UNIVERSITI PUTRA MALAYSIA

IMPACTS OF SOIL COMPACTION ON EMITTER PERFORMANCE IN SUB-SURFACE DRIP IRRIGATION SYSTEM

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By

MOHAMMED ISA BAMMAMI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

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DEDICATION

This thesis is dedicated to the Almighty Allah who has been my helper, sustainer, provider, guide, source of encouragement, keeper and my all in all throughout the course of my studies and also to my parents (Alhaji Isa Mohammed and Hajiya Fatima Mohammed) whose prayers and support has kept me going. Finally to my brothers Mohammed Isa, Adamu Mohammed and Sadiq Mohammed, my sisters Fatima and Maryam who are always by my side and ready with any kind of assistance.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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May 2015

Chairman: Md Rowshon Kamal, PhD
Faculty: Engineering

This research focuses the effect of soil compaction on performance of the Subsurface Drip Irrigation (SDI) system; since the emitters in this system are buried, by operating heavy farm machineries on the field, compaction is bound to occur and secondly finding methods of improving emitter performance, mainly in circumstances where the soil is compacted. Subsurface drip irrigation provides the required amount of water and fertilizer, directly onto the plant root zone with a high efficiency. However, SDI performance is often affected by poor distribution uniformity of emitters. Therefore, the aim of this study is to investigate the variation of the emitters' discharge rate and wetting patterns on SDI system performance due to soil compaction. To achieve this objective an experiment consisting of an air tank, water reservoir, digital flow meter, digital penetrologger, pressure gauge, emitters with three discharge rates of 2, 4, and 8 L/hr, three different soil samples loosely packed in lysimeters were carried out. Emitters were buried at a depth of 10 cm, 20 cm, and 30 cm in the lysimeters. External load was applied onto the soil surface while monitoring the discharge rate of emitters using the digital flow meter. The soil cone index was determined at different soil depth using the digital penetrologger. Data collected from these two devices were then used to establish a relationship between soil cone index and emitter discharge coefficient. Using the relationship developed, by imputing cone index (MPa) into the equation; the decrease in emitter discharge rate q can be predicted. A significant negative correlation was found between the cone index and emitter discharge rate. For all experiments using three soil samples, a substantial decrease in emitter discharge and emitter wetting diameter was observed. A decrease of 60% to 100% in the emitter discharge rate depending on the soil exposure to loading was recorded and 15% to 50% decrease in wetting diameter were recorded depending on the soil type and decrease in emitter discharge rate. Data obtained from the experiment was further fed into the HYDRUS software to simulate the wetting pattern of the emitters before and after compaction. A significant decrease in emitter discharge rate with the increase in a soil cone index was observed and consequently, a decrease in emitter wetting diameter. This study has shown a greater effect of compaction on emitter discharge rate compared to emitter wetting diameter. To ameliorate the effect of compaction on the emitter performance, the emitter operating pressure was increased from 1 bar to 1.5 bars; even at higher soil cone index, emitter discharge rate increases with the increase of operating pressure. Emitters buried at deeper lateral depth, have shown a higher resistance to soil compaction. In conclusion, this study has shown that emitter discharge rate and wetting diameter decreases with the increase in soil cone index and encourages deeper lateral depth and higher operating pressure depending on a soil cone index.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KESAN PEMADATAN TANAH KE ATAS PRESTASI PEMANCAR PADA SISTEM PENGAIRAN TITIS BAWAH PERMUKAAN

Oleh

MOHAMMED ISA BAMMAMI

May 2015

Pengerusi: Md Rowshon Kamal, PhD
Fakulti: Kejuruteraan

Kajian ini memberi tumpuan terhadap kesan pemadatan tanah ke atas prestasi sistem pengairan titis bawah permukaan (SDI); sejak pemancar dalam sistem ini ditanam, dengan mengendalikan jentera berat di ladang, pemadatan tanah pasti akan berlaku dan kedua mencari kaedah untuk meningkatkan prestasi pemancar, terutamanya dalam keadaan tanah yang dipadatkan. Pengairan titis bawah permukaan menyediakan jumlah air dan baja yang diperlukan terus ke zon akar tumbuhan dengan kecekapan yang tinggi. Walau bagaimanapun, prestasi SDI sering dipengaruhi oleh keseragaman pengagihan pemancar yang rendah. Oleh itu, tujuan kajian ini adalah untuk menyiasat perubahan kadar pelepasan pemancar dan corak kebasahan pada prestasi sistem SDI disebabkan oleh kepadatan tanah. Untuk mencapai matlamat ini satu eksperimen yang terdiri daripada tangki udara, takungan air, meter aliran digital, *penetrologger* digital, tolok tekanan, pemancar dengan tiga kadar pelepasan 2, 4, dan 8 L/jam dan tiga sampel tanah pada kelonggaran berbeza dibungkus menggunakan *lysimeter* telah ditanam di bawah permukaan tanah pada kedalaman 10, 20, dan 30 cm. Beban luaran telah dikenakan ke atas permukaan tanah sambil kadar pelepasan daripada pemancar dipantau menggunakan meter aliran digital. Indeks kon tanah ditentukan pada kedalaman tanah yang berbeza menggunakan *penetrologger* digital. Data yang dikumpul daripada kedua-dua peranti kemudiannya digunakan untuk membina hubungan antara indeks kon tanah dan pekali kadar alir pemancar. Menggunakan hubungan yang dibangunkan dengan memasukkan indeks kon tanah (MPa) ke dalam persamaan; penurunan dalam kadar pelepasan pemancar, q dapat diramalkan. Korelasi negatif yang signifikan didapati wujud antara indeks kon tanah dan pemancar kadar pelepasan, q. Dalam semua ujikaji yang dijalankan ke atas ketiga-tiga sampel tanah, penurunan yang ketara dalam pelapasan pemancar dan garis pusat pembasahan pemancar diperhatikan. Pengurangan sebanyak 60% hingga 100% dalam kadar pelepasan pemancar bergantung kepada pendedahan tanah kepada bebanan telah dicatatkan dan 15% hingga 50% pengurangan dalam diameter kebasahan telah dicatatkan bergantung kepada jenis tanah dan penurunan kadar pelepasan pemancar. Data yang diperolehi daripada eksperimen terus dimasukkan ke dalam perisian Hydrus untuk menyimulasikan corak kebasahan bagi pemancar sebelum dan selepas pemadatan tanah. Penurunan ketara dalam kadar pelepasan pemancar dengan peningkatan dalam indeks kon tanah diperhatikan dan akibatnya, diameter kebasahan pemancar tealh menurun. Kajian ini telah menunjukkan kesan pemadatan tanah adalah lebih besar terhadap kadar pelepasan pemancar berbanding garis pusat pembasahan. Untuk memperbaiki kesan pemadatan prestasi pemancar, tekanan pemancar telah ditingkatkan daripada 1 bar kepada 1.5 bar; walaupun pada indeks kon tanah yang lebih tinggi, kadar pelepasan pemancar meningkat dengan peningkatan tekanan operasi. Pemancar ditanam pada kedalaman yang lebih mendalam secara sisi, telah menunjukkan ketahanan yang lebih tinggi terhadap pemadatan tanah. Kesimpulannya, kajian ini telah menunjukkan bahawa kadar pelepasan pemancar dan diameter kebasahan berkurangan dengan peningkatan indeks kon tanah dan menggalakkan kedalaman sisi yang lebih mendalam dan tekanan operasi yang lebih tinggi bergantung kepada indeks kon tanah.

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APPROVAL

I certify that a Thesis Examination Committee has met on 03 April 2015 to conduct the final examination of Mohammed Isa Bammami on his Master of Science Thesis entitled "IMPACT OF SOIL COMPACTION ON EMITTER PERFORMANCE IN SUB-SURFACE DRIP IRRIGATION SYSTEM" In Accordance with the Universities and University College Act1971 and the constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science degree.
Members of the Examinations Committee were as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirements for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Declaration by graduate student

I hereby confirm that:

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision,
- Supervision responsibilities as stated in Rule 41 in Rules 2003 (Revision 2012-2013) were adhered to.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

With the rapid increase in population growth and climate change limiting the availability of fresh water for domestic and agricultural purposes, finding new methods of irrigation with higher efficiencies in terms of good water management and achieving excellent crop yield simultaneously becomes a necessity to provide enough food for our alarming increasing population growth.

Analysis on the use of available fresh water worldwide has shown that more than 70 % of this precious commodity is used for agricultural purpose with poor on farm water usage efficiency. Badr and Abuarab (2011) reported that about 85 % of water used in Egypt, a country where water is a scarce commodity is used in irrigating agricultural field, with poor on farm irrigation efficiency not exceeding 50 %. About 83 % of water used in Nevada is used for irrigation purposes, 45 % of this water is lost due to inefficiencies in irrigation processes while only 83 % part of the 55 % of water used in Nevada agricultural fields is used by the plants and the rest lost by evaporation at the soil surface (Nevada Water Facts, 1992). Drip irrigation has been suggested as the most efficient method of irrigation with efficiency of more than 90 % whereas sprinklers are 50 % to 70 % efficient (No, 2005). Subsurface Drip Irrigation (SDI) is the underground application of the required amount of water and nutrient directly to the plant root. A well designed and managed SDI uniformly wets the root zone of the field maintaining a dry soil surface.

Subsurface Drip Irrigation as defined by ASAE (American Society of Agricultural Engineers) as “application of water below the soil surface through emitters, with discharge rate generally in the same range as drip irrigation”. SDI can also be defined on the basis of lateral depth placement, for a system to be classified under SDI requires lateral placement below tillage depth ensuring lateral survival throughout the season indicating a degree of permanence. In recent, SDI is widely used to irrigate field crops, vegetables and fruits, since the development of plastic micro-irrigation technology. In general, the advantages of SDI systems are to improved efficiency of nutrient uptake, less water loss from the soil surface due to surface evaporation, zero runoff, less weed germination and growth. Moreover, an SDI system allows the incorporation of fertilizer in the irrigation water therefore simultaneously irrigating and applying fertilizer to the plant. Drip irrigation was introduced in 1960s but more attention escalated on the system in the 1980s. Yield response of over 30 different crops irrigated under SDI have shown better or equal yield with a higher water use efficiency in comparison to any other irrigation system including surface irrigation. In addition, SDI water use savings ranges from 0 to 50 % when compared with traditional irrigation systems (Camp, 1998). Normally in SDI system setup, lateral depths ranges from 0.10 m to 0.70 m with a spacing ranging from 0.25 m to 5 m.

In contrast to conventional surface drip irrigation, the performance of SDI is a function of the soil condition (soil hydraulic properties). The importance of uniformity of discharge of any kind of irrigation system cannot be over emphasized. The discharge rate of any irrigation system determines its irrigation scheduling and quantity of water to be applied (Wu, 1992). Therefore, any error in discharge uniformity of any irrigation system can lead to over or under irrigation or deprive the plants from required applied nutrients especially in subsurface drip irrigation where the application process is not visible to the eye since it is an underground process. Moreover, since we are considering precision farming where the equal number of product per plant or equal sizes of farm produce are required for easy handling and processing, achieving uniformity of discharge becomes very essential.

The discharge of SDI is a function of soil condition and therefore, when embarking on SDI system, the soil you are dealing with should come first. With detail study to enhance this efficient method of irrigation, researchers discovered backpressures to be one of the greatest limitations of SDI. Back pressures are pressures build up around the emitter in adjacent and opposite direction, preventing the emitter from discharging water at it's designed and expected rate. (Gil, Sánchez, Juana, & Asce, 2011) reported that positive water (back pressures) may develop around the emitter during irrigation following the principles of flow from a point source. (Warrick & Shani, 1996) also reported that emitters operating at a low pressure might discharge at lower rates as a result of back pressures. The extent of decrease in this discharge depends on the soil condition. When the infiltration rate of the soil is less than the rate at which water is discharged by the emitter, pressure builds up around the emitter restricting water movement away from the emitter.

To ensure uniformity of discharge of SDI system, the soil properties must be taken into consideration. Farm mechanization is a key factor that can change the soil condition and therefore, influencing the uniformity of discharge of SDI systems. Any change in soil condition will have a direct effect on buried emitter's discharge rate. Up till now, no investigation has been done to assess the effect of farm mechanization on SDI discharge rate and wetting pattern. However, researchers have worked and showed the changes caused by farm machineries on different soils.

1.2 Problem Statement

Operation of farm machineries in the field accelerates soil compaction (Sekwakwa and Dikinya, 2012) and the performance of Subsurface Drip Irrigation (SDI) depends on soil condition (Diamantopoulos and Elmaloglou, 2012). Then, the heavy use of farm machineries will alter the soil condition and subsequently the performance of Subsurface Drip Irrigation (SDI) since SDI performance depends on soil condition. The hypothesis of this study is therefore, compaction will affect buried emitter's design discharge rate and wetting pattern. The investigation of the variation of the emitter's discharge rate and wetting patterns on SDI system performance due to soil compaction is essential for sustaining the desirable systems performance. This study will focus on the effect on the changes in soil condition due to compaction on the performance of buried emitters.

1.3 Research Objectives

The main objective of this study was to investigate and develop the relationship in determining optimal operating pressure in accordance to the decreasing of discharge of SDI emitters and poor water distribution pattern due to the gradual soil compaction. The specific objectives were:

1. To determine the relationship between the change in discharge with increase in soil compaction and the most appropriate lateral depth that will reduce the effect of compaction on discharge rate and wetting pattern..
2. To analyze the change in wetting pattern of buried emitters as compaction increases using HYDRUS 2D.

1.4 Importance of the Study

The Importance of the study is highlighted below:

- This study showed the impact of compaction on emitter discharge rates based on the degree of soil compaction.
- This study established the allowable amount of load the soil can resist without affecting the rate of discharge of emitters and the soil moisture distribution.
- The study suggested practices to reduce the effect of soil compaction such as stop irrigation or cut off emitter discharge for a specified period before exposing the soil to any machinery operation.

1.5 Organization of Thesis

This thesis presents the study in a top-down approach. It begins with the functional description of the subject on Drip Irrigation systems and its importance over other methods, and then elaborates on the shortcomings of the system. Chapter 2 is mainly written for reviewing the methods used in this research and related applications for its use. Intensive study was reported on factors that can affect SDI systems in this chapter. Papers on HYDRUS 2D/3D which uses the Van Ganuchen model in stimulating wetting pattern of buried sources was also critically reviewed and its use in related applications are delineated. In Chapter 3, this study's methodologies are explained in full detail, the methods used in finding effects of compaction on emitter discharge and also the emitter wetting pattern were fully reported and elaborately explained. Chapter 4, reports the experimental result of the research problem and analysis of the data collected from experiments observed. Finally, in Chapter 5, detailed discussion on the results obtained and conclusion in summary of the thesis, stating the achievements and also identifying the future research direction of the work.

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