



UNIVERSITI PUTRA MALAYSIA

**EFFECT OF WATER DEFICIT ON GROWTH AND LEAF GAS
EXCHANGE OF PEPPER PLANTS (CAPSICUM ANNUUM L)**

MOHAMED HAMAD AWAD

FP 2001 12

**EFFECT OF WATER DEFICIT ON GROWTH AND LEAF GAS
EXCHANGE OF PEPPER PLANTS (*CAPSICUM ANNUUM* L)**

By

MOHAMED HAMAD AWAD

**Thesis Submitted in the Fulfilment of the Requirement for the Degree of Doctor
of Philosophy in the Faculty of Agriculture
Universiti Putra Malaysia**

November 2001



DEDICATION

To the soul of my beloved father in the heavens (*Rahmatullah alieh*), who regretfully did not live to see this work, which resulted from his gift of many years of love to me.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement of the degree of Doctor of Philosophy

EFFECT OF WATER DEFICIT ON GROWTH AND LEAF GAS EXCHANGE OF PEPPER PLANTS (*CAPSICUM ANNUUM* L.)

By

MOHAMED HAMAD AWAD

November 2001

Chairman: Associate Professor Mohd. Razi Ismail, Ph.D.

Faculty: Agriculture

The effect of different treatments of soil moisture on leaf gas exchange, growth and several metabolic parameters was investigated in three cultivars of chilli pepper plants *Capsicum annum* L. The study was done in potted plants under protective environment agriculture. The alteration in tissue water relations of leaves at different water deficit regimes was studied by pressure chamber techniques. Results revealed that the rate of photosynthesis decreased as leaf water status declined, and was more closely related to leaf water potential. Leaf conductance and net photosynthesis were significantly correlated to leaf water potential in severe water deficit. The close relationship between leaf conductance and net photosynthesis found at different level of water deficit showed that stomatal regulation effectively controlled the water balance (low transpiration rates) of the leaf at the expense of lower rate of photosynthesis. Re-watering stressed plants brings all leaf gas exchange parameters near to that of control plants. Stomatal conductance of chili pepper plants is more sensitive to soil drying and start to close

before any appreciable reduction in leaf water potential, suggesting that there is signal coming from the root system trigger stomatal closure.

Exposure to soil drying progressively reduce leaf soluble protein content and increase the level of accumulated proline. Measuring peroxidase activity level and xylem sap pH revealed that both parameters increase during soil drying and leaf expansion rates fall. This suggests that there is a role for both parameters in controlling leaf expansion rate.

In another experiment, plants were subjected to partial root drying and the roots in contact with the drying soil were removed. The results revealed that leaf gas exchange parameters and leaf elongation rates declined, the removal of roots in contact with drying soil trigger the increment of leaf gas exchange parameters and leaf growth rates. This suggests that there is a positive signal coming from the root system controlling shoot processes which could be used in agriculture to minimize plants water requirements and to regulate growth.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia bagi memenuhi syarat untuk mendapatkan ijazah Doktor Falsafah

KESAN TEGASAN AIR PADA TUMBESARAN DAN PERTUKARAN GAS DAUN PADA POKOK CILI (*CAPSICUM ANNUUM* L)

Oleh

MOHAMED HAMAD AWAD

November 2001

Pengerusi: Profesor Madya Mohd Razi Ismail, Ph.D.

Fakulti: Pertanian

Kesan daripada perbezaan rawatan kelembapan tanah pada pertukaran gas daun, tumbesaran dan beberapa parameter metabolik telah dikaji pada 3 kultivar cili *Capsicum annuum* L. Kajian telah dilakukan pada tanaman dalam pasu dengan persekitaran yang terkawal. Perubahan kesan daripada tegasan air yang berbeza telah dikaji dengan kaedah *pressure chamber*. Hasil yang didapati bahawa kadar fotosintesis menurun dengan pengurangan status air daun, dan demikian juga dengan potensi air daun. Konduksi stomata daun dan fotosintesis bersih berhubungan secara bermakna dengan potensi air daun yang rendah pada tegasan air yang teruk. Hubungan yang erat antara konduksi stomata daun dan fotosintesis bersih didapati pada peringkat tegasan air yang berbeza menunjukkan bahawa pengaturan stomata secara efektif dikawal oleh keseimbangan air daun (pada peringkat transpirasi yang rendah). Pemberian air semula kepada pokok yang mengalami tegasan mengembalikan pertukaran gas daun menghampiri rawatan kawalan. Konduksi stomata cili lebih sensitif terhadap pengeringan tanah dan stomata mula menutup

sebelum penurunan potensi air daun yang berarti. Hal ini menunjukkan bahawa arahan yang datang dari akar memacu penutupan stomata.

Pendedahan pada pengeringan air yang berterusan menurunkan kandungan protein dan meningkatkan kandungan jumlah prolin daun. Pengukuran aktiviti peroksidase dan pH cecair xylem menunjukkan bahawa kedua parameter tersebut meningkat selama pengeringan tanah dan penurunan pembesaran daun. Kenyataan ini menunjukkan bahawa kedua parameter itu mengawal pembesaran daun.

Dalam kajian pengeringan akar sebagian dan pembuangan akar pada bahagian yang mengalami tegasan air, memberikan hasil bahawa parameter pertukaran gas daun dan pemanjangan daun menurun. Pembuangan akar pada bahagian yang mengalami tegasan air memacu penambahan pertukaran gas daun dan pertumbuhan daun. Hal ini menunjukkan bahawa arahan positif dari sistem akar mengawal pertumbuhan pucuk, yang dapat digunakan dalam pertanian untuk mengurangkan pemberian air pada pokok dan untuk mengawal-atur pertumbuhannya.

ACKNOWLEDGMENTS

I would like to express my sincere thanks and profound appreciation to the chairman of my supervisory committee, Assoc. Prof. Dr. Mohd. Razi Ismail. Under his supervision, I have received heaps of assistance without which this work could not have been a reality. I am also indebted to Professor Marziah bit Mahmood, my co-supervisor who supplied me with the necessary chemicals and laboratory equipment to do my job far more effectively. Besides, her constructive criticism was most valuable. Special thanks to Dr. Mahmud T. M. Mohamed for his time and advice as a member of the supervisory committee, as well as for his encouragement and friendship.

I am certainly grateful to Professor Bill Davies for his most valuable support and his precious invitation to Lancaster University, UK. permitting me to run part of this research work in his laboratory, and for providing me with all the facilities needed, plus his valuable suggestions. His keen and critical assistance has doubtlessly contributed a lot to the completion of the research work. I also would like to thank Dr. M. A. Bacon, Dr. D. S.Thompson, and Dr. Sally Wilkinson (the “Three Musketeers”, lab 14), for their support and guidance while I was working in their lab in Lancaster. My sincere gratitude and thanks go to my truly Brother Ustaz Sulaiman Dufford, who generously offered me his computer, without which the writing of this manuscript and all my work during my studies would have been very time consuming.

My appreciation and honest thanks are due to all staff members from Department of Crop Science for their willing assistance and help during my studies, in particular, Dr. Ridzwan head department and Dr. Anuar Abd Rahim for their assistance in statistical analysis, and for their valuable suggestions and useful criticism. Moreover, I'm very thankful to the Dean of faculty of Agriculture Prof. Dr Mohd. Yousof Hussein for his encouragement.

Completing this research work owes much to my wife Suhair, for her encouragement, moral and financial support, which made life easy throughout my studies. I am very grateful to her. Last but not least, I would like to acknowledge my intimate and loving children, Alharith, Faiha and the naughty restless Isra, who donated great patience and much time, that would have otherwise been spent playing with them during the course of my studies. Special thanks to my son Muhand, and daughter Shiema, who also donated much time as they exerted great efforts concentrating on their own lessons. My salute for their patience and understanding. My special appreciation and gratitude go on particularly to my family in Sudan, and all friends for being a source of encouragement, and always ready to offer a helping hand.

Finally, most profound thanks go to the Malaysian government represented by Universiti Putra Malaysia, for giving me this opportunity to study in their prestigious and reputed institute, and to the Malaysian Technical Corporation Program (MTCP), for funding the registration fees for the research studies.



This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the Degree of Doctor of Philosophy.

AINI IDERIS, Ph.D.,
Professor/ Dean of Graduate School,
Universiti Putra Malaysia

Date:

TABLE OF CONTENTS

		Page
DEDICATION		ii
ABSTRACT		iii
ABSRAK		v
ACKNOWLEDGEMENTS		vii
APPROVAL SHEETS		ix
DECLARATION FORM		xi
LIST OF TABLES		xv
LIST OF FIGRURES		xvii
CHAPTER		
1	INTRODUCTION	1
2	LITREATURE REVIEW	6
	2.1 Water and Processes in Plants	6
	2.2 Plant Water Relations	7
	2.3 Water Deficit and Plant Growth	7
	2.3.1 Leaf Growth	7
	2.3.2 Root Growth	9
	2.4 Water Deficit and Leaf Gas Exchange	10
	2.5 Water Deficit and Reproductive Development	12
	2.6 Response of Plant After Re-watering	16
	2.7 Water Deficit and Proline Accumulation	20
	2.8 Water Deficit and Protein Content	23
	2.9 Water Deficit and Peroxidase Activity	25
	2.9.1 Role of Peroxidases	26
	2.10 Plant Water Deficit and Xylem Sap pH	27
	2.10.1 Role of Apoplastic pH	28
	2.11 The Sense of Soil Water Status	29
	2.11.1 ABA as a Candidate of the Root Signal	30
3	GENERAL MATERIALS AND METHODS	33
	3.1 Measurements of Leaf Gas Exchange	33
	3.1.1 Photosynthetic and Transpiration Rate	33
	3.1.2 Stomatal Conductance	33
	3.1.3 Leaf Water Potential	34
	3.2 Vegetative Growth Parameters	34
	3.2.1 Leaf Growth Increment	34
	3.2.2 Leaf Area and Plant Weight	35

4	EFFECT OF WATER DEFICIT ON GROWTH AND LEAF GAS EXCHANGE RESPONSES OF PEPPER PLANTS <i>CAPSICUM ANNUUM</i> L	36
	4.1 Introduction	36
	4.2 Materials and Methods	37
	4.2.1 Experimental Site	37
	4.2.2 Experimental Treatments and Design	37
	4.2.3 Determination of Field Capacity (F.C)	39
	4.2.4 Leaf Gas Exchange	40
	4.2.5 Growth	40
	4.2.6 Statistical Analysis	40
	4.3 Results	41
	4.3.1 Leaf Gas Exchange	41
	4.3.2 Plant Growth	56
	4.4 Discussion	65
5	EFFECT OF SOIL DRYING AND RE-WATERING ON LEAF GROWTH, LEAF GAS EXCHANGE AND PROLINE ACCUMULATION OF THREE <i>CAPSICUM</i> CULTIVARS	73
	5.1 Introduction	73
	5.2 Materials and Methods	73
	5.2.1 Plant Material and Soil Preparation	73
	5.2.2 Experimental Design	76
	5.2.3 Leaf Gas Exchange	76
	5.2.4 Leaf Growth	77
	5.2.5 Proline Assay	77
	5.2.6 Protein Extraction	78
	5.2.7 Statistical Analysis	78
	5.3 Results	79
	5.3.1 Soil Water Content	79
	5.3.2 Midday Leaf Water Potential (LWP)	81
	5.3.3 Stomatal Conductance	84
	5.3.4 Photosynthetic Rate	87
	5.3.5 Proline Accumulation	90
	5.3.6 Soluble Protein Content	90
	5.3.7 Leaf Growth Increment	92
	5.4 Discussion	95
	5.4.1 Leaf Gas Exchange	95
	5.4.2 Proline Accumulation and Protein Content	95
	5.4.3 Leaf Growth Increment	96
6	THE INVOLVMENT OF CELL WALL ASSOCIATED PEROXIDASE ACTIVITY AND XYLEM SAP pH IN LIMITING PEPPER <i>CAPSICUM ANNUUM</i> L. LEAF EXPANSION UNDER WATER DEFICIT	98
	6.1 Introduction	98
	6.2 Materials and Methods	99

6.2.1	Experimental Site	99
6.2.2	Soil Moisture Content	100
6.2.3	Leaf Water Potential and Sap Collection for pH Determination	100
6.2.4	Spatial Distribution of Leaf Expansion	100
6.2.5	Validation of Cell Wall Associated Peroxidase Extraction Assay	101
6.2.6	Extraction and Assay of Cell Wall Peroxidase Activity	102
6.2.6	Extensiometric Assay	105
6.3	Results	106
6.3.1	Soil Moisture Content	106
6.3.2	Midday Leaf Water Potential	108
6.3.3	Xylem Sap pH	108
6.3.4	Leaf Expansion Rate	111
6.3.5	Spatial Distribution of Leaf Expansion	113
6.3.6	Spatial Distribution of Cell Wall-associated Peroxidase Activity	113
6.3.7	Relationship between Spatial Distribution of Peroxidase Activity and Leaf Growth	117
6.3.8	Extensiometric Results	117
6.4	Discussion	120
7	THE EXPLOITATION OF ROOT –SOURCED SIGNALS TO REDUCE IRRIGATION AND TO REGULATE LEAF GROWTH OF PEPPER PLANTS <i>CAPSICUM ANNUUM</i> L	125
7.1	Introduction	125
7.2	Experimental Hypothesis	126
7.3	Materials and Methods	127
7.3.1	Experimental Treatment and Design	127
7.3.2	Leaf Gas Exchange	128
7.3.3	Leaf Expansion Rate	130
7.3.4	Reproductive Growth and Yield	130
7.4	Results	130
7.4.1	Midday Leaf Water Potential	130
7.4.2	Stomatal Conductance	133
7.4.3	Transpiration Rate	133
7.4.4	Photosynthetic Rate	136
7.4.5	Leaf Length Increment	136
7.4.6	Growth and Reproductive Responses	140
7.5	Discussion	141
7.5.1	Water Relations and Leaf Gas Exchange	141
8	GENERAL DISCUSSION AND CONCLUSION	146
	REFERENCES	153
	APPENDICES	173
	BIODATA OF AUTHOR	184



LIST OF TABLES

Table	Page	
1.1	Water scarcity in twentieth century	2
1.2	Detail of reports on stomatal opening of droughted plants Regulated by ABA	18
4.1	Main effect of three watering regimes on midday leaf water Potential of three capsicum cultivars	43
4.2	Main effect of three watering regimes on stomatal conductance of three capsicum cultivars	48
4.3	Main effect of three watering regimes on photosynthetic rate of three capsicum cultivars	52
4.4	Changes of leaf area of three capsicum cultivars grown under three watering regimes	58
4.5	Changes of leaf dry weight of three capsicum cultivars grown under three watering regimes	60
4.6	Changes of stem dry weight of three capsicum cultivars grown under three watering regimes	61
4.7	Effect of watering level on % dry matter distribution of Shoot and root: shoot ratio of three capsicum cultivars	63
4.8	Changes of flower dry weight of three capsicum cultivars Grown under three watering regimes	64
4.9	Changes of root dry weight of three capsicum cultivars grown under three watering regimes	66
5.1	Effect of water deficit and re-watering on midday leaf water potential of three capsicum cultivars	82
5.2	Effect of water deficit and re-watering on stomatal Conductance of three capsicum cultivars	86
5.3	Effect of water deficit and re-watering on photosynthetic rate of three capsicum cultivars	89
6.1	Leaf elongation rate (cm/day) of currently expanding leaf of Well watered plants and plants growing in drying soil for 9 Days	111
6.2	Peroxidase activity level of leaf number 4 from the top of	

	well watered plants and plants growing in drying soil for 9 days	115
7.1	Growth responses of <i>Capsicum annuum</i> L. cv. Mc12 grown either under well-watered (control) or the other half allowed to dry moisture over 10 days.	140

LIST OF FIGURES

Figure		Page
1.1	World map showing water status in the planet for the coming 25 years	3
4.1	Maximum and minimum temperature inside the glasshouse for the first drying cycle	38
4.2	Changes of midday leaf water potential of three <i>Capsicum annum</i> L. cultivars under three levels of water deficit conditions	42
4.3	Effect of three watering treatments on midday leaf water potential of three <i>Capsicum annum</i> L. cultivars	44
4.4	Changes of midday stomatal conductance of three <i>Capsicum annum</i> L. cultivars grown under three watering regimes	46
4.5	Effect of three watering regimes on stomatal conductance of three <i>Capsicum annum</i> L. cultivars	47
4.6	Changes of photosynthetic rate of three <i>Capsicum</i> cultivars grown under three watering regimes	50
4.7	Effect of three watering regimes on photosynthetic rate of three <i>Capsicum annum</i> L. cultivars	51
4.8	Relationship between leaf gas exchange parameters of three <i>Capsicum</i> cultivars as affected by three watering regimes	54
4.9	Changes of transpiration rate of three <i>Capsicum annum</i> L. cultivars grown under three watering regimes	55
4.10	Relationship between leaf water potential and water use efficiency of <i>Capsicum annum</i> L. cultivars grown under three watering regimes	57
5.1	Mean day temperature inside the experimental site measured during the drying cycle.	75
5.2	Soil moisture content of the growing media of three <i>Capsicum</i> cultivars grown under two drying cycle	80
5.3	Changes of midday leaf water potential of three <i>Capsicum annum</i> L. cultivars grown either in well watered conditions or under water deficit and re-watered after	

	symptoms of wilting	83
5.4	Change of midday stomatal conductance of three <i>Capsicum annuum</i> L. cultivars	85
5.5	Effect of water deficit and re-watering on photosynthetic rate of <i>Capsicum annuum</i> L. cultivars.	88
5.6	Effect of water deficit and re-watering on proline accumulation of fully matured leaves of three <i>Capsicum annuum</i> L. cultivars	91
5.7	Effect of water deficit and re-watering on leaf protein content of three <i>Capsicum annuum</i> L. cultivars	93
5.8	Effect of water deficit and re-watering on leaf elongation rate of three <i>Capsicum annuum</i> L. cultivars	94
6.1	Assessment of the ability of low and high ionic salt washes to remove and recover peroxidase activity from the Leaf of Capsicum plants grown under well watered conditions	103
6.2	Cell wall associated peroxidase activity plotted as change in light absorbance against time for 4 th and 5 th pellet washes of well watered Capsicum plants	104
6.3	Moisture content of plant growing media which was either well watered or allowed to dry over 10 days	107
6.4	Effect of soil drying on midday leaf water potential of well watered and droughted plants where soil was allowed to dry over 10 days	109
6.5	Effect of soil drying on xylem sap pH of well watered plants and stressed plants that grown in soil allowed to dry over 10 days	110
6.6	Leaf expansion rate of well watered plants and water deficit plants where water withheld for 10days	112
6.7	Spatial distribution of leaf expansion rate of well watered plants and plants where water was withheld for 10 days	114
6.8	Spatial distribution of cell wall associated peroxidase activity of well watered plants and water deficit plants where water was withheld for 10 days	116
6.9	Spatial distribution of cell wall associated peroxidase activity and leaf expansion rate of currently expanding leaf of Capsicum plants under well watered or during soil	

	drying	118
6.10	Extensiometric data of relative growth rate of leaves of well watered and stressed plants over 10 days of Capsicum plants	119
7.1	Schematic representation of partial root drying technique	129
7.2	Midday leaf water potential of Capsicum plants cv. MC12 grown under well-watered condition or half of the root system allowed to deplete soil moisture over weeks.	132
7.3	Stomatal conductance of Capsicum cultivar MC12 both halves of the root system grown under well watered conditions or plants were grown half of the root system in drying soil and the other half in well watered conditions	134
7.4	Transpiration rate of Capsicum cultivar MC12 grown under well watered conditions or plants grown under partial root drying	135
7.5	Photosynthetic rate of Capsicum cultivar MC12 grown either under well watered conditions of under partial root drying	137
7.6	Leaf elongation rate of Capsicum cultivar MC12 either grown under well watered conditions or under partial root drying	138
7.7	Relationship between photosynthesis, leaf water potential and leaf conductance of well watered plants or plants growing under partial root drying	139

CHAPTER I

INTRODUCTION

Water is one of the principle environmental limiting factors for crop production and distribution throughout the world. Water deficit, which is a consequence of either intermittent or terminal period of drought, causes significant yield reduction on presently cultivated lands (Boyer, 1982; Ludlow and Muchow, 1990). It was found that in fertile soil, plant growth and yield are reduced more often by water deficits than any other cause (Kramer, 1974). These restrictions on yield potential are of great concern in terms of meeting food demand for accelerated increasing world population.

The problem of water deficit is becoming more serious (Table1.1 and Figure1.1) and United Nation Organizations ringing the bell of danger from the looming crisis of drought. Although Malaysia is tropical country characterized by excellent source of water, but incidence of dry periods occur from time to time in some of the agricultural production areas. The fast growing industrial sectors compete with agriculture for water sources, acts as a source of underground water pollution and this will push the agricultural activities to remote areas where water and salinity is the major problems. Consequently, studies in water deficit effect on crop plant seem to be of prime importance now and in the future for proper water use and rational water utilization.

Table 1.1 Water scarcity in the twentieth century

Category 1 (absolute water scarcity)	Category 2 (economic water scarcity)	Category 3	Category 4
Afghanistan	Angola	Albania	Argentina
Egypt	Benin	Algeria	Austria
Iran	Botswana	Australia	Bangladesh
Iraq	Burkina Faso	Belize	Belgium
Israel	Burundi	Bolivia	Bulgaria
Jordan	Cameron	Brazil	Canada
Libya	Congo	C. Africa	China
Oman	Cote d'Ivoire	Chile	Cuba
Pakistan	Ethiopia	Colombia	China
Saudi Arabia	Gabon	El Salvador	Dominican
Singapore	Guinea-Bissau	Gambia	Ecuador
South Africa	Haiti	Guatemala	Finland
Syria	Lesotho	Guinea	France
Tunisia	Liberia	Honduras	Germany
Yemen	Niger	Kenya	Guyana
India*	Paraguay	Madagascar	India*
United Arab Emirates	Zaire	Morocco	Mexico
Kuwait	Chad	Myanmar	Netherlands
China*	Mozambique	New Zealand	N. Korea
	Somalia	Peru	Philippines
	Sudan	Senegal	Portugal
	Uganda	Tanzania	S. Korea
	Nigeria	Venezuela	Japan
		Zambia	Sri Lanka
		Cambodia	Sweden
		Indonesia	Switzerland
		Malaysia	UK
		Mali	Uruguay
		Mauritania	USA

Definitions:

Category 1: These countries face "absolute water scarcity" They will not be able to meet water needs in the year 2025.

Category 2: These countries face "economic water scarcity." They must exert more than double their efforts to extract water to meet 2025 water needs, but they will not have the financial resources available to develop these water supplies.

Category 3: these countries have to increase water development between 25 and 100% to meet 2025 needs, but have more financial resources to do so.

Category 4: these countries will have to increase water development modestly overall on average, by only 5% to keep up with 2025 demands.

*These countries have severe regional water scarcity. Portions of their populations (381 million people in China in 1990 and 280 million people in India in 1990) are in Category 1. The rest of their populations are in Category 4.

Source: WMO, 1996.

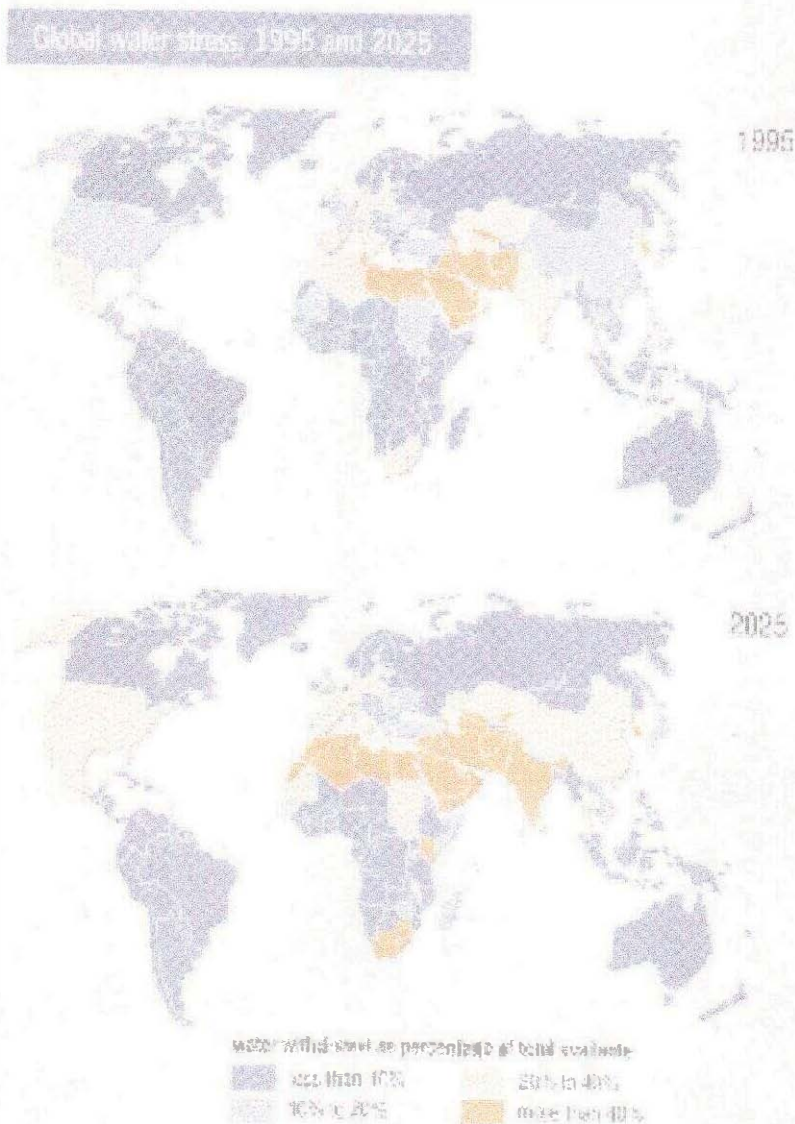


Figure 1.1 World map showing water stress status in the planet for the coming 25 years.

Note: water stress is defined as follows:
 Low less than 10% of total available is withdrawn.
 Moderate 10-20% of total available is withdrawn.
 Medium-high 20-40% of total available is withdrawn.
 High, more than 40% of total available is withdrawn.
 Source WMO and others 1996.

Chilli is a member of the Solanaceae family and the genus *Capsicum* consists of about 30 species. The domesticated species in this genus are *Capsicum annuum*, *Capsicum frutescens*, *Capsicum chinense*, *Capsicum baccatum* and *Capsicum pubescens*.

Capsicum annuum L. was domesticated in Mexico (Andrews 1984) and it is the most important species cultivated all over the world, since it includes all the commercially important sweet pepper and many spicy types. The center of morphological diversity for *C. annuum* is probably Mexico. After Columbus introduced pepper to Europe in 1493, *Capsicum annuum* spread rapidly from Europe to Asia and Africa.

In Malaysia chilli is one of the most important commercially grown fruit vegetable in the low lands. It leads all other vegetables grown in terms of value and per capita consumption. In addition there are a wide range of dishes prepared in Malaysian cuisine have chilli as one of its ingredient with very few that are not spiced by chillies. The domestic production of fresh chilli marketed as green, red and bird chilli is estimated at 21,900 metric tones from farms with total acreage of 2661 ha in 1999 (http://agrolink.moa.my/doa/BI/Statistics/veg02_f.html). Imports of chilli both fresh and dried have increased in recent years with over 18,000 metric tones of dried chilli and over 6,400 metric tones of fresh chilli imported in 1999 (Department of Statistic, Malaysia, 1999). It is no wonder that the chilli plant is prevalent throughout Malaysia.

Pepper production is carried out in open fields and protected structures. Under controlled environment or traditional shade-houses, production factors are often provided in a crude manner. At any stage of development, whether in open field or under protected environment, plants may experience some degree of transient, midday water deficit especially during hot, sunny weather or sometime even when growing in moist soil (Boyer *et al.*, 1995; Kramer, 1983). However, the development of long term water deficit in plants due to progressive reduction of the available soil water which is crucial for overall growth and productivity, may cause severe disturbance of physiological and biochemical processes and hence inducing injury (Hsiao, 1973) and reduction of the crop yields.

How the various plant processes such as leaf gas exchange, proline accumulation, leaf growth which associated with biochemical modification of cell wall and xylem sap pH, intermingle and interact as a response to water deficit need to be understood. Indeed understanding these physiological mechanisms which, is regarding the response of *Capsicum* plants to water deficits form the main objective of this thesis. Therefore the sub-objective of this study is to: -

- 1) Understand the effect(s) of water deficit on growth and leaf gas exchange responses of pepper *Capsicum annuum* L., cultivar Padi, Kulai and MC12.
- 2) Look at the effect of water deficit and re-watering on proline accumulation and leaf gas exchange of pepper plants.
- 3) Address the potential role of cell wall-associated peroxidase activity and xylem sap pH in mediating the leaf expansion response of droughted pepper plants.
- 4) Reduce irrigation and regulate the growth of the pepper plants by the use of partial root drying technique (PRD).