UNIVERSITI PUTRA MALAYSIA

WATER AND SOLUTE DISTRIBUTION PATTERN IN SOIL UNDER POINT SOURCE TRICKLE IRRIGATION

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Dedicated to

my Parents as they did care for me when I was little

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Doctor of Philosophy

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By

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A basic requirement in the design of a trickle irrigation system is to obtain more information about the shape and size of the wetted soil zone. This will ensure precise placement of water and nutrients in the active root zone to meet the requirements of precision farming. A series of laboratory and field experiments were conducted to determine water and solute distribution pattern in soil under point source trickle irrigation. Three types of experiments were conducted. The focus of the first type of experiment was to study the effect of water application rate and the amount of water on water movement in the lateral and vertical direction. River sand and sandy loam soil were used as the media in a plexiglass container. These experiments were conducted under laboratory conditions where the application rates of 0.75 and 3.4 l/h were used for river sand soil while 1 and 3.0 l/h were used for sandy loam soil. The second type of experiments was conducted on river sand in the laboratory using a wooden box. The purpose of this experiment was to study the effect of application rate and amount of irrigation water on the surface wetted radius. Application rates of 3, 5.5 and 7 l/h were used. The third type of experiment was conducted under field conditions. The experiments were designed for field evaluation of water and solute movement from a point source. Sandy and sandy loam soils were selected for these experiments and the application rates varied from 1.5 to 6 l/h. The results from the experiments revealed that for all soil types, lateral movement of the wetting front and the surface wetted radius as measured at the soil surface approached a limit with elapsed time. A linear relationship was found between vertical wetting front advance and the square root of elapsed time. The results obtained from both plexi glass and wooden box experiment showed that the water application rates caused a notable effect on the surface wetted radius, where increase in the application rates contributed to an increase in the surface wetted radius. On the other hand the statistical analysis of the field experiment results showed insignificant effect of the application rates on the surface wetted radius. Increase in the discharge rate caused a decrease in the vertical advance of the wetting front for both sandy and sandy loam soils under field conditions, and sandy loam soil in the plexiglass experiments. The maximum volumetric moisture content after irrigation was found in the region just below the irrigation source. The statistical analysis of moisture distribution data under field conditions showed insignificant effect of water application rate on the water content distribution within the boundary of 17.5 and 27.5 cm in radial and vertical distance, respectively. The patterns of the chloride concentration distribution were similar to those for moisture content distribution. The effect of inlet chloride concentration on the distribution of chloride concentration was significant in both soils. The greater the concentration at the inlet, the higher the chloride concentration in the soil. For both types of soil, most of the treatments indicated insignificant effect of application rate on the chloride distribution. Two simple models based on the average change in volumetric water content ($\Delta\theta$), total volume of water

applied (V_w), application rate (q_w) and the saturated hydraulic conductivity (k_s) were developed to determine the surface wetted radius (r) and vertical advance of the wetting front (z) produced from point source trickle irrigation, $r = \Delta\theta^{-0.56} V_w^{0.26} q_w^{-0.03} k_s^{-0.03}$ and $z = \Delta\theta^{-0.38} V_w^{0.36} q_w^{-0.1} k_s^{0.19}$. These models were verified with the data from this study and other published experiments under different conditions. The results obtained from both types of data improved the capability of using these models for designing a trickle irrigation system. In this study, Hydrus_2D model was used to simulate water and solute distribution under point source trickle irrigation. Good agreements were found between simulated and experimental results regarding location of the wetting front, water distribution and solute concentration under different application rates.

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

BENTUK PERTABURAN AIR DAN SOLUT DALAM TANAH DIBAWAH PENGAIRAN CUCUR SUMBER TITIK
Oleh

AHMED I. M EKHMAJ

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Keperluan asas dalam rekabentuk sistem pengairan cucur adalah untuk mendapat lebih banyak maklumat tentang bentuk dan saiz kawasan tanah yang dibasahi. Ini memastikan ketepatan pemberian air dan baja di ladang bagi memenuhi keperluan pertanian presis. Kajian di makmal dan di ladang telah dilakukan bagi menentukan bentuk taburan air dan solut dalam tanah di bawah pengairan cucur sumber titik. Tiga jenis kajian telah dilakukan. Tumpuan bagi kajian pertama adalah untuk mengkaji kesan kadar pembubuhan air dan jumlah air bagi gerakan air secara mendatar dan menegak. Pasir sungai dan tanah lom berpasir telah digunakan sebagai media dalam bekas plexiglass. Kajian ini telah dilakukan di dalam makmal yang mana kadar pengairan 0.75 dan 3.4 l/j telah diberi bagi pasir sungai, sementara kadar 1.0 dan 3.0 l/j telah diguna bagi tanah lom berpasir. Kajian kedua telah dilakukan bagi pasir sungai di makmal dengan menggunakan bekas kotak kayu. Tujuan kajian ini adalah untuk mengkaji kesan kadar pembubuhan dan jumlah air pengairan keatas jarak lingkungan permukaan yang dibasahi. Kadar pembubuhan 3, 5.5 dan 7 l/j telah digunakan. Kajian yang ketiga telah dilakukan di ladang. Kajian direka untuk penilaian di ladang bagi pergerakan air dari sumber titik. Jenis tanah

dilakukan di ladang. Kajian direka untuk penilaian di ladang bagi pergerakan air dari sumber titik. Jenis tanah berpasir dan lom berpasir telah dipilih bagi semua kajian ini dan kadar pembubuhan 1.5 hingga ke 6 l/j telah digunakan. Keputusan dari semua kajian tersebut di atas menunjukkan bahawa bagi semua jenis tanah, garisan basah dan jarak lingkungan permukaan yang dibasahi bagi gerakan mendatar yang diukur di permukaan tanah adalah terhad dengan masa yang berlalu. Satu hubungkait secara lelurns telah diperolehi di antara garisan basah yang tegak dan masa ber lalu berkuasa seperdua. Keputusan yang terdapat dari kajian plexiglass dan kotak kayu menunjukkan bahawa kadar pembubuhan air menyebabkan kesan yang jelas ke atas jarak lingkungan permukaan yang dibasahi yang mana peningkatan kadar pembubuhan melibatkan peningkatan jarak lingkungan permukaan yang dibasahi. Dalam hal yang sama, keputusan analisis statistik bagi kajian di ladang menunjukkan kesan yang penting bagi kadar pembubuhan ke atas jarak lingkungan permukaan yang dibasahi. Peningkatan kadar luahan menyebabkan kekurangan pergerakan menegak bagi kedua-dua jenis tanah berpasir dan lom berpasir di ladang, dan jenis tanah lom berpasir bagi kajian plexiglass. Kelembapan isipadu yang maksimum selepas pengairan terdapat dibahagian pemancar pengairan cucur. Analisis statistik bagi taburan lembapan di ladang menunjukkan kesan yang penting bagi kadar pembubuhan air ke atas taburan lembapan dalam jarak lingkungan sempadan 17.5 hingga 27.5 sm masing-masing bagi jarak lingkungan dan jarak tegak.. Bentuk taburan klorida adalah sama dengan taburan lembapan. Kesan klorida yang pekat di alur masuk ke atas taburan klorida yang pekat adalah penting bagi kedua-dua jenis tanah. Kepekatan lebih di alur masuk menghasilkan klorida pekat yang tinggi di dalam tanah. Bagi kedua-dua jenis tanah, kebanyakan rawatan menunjukkan kesan yang penting bagi kadar pembubuhan ke atas taburan klorida dalam bentuk kepekatan tanpa dimensi. Dua jenis model mudah yang berdasarkan purata pertukaran kandungan lembapan isipadu ($\Delta\theta$), jumlah air yang diberi (V_w), kadar pembubuhan (q_w) dan keberkondukan hidraul tepu (k_s) telah dibangunkan untuk menentukan jarak lingkungan permukaan yang dibasahi (r) dan garis basah menegah (z) yang telah dihasil dari pengairan cucur sumber titik, $r = \Delta\theta^{-0.56} Vw^{0.26} qw^{-0.03} ks^{-0.03}$ dan $z = \Delta\theta^{-0.38} Vw^{0.36} qw^{-0.1} ks^{0.19}$. Model-model ini telah dibuat pengesahan dengan data dari kajian ini dan kajian lain yang telah diterbitkan dalam keadaan yang berlainan. Keputusan yang dapat bagi kedua-dua jenis data mendorong keupayaan kegunaan kedua-dua model bagi rekabentuk sistem pengairan cucur. Dalam kajian ini, model Hydrus_2D telah digunakan untuk simulasi taburan air dan solut di bawah pengairan cucur sumber titik. Persetujuan yang baik telah diperolehi di antara keputusan simulasi dan kajian berkenaan lokasi garisan basah, taburan air dan kepekatan dengan kadar pembubuhan yang pembubuhan

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