UNIVERSITI PUTRA MALAYSIA

RESPONSE OF OKRA PLANT TO SUBSURFACE DRIP IRRIGATION USING MIXED AGRICULTURAL DRAINAGE WATER

YOUSEF ABDULAZIZ AL-MOLHEM

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By

YOUSEF ABDULAZIZ AL-MOLHEM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

January 2009

Dedicated

To

The souls of my parents

My lovely family, wife, sons and daughters

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

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Chairman: Professor Mohd Amin Mohd Soom, PhD,

Faculty: Engineering

Agriculture in arid areas with its limited water resources will tremendously benefit from drip irrigation. Subsurface drip irrigation system applies water below the soil surface through emitters. It has many advantages over surface drip including better use of low quality drainage water. However there is a need to determine the best irrigation rate and placement of the emitters such that optimal yield can be obtained. A study was carried out to see the response of various moisture regimes supplied through subsurface drip irrigation system using mixed drainage water on the growth and yield of okra *Abelmoschus esculentus* (Climson Spineless CV). An experiment was conducted during November 2006 to May 2007 inside a greenhouse in the Agriculture Research Station at the University of King Faisal in Al-Hasa, Saudi Arabia. The experiment was laid out following a split plot design. The experiment was divided into two main categories of fresh water and mixed-drainage water. Every category consisted of three water quantities (WQ) viz. V1=100%, V2=75% and V3=50% of the water needs. Every water quantity had three replications R1, R2, and R3. Every replication was divided into five irrigation emitter lateral depths D0

cm, D10 cm, D20 cm, D30 cm, and D40 cm. Statistical analysis was performed for all crop performance parameters. The effect of irrigation emitter lateral depths on okra growth parameters such as plant height, number of leaves per plant, okra moisture, root zone width, root zone depth, okra fruit diameter, and average weight of single okra fruit were analyzed. Results were compared for various irrigation emitter lateral depths (LD) and water quantities (WQ) applied. Irrigation emitter lateral at 10 cm depth was found to be the best to grow okra plant using both fresh and mixed drainage water due to higher concentration of roots even with deficit irrigation supplying only 73% of the required water quantity. Yields were lower with emitters at depths of 30 cm and 40 cm due to lower concentration of roots as the root zone width decreased from the ground to D40 cm. The emitter placement beyond 20 cm depth is not recommended for the okra plants, as the root concentration is less beyond that depth. The average okra plant height with full irrigation using fresh water and emitters at the soil surface was 23 cm; however, it was 31 cm using the mixed water, probably due to some salts present in the mixed drainage water. The study showed that good okra harvest is still possible with mixed drainage water at 4.2 dS/m applied using only about three-quarter of the irrigation water requirement as compared to 2.2 dS/m for fresh water. The possibility of using mixed drainage water under deficit irrigation will increase the water availability for agriculture in arid areas. Consequently, better fresh water conservation is possible. A drip irrigation system design that can be considered as a typical system to grow okra plant in arid areas was developed in this study. The results of the experiment and the crop production models achieved from the statistical analysis provide a good example for growing okra using mixed drainage water under deficit irrigation for conservation of fresh water resources in the arid areas.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

RESPON TANAMAN KACANG BENDI TERHADAP PENGAIRAN TITIS SUBPERMUKAAN MENGGUNAKAN ADUNAN AIR SALIRAN PERTANIAN

Oleh

YOUSEF ABDULAZIZ AL-MOLHEM

Januari 2009

Pengerusi: **Professor Mohd Amin Mohd Soom, PhD,**

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Pertanian di kawasan beriklim gersang dengan sumber air yang terhad akan mendapat manfaat daripada pengairan titis. Pengairan titis subpermukaan menyampaikan air di bawah permukaan tanah melalui pemancar. Ia mempunyai banyak kelebihan daripada pengairan titis permukaan termasuklah penggunaan lebih berkesan sumber air saliran berkualiti rendah. Namun, terdapat keperluan untuk menentukan kadar pengairan dan kedudukan terbaik pemancar supaya hasil tuaian optimum dapat diperolehi. Satu kajian telah dijalankan untuk melihat respon pada tumbesaran dan hasil tanaman kacang bendi *Abelmoschus esculentus* (Climson Spineless CV). Ujikaji telah dijalankan dari bulan November 2006 sehingga Mei 2007 dalam sebuah rumah hijau di Stesen Penyelidikan Pertanian Universiti Raja Faisal di Al-Hasa, Arab Saudi. Ujikaji tersebut dibuat mengikut satu rekabentuk plot berasingan. Ujikaji dibahagikan kepada dua kategori utama iaitu air tawar dan air saliran campuran. Setiap kategori mempunyai tiga kuantiti air (WQ) iaitu V1 = 100%, V2 = 73% dan V3 = 50% daripada keperluan air untuk tanaman kacang bendi. Setiap kuantiti air mempunyai tiga replikasi R1, R2 dan R3. Setiap replikasi

dibahagikan kepada lima kedalaman pemancar di saluran sisi pengairan D0 cm, D10 cm, D20 cm, D30 cm, dan D40 cm. Analisis statistik dijalankan bagi mencapai objektif kajian untuk semua parameter prestasi tumbesaran tanaman. Kesan daripada kedalaman pemancar pengairan telah dianalisis pada parameter bendi seperti ketingggian pokok, bilangan daun per pokok, kelembapan buah bendi, kelebaran zon akar, kedalaman zon akar, garispusat bendi, dan purata berat buah bendi. Hasil yang didapati dibandingkan dengan pelbagai kedalaman pemancar (LD) dan kuantiti air (WQ) yang digunakan. Kedalaman pemancar pengairan D10 cm diperhatikan sebagai kedalaman terbaik untuk tumbesaran pokok kacang bendi menggunakan kedua-dua jenis air kerana konsentrasi akar yang tinggi walaupun dengan memenuhi hanya 73% keperluan air. Hasil tuaian adalah rendah pada D30 cm dan D40 cm dengan kehadiran akar yang berkurangan kerana zon akar mengecil dari permukaan hingga 40 cm. Kedudukan pemancar melewati kedalaman 20 cm adalah tidak disyorkan untuk tanaman kacang bendi ini kerana konsentrasi akar berkurangan melewati kedalaman tersebut. Purata ketinggian pokok bendi adalah 23 cm dengan menggunakan air tawar memenuhi 100% keperluan tanaman, tetapi 31 cm dengan air campuran, mungkin kerana kehadiran berbagai garam dalam air saliran campuran. Kajian menunjukkan hasil tuaian bendi masih boleh tinggi dengan air saliran campuran berkonduksian elektrik 4.2 dS/m dan memenuhi hanya tiga suku keperluan air tanaman tersebut berbanding dengan air tawar berkonduksian elektrik 2.2 dS/m. Potensi untuk menggunakan campuran air saliran di bawah pengairan defisit akan meningkatkan lagi sumber air untuk pertanian di kawasan gersang. Oleh itu, pemuliharaan air tawar akan menjadi lebih baik. Dalam kajian ini, satu rekabentuk sistem pengairan titis subpermukaan menggunakan air saliran campuran telah berjaya dibangunkan bagi tanaman kacang bendi. Keputusan daripada ujikaji dan model hasil pengeluaran yang dicapai daripada analisis statistik memberi satu contoh baik untuk tanaman bendi menggunakan air saliran campuran dengan pengairan defisit bagi tujuan pemuliharaan sumber air tawar di kawasan gersang.

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I certify that an Examination Committee has met on 9 January 2009 to conduct the final examination of Yousef A. Al-Molhem on his PhD thesis entitled "Response Of Okra Plant To Subsurface Drip Irrigation Using Mixed Agricultural Drainage Water" in accordance with Universities and University colleges Act 1971 and Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the candidate be awarded the relevant degree.

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institution.

YOUSEF ABDULAZIZ AL-MOLHEM

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INTRODUCTION

1.1 Introduction

Increasing human population has resulted in increasing water demands. In the past these increased demands had been met by large scale water projects consisting of dams and series of distributing canals. The opportunity for more water projects is diminishing as the cheapest and best opportunities have already been exploited. Thus, it becomes imperative to manage irrigation water with the highest degree of efficiency. Drip irrigation potentially provides that opportunity. With drip irrigation, the salt stress is relatively low because the soil solution is diluted continuously and salt accumulation around the roots is partially leached.

The traditional approach to deal with shallow groundwater problems is to install subsurface drainage systems for water table control and improved leaching. Proper operation of the drainage systems requires disposal of the subsurface drainage water.

The scarcity of fresh water in arid regions makes drainage water a valuable alternative water source for irrigation. However drainage-water use for agricultural irrigation is associated with some reduction in crop yield. The drainage problem must be addressed through options such as better management of irrigation water to reduce drainage below the root zone, increasing crop water use of the shallow groundwater without any yield reductions, and drainage water reuse for irrigation (Hanson and Ayars, 2002). One option for improving irrigation water management is to convert from surface or sprinkler irrigation to drip irrigation. Drip irrigation can apply water both precisely and uniformly compared with surface and sprinkler irrigation resulting in the potential to reduce subsurface drainage control soil salinity, and increase yield. The main disadvantage of drip irrigation is its cost. For drip irrigation to be at least as profitable as the other irrigation methods, more income from higher yields and reduced irrigation and cultural costs must occur.

Most of the previous researches are directed towards developing the technology such as appropriate filter systems and emitter types, as well as investigating irrigation efficiency. Relatively little attention has been given to the salt distribution, particularly as related to placement of the drip system at the surface or at various depths below the surface.

The choice of the best irrigation system is to be achieved by a major role in assuring that crops receive the desired water quantity and/or quality with minimum non-beneficial water losses occurring in the process. One of the first goals of water management should be to select and use irrigation systems which allow the application of water at frequencies and amounts necessary to achieve high water-use efficiency (Phene et al., 1988).

Since the present agricultural situation is not likely to improve in the near future and large new water supplies are unlikely to be developed, irrigated agriculture must improve its use of water in the semi-arid and arid areas and/or alternative water sources must be sought (Vaux, 1990). Present cost of alternative water sources makes them expensive for most agricultural uses for instance most water desalinization methods in the Kingdom of Saudi Arabia as well as in California, USA, would produce costly water (Brickson, 1991).

Drip irrigation, combined with wastewater reuse, may offer the most effective and efficient way to cope with water shortage for crops and protect the environment receiving wastewater. However, emitter and filter clogging are the main problems in the operation of drip systems in developing countries and small communities where treated wastewater is of poor quality. The main results of experimental trials on the behavior of several kinds of filter and drip emitters using poor quality municipal wastewater show that the performance of the emitters and filters depends on the quality of the wastewater (Capra and Scicolone, 2006).

1.2 Drip Irrigation with Unconventional Water

The water supply in Saudi Arabia, to meet the growing agricultural requirements, increased from 1.75 billion m^3 in 1975 to 22.93 billion m^3 in 1992. The total amount of wastewater available is around 1.32 million m^3/d (Hussain and Al-Saati, 1999). The total water salinity ranges between 1000–7273 mg L−1 in different areas. The quality of