UNIVERSITI PUTRA MALAYSIA

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

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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.)

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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 annuum* 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 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 paremeter 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 pertambahan 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.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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

Category1 (absolute water scarcity)	Category 2 (economic water scarcity)	Category 3	Category 4
Afaganistan	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.

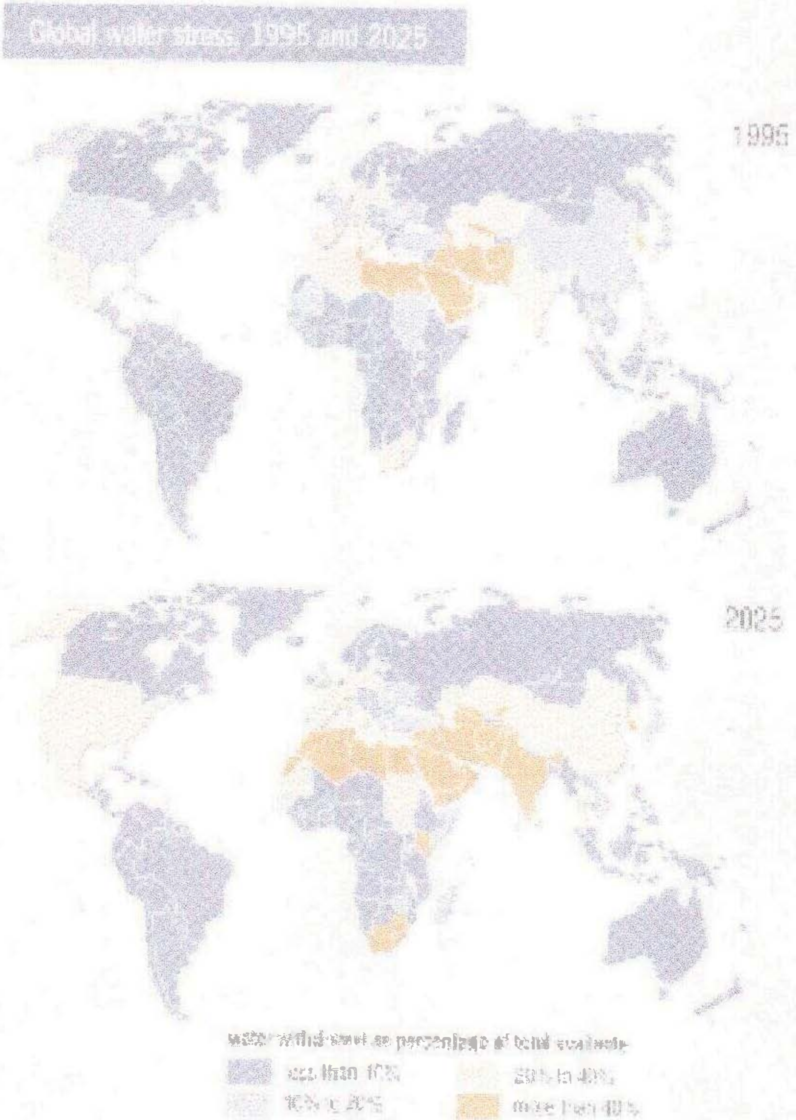

Figure 1.1 World map showing water stress status in the planet for the coming 25 years.

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 frutesence, Capsicum chinense, Capsicum baccatum* and *Capsicum pubescens.*

Capsicum annum 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).