli plants were originated from Mexico but are commonly known in North America (Kraft *et al.*, 2013, Quiros, 2010). Chillies are famous around the world as they are widely used as food and medicine. Their fruits are an important vegetable crop for the fresh market and processed products. Meanwhile, the increase in population has led to an increase in the demand for food and fibre. Therefore, irrigation management is known to be one of the important factors that should be considered in producing high quantity and quality of chilli (Akinbile and Yusoff, 2011).

Many people believe that applying more water will increase crop yields. Instead, over watering can reduce yields because the excess of soil moisture often results in plant diseases, nutrient leaching and reduced pesticide effectiveness (Luvaha *et al.*, 2008, Gunawardena and Silva, 2014, Farooq *et al.*, 2009). Besides, plants that are over watered produces lower yield because too much water in soil causes soil oxygen deficiency in roots (Luvaha *et al.*, 2008).

Furthermore, over-watering can cause the flower or developed fruit to drop or even causes severe blossom-end rot. Even worst, over watering causes risk to the plants by spreading of diseases which then plant growth and also yield productions will be reduced (Khan *et al.*, 2008).

Water deficit during the period between flowering and fruit development can also reduce the final fruit production which it can reduce the fresh fruit weight and fruit dry weight when plants undergo continuous water stress (Bosland and Votava, 2012).

1.2 Justification

Chilli has its unique place in Asian diet a spice as well as a vegetable. It is also a high value crop commercially grown in Malaysia. Chilli is grown as a mono crop in most of the dry zone areas and the harvest can be sold as fresh or dried. Because dry chilli fetches high price, farmers tend to dry their produce and sell it when the prices are high. Due to these farmers grow chilli in large extents. With the growing concerns of irrigating with varying rate of water to chilli plant, it can be no watering or excess watering.

The production of chilli in Malaysia increases from year 2011 to 2013, where it rises from 28,766 tonnes to 59,775 tonnes. As the production rate increases, the production value (ex-farm price and wholesale) also increases even though the average yield decrease by 0.6 tonne per hectare in year 2013. From this statement, it shows that the price of chilli increases in markets but the yield reduction in field can be due to irrigation problem (Department of Agriculture Malaysia, 2014).

Meanwhile, it is important to study how chilli plants behave under water stress conditions. This study is focused to understand the impact on growth and yield of chilli when exposed to water stress conditions and to suggest possible adaptation measures. This is also to provide important information on better future production of chillies either in fresh or dried.

1.3 Objectives

The objective of this study was to know the effects of water stress on the growth and yield of chilli (*Capsicum annuum L.*). Besides, it was also to identify the optimum rate of water that should be irrigated to chilli (*Capsicum annuum L.*).

1.4 Hypothesis

H_0: There is no significant difference on the effects of water stress on the growth and yield of chilli (*Capsicum annuum L.*).

H_A: There is a significant difference on the effects of water stress on the growth and yield of chilli (*Capsicum annuum L.*).

CHAPTER 2

LITERATURE REVIEW

2.1 Basic Information on *Capsicum annuum L.*

Capsicum species are commonly known as chillies or peppers and they are among the most important vegetable crops worldwide. *Capsicum annuum L.* is one of the main cultivated species among more than 30 species where they are grown for fresh, dried and also for processing food consumption (Lin and Saltveit, 2012). *Capsicum annuum L.* has high nutritional values and they also has high economic value because they had been used as cooking seasoning or as a staple food in various industries of food, beverages and medicines which makes *Capsicum annuum L.* more interesting to be cultivated (Sumarni and Muharam, 2011).

2.1.1 Centre of Origin

Capsicum annuum L., a tropical plant was found to be domesticated in one or both of the two areas of Mexico which is north eastern Mexico and central east Mexico (Kraft *et al.*, 2013). *Capsicum annuum L.* was the most common species known in North America with a wide range distribution from Mexico as the main centre to Northern Argentina and it was recognized as cultivated type of varieties (Quiros, 2010).

Capsicum annuum L. var. 'Kulai' is a type of variety produced through open pollination (OP) where their seeds are known as hybrid seeds and can be sold with a high price (Redaksi AgroMedia, 2008).

2.1.2 Taxonomy of *Capsicum annuum L.* var. 'Kulai'

Table 2.1 The taxonomy of *Capsicum annuum L.* var. 'Kulai'

Kingdom	Plantae
Subkingdom	Viridiplantae
Infrakingdom	Streptophyta
Superdivision	Embryophyta
Division	Tracheophyta
Subdivision	Spermatophytina
Class	Magnoliopsida
Superorder	Asteranae
Order	Solanales
Family	Solanaceae
Genus	*Capsicum L.*
Species	*Capsicum annuum L.*
Variety	*Capsicum annuum L.* var. 'Kulai'

Source: Integrated Taxonomic Information System (ITIS)

2.1.3 Botanical Descriptions of Chilli

Capsicum annuum L., a member of Solanaceae is a perennial plant of 2 metre tall shrubs. As a perennial plant, the plant turns woody as the age of plant increases. Besides that, *Capsicum annuum L.* is a dicotyledonous plant of epigaeic germination where the cotyledons may differ in shape and size of different variation (Bosland and Votava, 2012).

a. Root

Roots are responsible for the uptake of water, minerals and other important materials. Chilli plant is recognized to have a taproot system, composed of a large central root (primary root), with smaller roots (lateral roots or secondary and tertiary roots) and root hairs grows. Taproot systems are relatively small in surface area; they are not effective at

absorbing water and nutrients from the soil. However, this type of root system has a large taproot which can store water and nutrients and this is an advantage for the plants to grow in regions with minimal water (Anonymous, 2013). The roots of chilli plant may extend 20 to 30 cm deep and they remain fairly fine (Department of Agriculture, Forestry and Fisheries, 2013).

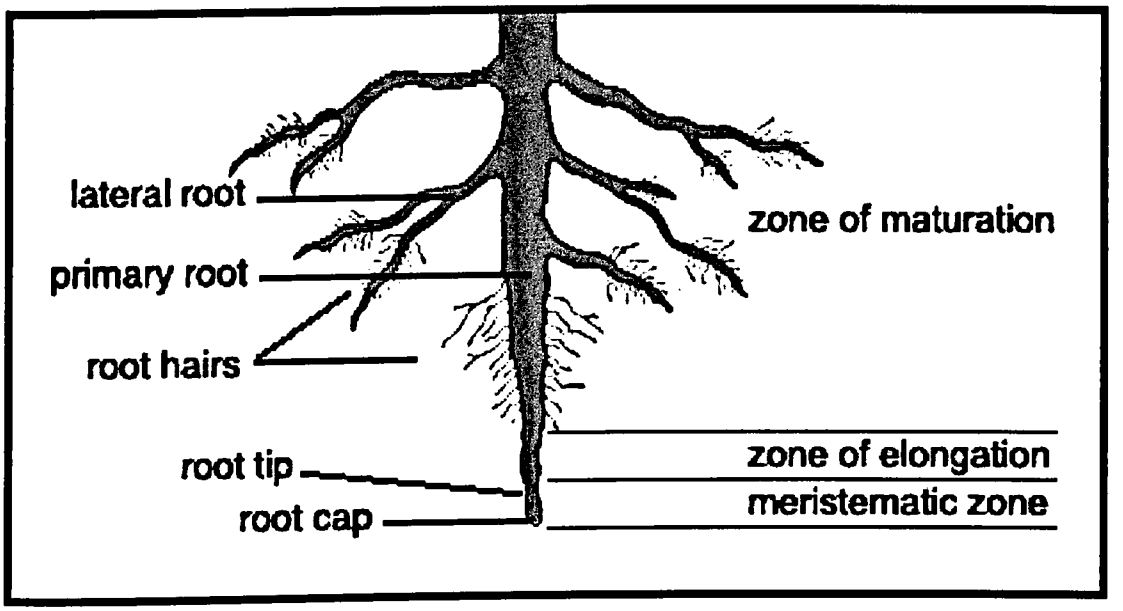


Figure 2.1: Taproot system of *Capsicum annuum L.* plant

Source: Anonymous, 2011.

b. Stem

The stem of chilli plant is organized in concentric layers which are the cuticle, the epidermis, the cortex, the central cylinder and the medulla (from the outer layer to inner layer). The cuticle, epidermis and cortex functions as a protective layer for the chilli stem where the cuticle and epidermis act as the external protection to control the water loss by evaporation while cortex is an inner protective layer for the central cylinder consist of xylem and phloem (Rizzi and Tebon, 2005).

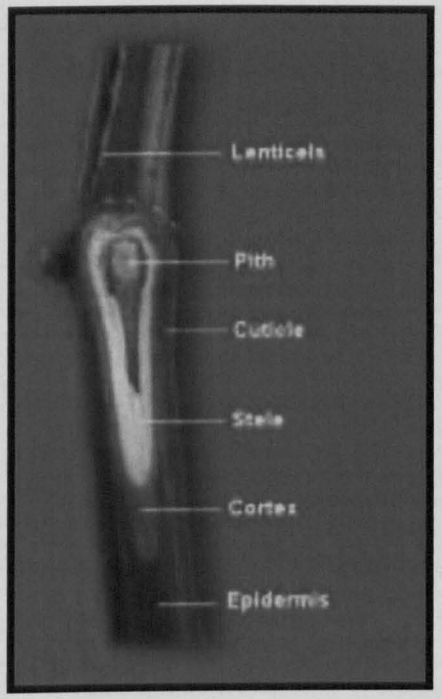


Figure 2.2: Stem structure of *Capsicum annuum L.* plant

Source: Rizzi and Tebon, 2005.

c. Flower

Capsicum species have prefect and complete flower with five sepals, petals, stamens and pistils. The petals or known as corolla, stamens and pistils can be white, greenish-white or purple. The corolla of *Capsicum annuum L.* var. 'Kulai' have white coloured corolla that grow from the auxillary bud (Department of Agriculture, Penang, 2013). High temperatures adversely affect the productivity of many plant species including green pepper. Chilli plant requires optimum day and night temperatures of 25 °C and 21 °C respectively during flowering. The exposure of flowers to temperatures as high as 33 °C for longer than 120 hours leads to flower abscission and therefore reduced yields. Pollen exposed to high temperatures normally becomes non-viable and appears to be deformed, empty and clumped (Department of Agriculture, Forestry and Fisheries, 2013).

Figure 2.3: Flower of *Capsicum annuum L.* plant

Source: Rizzi and Tebon, 2005.

d. Fruit

The varieties and cultivars of *Capsicum annuum L.* are classified by their fruit shapes. The fruit is a berry and may be green, yellow, or red when ripe (Zhigila *et al.*, 2014). The fruit skin colour of chilli changes from green, purple to red and their skin is a waxy coated type. Meanwhile, the red colour in chillies is mainly due to the carotenoid pigments. There are almost 37 pigments have been isolated from capsicums, of which capsanthin is the major red pigment of chillies contributing towards 35 percent of the total pigments and the other major carotenoids which contribute to red colour are capsolubin and zeaxanthin with 6.4 percent and 2.3 percent respectively (Pradesh, 1999).

Different variety of *Capsicum annuum L.* can be identified according to the characteristics such as plant height, fruit length and fruit weight of chilli. Chilli of variety 'Kulai' has a fruit length in the range of 10 cm to 15 cm and the fruit weight with 7 g to 10 g per fruit (MARDI, 2005).

Table 2.2 The Characteristic of *Capsicum annuum L.* Varieties

Variety	Plant Height (cm)	Fruit Length (cm)	Fruit Weight (g)	Production (t/ha)
MC 11	85-110	8-10	7-10	17-24
MC 12	60-80	10-13	12-14	15-29
Kulai	70-80	10-15	7-10	15-20

Source: MARDI, 2005.

2.1.4 Growth and Development of *Capsicum annuum L.* Plant

a. Germination Process

Germination is known to be the first phase for chilli planting. There are various techniques that can be practised for germination. One of the techniques is cultivation with soil on plastic cups or germination tray with hole underneath to prevent accumulation of water and also suitable soil, mixture of soil and sand need to be used to ensure root penetration (Rizzi and Tebon, 2005).

During germination, the soil must be moist but not wet as moisture helps seeds to sprout by softening their pods. Pre-soaking the seeds before germinating helps to speed up the germination process where the seeds will sprout for few days to few weeks (Anonymous, 2010). Furthermore, a way is suggested to maintain the moisture of soil which is by covering with dark or black plastics (Mohd. Yaseer *et al.*, 2012).

As the seeds had germinated, a small white root can be seen. The seeds should be transplanted in the pot or soil bed before the roots elongate which then causes the roots to be restricted to grow and lastly stunted plant is produced (Rizzi and Tebon, 2005). Therefore, the seedlings should be transplanted after they had four to six true leaves or about 5 cm in height (Anonymous, 2010).

b. Transplanting

Transplanting is to move a plant or seedling from soil or culture medium to another. Transplanting helps to establish a well-distributed stand of plants, reduces seed and thinning cost and also requires less cultivation and irrigation. Besides that, transplanted plants are more uniform, can tolerate early biotic and abiotic stress and achieve early maturity stage compared to direct seeding method (Bosland and Votava, 2012).

c. Vegetative Growth Stage

This stage is where plants prepare or harden-off after transplanting to another medium. Thickening of cell walls and the development of roots would happen at this stage as the plants attempt to retain turgor. Nutrients should be given to encourage roots to elongate to search for the nutrients given. One of the physiological responses that the seedlings undergo during this process is the deposition of lignin in the cell walls (Grey and Webster, 2012).

d. Flowering Stage

Flowering is known to be the most sensitive stage in developing the yields of plants because it can be easily affected by air temperature especially the night air temperature. Flower generally opens three hours after sunrise and stay opens for less than 24 hours while the anthers may open from one to ten hours after the flower opens (Bosland and Votava, 2012).

e. Fruit Development Stage

Fruit development is dependent on the ovule development, whether it is fertilized or not. The shape of fruit is based on cell division which takes place at the pre-anthesis stage will the fruit size are determined by the elongation during anthesis and postanthesis (Munting,

1974). During fruit ripening, the pod colour would change from green to red which shows that chlorophyll disappears and the carotenoid content increases. Carotenoids are responsible for the colour of yellow, orange and red colour in fruits. The amount of carotenoids in chilli fruit are controlled by the plant genotype and environment factors (Bosland and Votava, 2012).

f. Harvesting Stage

The suitable maturity levels that are suitable for harvesting is the level 3, 4 and 5 which is near mature, mature and over ripe fruit respectively (Drevale, 2014).

2.1.5 Maturity Index of *Capsicum annuum L.*

There are 6 level of maturity index for chilli which are immature, slight mature, near mature, mature, fully ripe and lastly over ripe (Drevale, 2014).

Table 2.3 The physiological maturity index of *Capsicum annuum L.*

Level	Maturity Level	Colour of fruit
1	Immature	Light green
2	Slight mature	Dark green
3	Near mature	Red greenish/ green reddish
4	Mature	Dark red
5	Fully ripe	Fully red
6	Over ripe	Red blackish

Source: Drevale, 2014.

REFERENCES

Ministry of Agriculture and Agro-Based Industry (MARDI), Malaysia. 2014. *Agrofood Statistics.* April 2015. 164

Akinbile, C. O. and Yusoff, M. S. 2011. Growth, Yield and Water Use Pattern of Chilli Pepper under Different Irrigation Scheduling and Management. *Asian Journal of Agricultural Research.* 1819-1894

Ali, M. A., Golam Sarwar, A. K. M. and Azad-Ud-Doula Prodhan, A. K. M. 1999. Effect of Water Stresses on the Growth Features of Different Maize (*Zea mays L.*) Cultivars. *Pak. J. Bot.* **31(2):** 455-460

Alias, I. 2014. Kegunaan Baja NPK Hijau 15-15-15. http://www.kebunbandar.com/kegunaan-baja-npk-hijau-15-15-15/. Access on 25 August 2016.

Anonymous. 1998. Potassium Deficiency Symptoms in Some Crops. *Better Crops.* **82:** 20-23.

Anonymous. 2010. Growing and Germination. http://www.chileplanet.eu/germination.html. Access on 20 August 2016.

Anonymous. 2011. Botany. My Year in Horticulture. https://diggingdazza.wordpress.com/2011/04/06/week-7/. Access on 11 August 2016.

Anonymous. 2013. Growing Chilli. Jungle Rain, Boutique Chilli Sauces. http://junglerain.com.au/chilli-info/growing-chilli. Access on 11 August 2016.

Bosland, P. W. and Votava E. J. 2012. Peppers: Vegetables and Spice Capsicums. Crop Production Science in Horticulture Series 22. 2nd edition. *CAB International.* 230

Black, L. L., Grenn, S. K., Hartman, G. L. and Poulos, J. M. 1991. Pepper Diseases: A Field Guide. *Asian Vegetable Research Development Center, AVRDC Publication.* 98

Chavarria, G. and Santos, H. P. D. 2012. Plant Water Relations: Absorption, Transport and Control Mechanisms. Montanaro, G and Dichio, B (Eds.). *Advance in Selected Plant Physiology Aspects. InTech.* 105-132

Department of Agriculture, Forestry and Fisheries. 2013. Sweet Pepper (*Capsicum annuum*). March 2013. 20

Department of Agriculture, Penang. 2013. http://jpn.penang.gov.my/index.php/teknologi-tanaman-2/sayur-sayuran/74-cili-sp-2439. Access on 11 August 2016.

Dezfouli, M. M. S., Mat, S., Mohd Hafidz, R., Sopian, K. 2013. Evaluation of Drying Chili by Two Methods: Solar Assisted Heat Pump Dryer and Open Sun Drying. *Latest Trends in Renewable Energy and Environmental Informatics.*

Drevale, R. 2014. http://www.slideshare.net/RioneDrevale/chili-39036164. Access on 28 August 2016.

Ermina Sari. 2007. Development of Processing Technique for the Production of Chilli (*Capsicum annuum* variety Kulai) Puree. Master of Science. Universiti Putra Malaysia.

Farooq, M., Wahid, A. Kobayashi, N., Fujita, D. and Basra, S. M. A. 2009. Plant Drought Stress: Effects, Mechanisms and Management. *Agronomy for Sustainable Development, Springer.* **29(1)**: 185-212

Ferguson, M. H. 1959. The Role of Water in Plant Growth. *USGA Journal and Turf Management.*

Garnier, E. and Berger, A. 1986. Effect of Water Stress on Stem Diameter Changes of Peach Trees Growing in the Field. *Journal of Applied Ecology.* **23(1):** 193-209.

Gorry, S. C. 2004. Fertilizing Basics. Fine Gardening. http://www.finegardening.com/fertilizing-basics. Access on 2 September 2016.

Grey, T. L. and Webster, T. M. 2012. Transplant Production. Russo, V. M. (Eds.). Peppers: Botany, Production and Uses. *CAB International.* 57-68

Gunawardena, M. D. M. and De Silva, C. S. 2014. Identifying the Impact of Temperature and Water Stress on Growth and Yield Parameters of Chilli (*Capsicum annuum L.*). *OUSL Journal.* **7**: 25-42

Hayatu, M., Muhammad, S. Y. and Habibu, U. A. 2014. Effect Of Water Stress On The Leaf Relative Water Content And Yield Of Some Cowpea (*Vigna Unguiculata (L) Walp.*) Genotype. *International Journal of Scientific & Technology Research.* **3(7):** 148-152

Hussain, F. and Abid, M. 2011. Pests and Diseases of Chilli Crop in Pakistan*: A Review. Int. J. Biol. Biotech.*, **8 (2)**: 325-332

Integrated Taxonomic Information System (ITIS). 1990. Taxonomic Hierarchy. https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=30492#null. Access on 4 May 2016.

Iqbal, S., Inam, A., Sahay, S. and Inam, A. 2015. Growth, Physiological, Yield and Quality Response in Chilli (*Capsicum annuum L.*) Under Wastewater Irrigation and Different Levels of Phosphorus. *American Journal of Experimental Agriculture.* **5(1):** 70-81

Jabatan Pertanian Malaysia. 2009. Pakej Teknologi Cili. *Kementerian Pertanian dan Industri Asas Tani, Malaysia.* 36

Jaleel, C.A., P. Manivannan, A. Wahid, M. Farooq, R. Somasundaram and R. Panneerselvam, 2009. Drought Stress in Plants: A Review on Morphological Characteristics and Pigments Composition. *Int. J. Agric. Biol.* **11**: 100–105

Khan, M. A. I., Faroque, A. M., Haque, M. A., Rahim, M. A., Hoque, M. A. 2008. Effects of Water Stress at Various Growth Stages on the Physio-morphological Characters and Yield in Chilli. *Bangladesh J. Agril. Res.* **33(3):** 353-362

Kraft, K. H., Brown, C. H., Nabhan G. P., Luedeling, E., Luna Ruiz, J. J., d'Eeckenbrugge, G. C., Hijmans, R. J. and Gepts, P. 2013. Multiple Lines of Evidence for the Origin of Domesticated Chili Pepper, *Capsicum annuum*, in Mexico. *Proceedings of the National Academy of Sciences.* 6 September 2013. United States of America. 6165-6170.

Surendar, K. K., Rajendran, V., Durga Devi, D., Jeyakumar, P. Ravi, I. and Velayudham, K. 2013. Impact of Water Deficit on Growth Attributes and Yields of Banana Cultivars and Hybrids. *African Journal of Agricultural Research.* **8(48)**: 6116-6125

Lamb, R. S. 2012. Abiotic Stress Responses in Plants: A Focus on the SRO Family. Montanaro, G and Dichio, B (Eds.). *Advance in Selected Plant Physiology Aspects. InTech.* 3-22

Lin, W. C. and Saltveit, M. 2012. Greenhouse Production. Russo, V. M. (Eds.). Peppers: Botany, Production and Uses. *CAB International.* 57-68

Lob, S. 2009. Kesan Interaksi Mikoriza Vesikular-Arbuskular (Mva), Paras Berbeza Vermikas dan Baja Kimia Terhadap Pertumbuhan 3 Varieti Cili (*Capsicum annum L.*) Tempatan. Disertasi Ijazah Sarjana Sains. Universiti Sains Malaysia.

Luvaha, E., Netondo, G. W. and Ouma, G. 2008. Effect of Water Deficit on the Physiological Morphologicsl Characteristics of Mango (*Mangifera indica*) Rootstock Seedlings. *American Journal of Plant Physiology.* **3(1)**: 1-15

Madhavi, K. R., Shivashankara, K. S., Geetha, G. A. and Pavithra, K. C. 2016. *Capsicum* (Hot Pepper and Bell Pepper). Srinivasa Rao, N. K., Shivashankara, K. S. and Laxman, R. H. (Eds.). *Abiotic Stress Physiology of Horticultural Crops.* 151-166.

Marini, R. P. and Reighard G. L. 2008. Crop Load Management. Layne D. R. and Bassi, D. (Eds.). The Peach: Botany, Production and Uses. *CAB International.* 289-302

Mc Dougall, S., Watson, A., Stodart, B., Napier, T., Kelly, G., Troldahl, D. and Tesoriero, L. 2013. Tomato, Capsicum, Chilli and Eggplant. *Australian Centre for International Agricultural Research.* 232

Mohd. Yaseer, S., Shahid, M., Abd. Manas, M. and Yusoff, A. K. 2012. Penanaman Cili Menggunakan Sistem Fertigasi Terbuka. *Buletin Teknologi MARDI.* **1**: 89-96

Munting, A. J. 1974. Development of Flower and Fruit of *Capsicum annuum L. Acta Botanica Neerlandica.* **23(4)**: 415-432

Naik, L. B. 2004. Irrigational Aspects of Capsicum. Krishna, A. D. (Eds.). Capsicum: The Genus Capsicum. *Taylor & Francis Group.* 129-137

Osakabe, Y.,Osakabe, K., Shinozaki, K. and P.Tran, L. S. 2014. Response of Plants to Water Stress. *Frontiers in Plant Science, Plant Physiology.* **96(4)**

Pradesh, A. 1999. Morphology and Growth. http://www.ikisan.com/tg-chilli-morphology-growth.html. Access on 28 July 2016.

Quiros, C. F. 2010. Solanacea: Pepper: Capsicum spp. Wild and Domesticated Species, Identification. http://www.plantsciences.ucdavis.edu/vc221/pepper/PEPPERrd.htm. Access on 11 August 2016.

Redaksi AgroMedia. 2008. Budi Daya Caba Hibrida. 3rd Edition. *PT AgroMedia Pustaka.* 57

Rizzi, N. and Tebon, S. 2005. Anatomy of Chili, and Its Flower. http://www.chileplanet.eu/Chili-anatomy.html. Access on 28 July 2016.

Rizzi, N. and Tebon, S. 2005. Germination and Cultivation of Chilli. http://www.chileplanet.eu/germination.html. Access on 28 July 2016.

Small, M. 2011. Plant Pathology. *Colorado State University Extension.* 331-20

Sumarni, N. and Muharam, A. 2011. Sukses Bertanam Cabai Dimusim Hujan dan Kemarau. 2nd Edition. *Perpustakaan Nasional RI: Katalog Dalam Terbitan (KDT).* 56

Vinje, E. 2012. What's in a Number? Planet Natural Research Centre. https://www.planetnatural.com/fertilizer-numbers/. Access on 2 September 2016.

Wade, N. C., Wane, S. S. and Kshirsagar, S. M. 2014. Comparative Study of Drying Characteristics in Chillies. *Ind. J. Sci. Res. and Tech.* **2(3):**105-111

Zhao, D., Reddy, K. R., Kakani, V. G. and Reddy V. R. 2005. Nitrogen Deficiency Effects on Plant Growth, Leaf Photosynthesis, and Hyperspectral Reflectance Properties of Sorghum. *European Journal of Agronomy.* **22**: 391-403.

Zhigila, D. A., AbdulRahaman, A. A., Kolawole, O. S. and Oladele F. A. 2014. Fruit Morphology as Taxonomic Features in Five Varieties of *Capsicum annuum L.* Solanaceae. *Journal of Botany*