Evaluation of Existing Drip Irrigation System Using the Coupled Source-sink Model Approach

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Abstract

Drip irrigation is a highly efficient water delivery method in agriculture, where water is supplied directly to the plant roots through a network of tubes, pipes, and emitters. This technique minimizes water wastage, reduces evaporation, and ensures precise moisture control, promoting healthy crop growth. Drip irrigation is especially vital in arid regions or areas facing water scarcity by conserving water. It also enhances crop yield, reduces weed growth, and lowers labor costs. As the global demand for food rises amid environmental challenges, drip irrigation is a sustainable solution that optimizes resource use and boosts agricultural productivity. This study uses the coupled source-sink model approach to evaluate drip irrigation efficiency by analyzing water distribution, plant uptake, and system performance for optimization. A modeling approach was used to assess the performance of the exciting drip irrigation system. Soil Parameters data were acquired/collected from the farms using standard methods. The DIDAS model was used to assess the performance of the already drip irrigation system in the study area. This study investigated the influence of root radius, emitter spacing, and drip irrigation schedules on relative water use uptake (RWUR) in five different farm scenarios. The study concludes that emitter spacing in drip irrigation systems is a key factor for the effective running of drip irrigation systems. Root radius plays a significant role in RWUR. Larger root systems are better equipped to access water from the surrounding soil, reducing their reliance on emitters.

Keywords: ***Drip Irrigation System, Source-sink Model, Emitter, Soil Parameters, Roots Radius***

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Introduction

A global water shortage is due to an imbalance between supply and demand. This situation is impacting food production and industrial processes, and it explains the scarcity of water for all other uses (Ram et al., 2015). The country like Pakistan is also suffering a severe shortage of water and faces nearly undefeatable challenges in meeting the demand of its growing population, which was 140 million in 2000 and is projected to double by the year 2025 (Ahmad et al., 2013). Pakistan, once a water-rich country, is now water-scarce due to the enormous water resources of the Indus River (Gohari et al., 2013). Pakistan currently has one of the lowest per capita water availability of 1200 cubic meters in the world. The immediate water scarcity crisis in Pakistan is severe, and experts believe the long-term outlook is bleak (Aminifard et al., 2010). Essential to plan strategies with concrete measures to manage irrigation water (Bhogi et al., 2015). Drip irrigation is a water-efficient system that delivers water directly to plant roots through a network of tubes and emitters. (Gao et al., 2016). This technique is often used in arid and semi-arid regions. Water use efficiency is an important indicator of water-saving irrigation. It is an important indicator for measuring the relationship between crop yield and water use efficiency (Yang et al., 2016). Under drought conditions, water use is more efficient. However, under aqueous conditions, plants are less efficient at using water. Drip irrigation can quickly wet the topsoil conducive to water uptake and utilization by plants. This study found a significant linear relationship between irrigation water, water usage, and total number of flowers per plant (Karam et al., 2016). Drip irrigation can be used for many different types of plants, but designing a drip irrigation system according to the needs of a particular crop can present major challenges. Finding the optimal spacing between emitters along the drip line for different plants to evenly apply water to the plant roots and ensure adequate hydration is difficult through field trials and experimentation. can be a time-consuming process. Simulation and modeling offer an efficient alternative to this problem. Various computer programs, such as Wet Up, are available based on analytical or numerical solutions that can simulate water uptake, soil hydraulics, and wetting patterns in the root zone of surface and subsurface irrigation systems. (Arbat et al., 2013). HYDRUS 2D/3D, So-WaM, Neuro-Drip, Coup Model, and Drip-Irri water are based on numerical solutions. The model considers soil and root system properties, climate, and plant/emitter configuration of the irrigation system and simulates soil moisture conditions in active root zones. DIDAS is similar to computer software based on the analytical solution of the Richards equation for steady and unsteady water fluxes at the surface and subsurface emitters/sources for point and line sources in semi-infinite soil domains. DIDAS evaluates existing system designs and irrigation plans and develops new water-efficient designs and plans. The software is especially useful for finding optimal emitter spacing for narrow growing crops such as bulbs that require closely spaced drip lines without conducting costly and time-consuming field trials and experiments (Mehla et al., 2019).

MATERIALS AND METHOD

Experimental site

Five number farms in the vicinity of Kotri, District Jamshoro, Sindh were investigated.

Data Collection or Acquisition

Soil Parameters data were acquired/collected from the farms using standard methods and shown in Table 1.

Tab: 1 Soil parameters

Sr. No.	Parameter	Adopted method
1	pH	pH meter
1	Soil texture	Hydrometer by Bouyouco (Bouyoucos,1962)
2	Bulk density(g/cm^3)	**Core Sampling Method**
3	Soil hydraulic conductivity	Auger hole method

A Coupled Source-Sink Model

DIDAS model was used to evaluate existing drip systems and the sequence of computation processes that a practical user would follow when examining a particular drip irrigation scenario, allowing for essential quantitative evaluation of the effects of changes to the system parameters on its performance. By varying the input parameters within allowable ranges, the user could obtain comprehensive design and scheduling recommendations that correspond to the anticipated operating conditions.

Examination of Results in DIDAS

The computed RWURs and RWUVs are displayed graphically, and the output of tabulated results can be exported to external files in a CSV format. An outline of the steps required for evaluating an irrigation scenario is presented in Fig.2. The individual steps ineach scenario are quite similar across the three modules (except water application scheduling, which applies only in the Irrigation Scheduling module), which simplifies understanding and operation of DIDAS. Moreover, since configuration parameters are almost identical in the scenario definitions of the three respective modules, once parameters have been defined in one module they later appear as default values in subsequent use of the equivalent scenario in the other two modules.

The DIDAS US module evaluates the diurnal pattern of the RWUR and its integral, the daily relative water uptake volume RWUV.

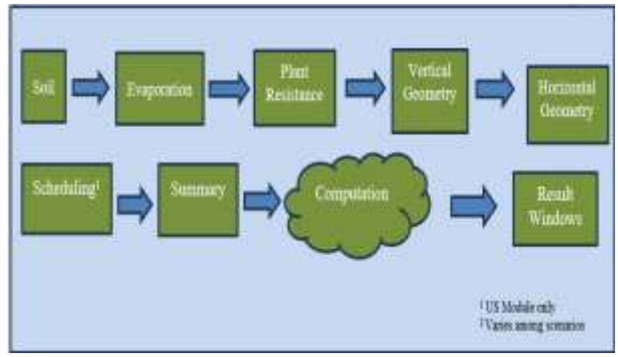

Fig.1: DIDAS US Module Pattern of the RWUR and RWUV

Input Parameters.

The Soil-type Parameters (a, k_{eff}, b, K_s, h_s, n)

DIDAS is a hydrological model for irrigation design and scheduling that considers soil-type parameters such as a, k_{eff}, b, K_s, h_s, and n. These parameters are used to estimate water flow and uptake in the soil-plant system, characterize the soil's water retention properties, and determine the ability of the soil to transmit water under saturated conditions. By incorporating these parameters, DIDAS becomes a comprehensive tool for designing efficient irrigation systems and optimizing irrigation scheduling based on the soil's hydraulic properties and the water needs of the crops.

Depth (d_0) and radius (r_0) of the root zone

DIDAS requires the depth and radius of the root zone to design irrigation and scheduling. The depth (d_0) is the distance from the soil surface to where roots absorb water, which can be estimated through observations, crop information, field investigations, and soil profile characteristics. The radius (r_0) is the lateral extent of the area where roots extract water and nutrients, which can be estimated through root distribution studies, modelling, and crop information. Accurate determination of these parameters is crucial for successful irrigation design and scheduling as they affect water and nutrient distribution, plant growth, uptake, and crop performance. Reliable data sources and careful consideration should be used to estimate root zone dimensions accurately.

The potential evaporation rate parameter, m, and its diurnal pattern, mt (t)

DIDAS is a tool that estimates daily evapotranspiration (ET) rates of crops using the potential evaporation rate parameter (m) and its diurnal pattern (mt(t). ET is the process of water loss from the soil through evaporation and transpiration by plants. Accurate estimation of ET rates is crucial for determining crop water requirements and optimizing irrigation scheduling. The potential evaporation rate parameter (m) represents the potential rate of water loss from the soil surface due to evaporation under standard reference conditions, such as solar radiation, air temperature, wind speed, and humidity. The diurnal pattern of potential evaporation ($m_t(t)$) describes how the potential evaporation rate varies throughout the day. DIDAS uses weather data to obtain the mt(t) function, applying empirical or physically-based equations to calculate the potential evaporation rate at different times of the day, considering diurnal variations in environmental factors. By considering both the potential evaporation rate parameter (m) and its diurnal pattern ($m_t(t)$, DIDAS can estimate crop water requirements more accurately and optimize irrigation schedules to ensure plants receive sufficient water for their needs and maintain optimal growth and yield.

RESULTS

Design parameters of drip irrigation at various farms

Farm-Saleem Raza is characterized by having a Coarse Sand (New) soil type. The soil infiltration parameter 'a' is 0.389 1/cm, indicating a high infiltration rate. The saturated hydraulic conductivity (Ks) is 85 cm/h, implying a relatively good water flow rate through the soil. The effective hydraulic conductivity (keff) is 270.7 cm/h, which determines the overall ability of the soil to transport water under various conditions. The value of 'n' is 2, indicating the Manning's roughness coefficient, which represents the surface roughness of the soil. The 'qs' value is 0.35, representing the soil moisture at saturation, suggesting a moderate water-holding capacity of the soil. The value of 'b' is 0, indicating the slope of the soil-water characteristic curve. The emitter type used in this farm is "Dripper 16 lph," with an emitter spacing of 20 + Δ10 cm, and dripline spacing of 609 cm. The arrangement of emitters is in a Rectangular Array of Emitters/Plants.

Farm-Irfan Akbar shares similar characteristics with Farm-Saleem Raza, including Coarse Sand (New) soil type, 'a' value of 0.389 1/cm, Ks of 85 cm/h, keff of 270.7 cm/h, and an 'n' value of 2. The moisture retention (qs) and the slope of the soil-water characteristic curve (b) are also the same as Farm - Saleem Raza. The emitter type used is "Dripper 16 lph," with similar emitter and dripline spacing, and the arrangement of emitters is in a rectangular array of emitters plants^{-1}.

Farm-Asif Ali has a different soil type, Loamy Sand (New). The soil infiltration parameter 'a' is 0.127 1/cm, indicating a moderate infiltration rate. The saturated hydraulic conductivity (Ks) is 65 cm/h, implying a relatively good water flow rate through the soil. The effective hydraulic conductivity (keff) is 250.7 cm/h, which determines the overall ability of the soil to transport water under various conditions.

The value of 'n' is 2, indicating the Manning's roughness coefficient, which represents the surface roughness of the soil. The 'qs' value is 0.40, representing the soil moisture at saturation, suggesting a moderate water-holding capacity of the soil. The value of 'b' is 0, indicating the slope of the soil-water characteristic curve. The emitter type used in this farm is "Dripper 75 lph," with an emitter spacing of 25 + Δ10 cm, and dripline spacing of 762 cm. The arrangement of emitters is in a rectangular array of emitters plants^{-1}.

Farm -Asif shares the same soil type, hydraulic parameters and the emitter type used in this farm is "Dripper 75 lph," with an emitter spacing of 20 + Δ10 cm, and dripline spacing of 609 cm, suggesting a different layout for the irrigation system.

Farm-Hidayatullah stands out with a different soil type Hilly Sand (New), the soil infiltration parameter 'a' is 0.4031/cm, indicating a high infiltration rate. The saturated hydraulic conductivity (Ks) is 100 cm/h, implying a relatively very good water flow rate through the soil. The effective hydraulic conductivity (keff) is 285.7 cm/h, which determines the overall ability of the soil to transport water under various conditions. The value of 'n' is 2, indicating the Manning's roughness coefficient, which represents the surface roughness of the soil. The 'qs' value is 0.20, representing the soil moisture at saturation, suggesting a very low water-holding capacity of the soil. The value of 'b' is 0, indicating the slope of the soil-water characteristic curve. The emitter type used in this farm is "Dripper NPC Adjustable 70 lph," indicating a higher flow rate emitter "with an emitter spacing of 15 + Δ10 cm, and dripline spacing of 457 cm. The arrangement of emitters is in a rectangular array of emitters plants^{-1}.

These results indicate that each farm has unique characteristics and irrigation setups, primarily determined by the soil type, emitter type, and emitter spacing. These factors play a vital role in determining the overall efficiency and water management practices of each farm.

Tab.2 Design parameters of various farms

Parameter	Farm-Saleem Raza	Farm-Irfan Akbar	Farm-Asif Raza	Farm-Asif	Farm-Hidayatullah
Soil Type	Coarse Sand Sand : 85% Silt : 10% Clay : 5%	Coarse Sand Sand : 85% Silt : 10% Clay : 5%	Loamy Sand Sand : 70% Silt : 20% Clay :10%	Loamy Sand Sand : 70% Silt : 20% Clay :10%	Hilly Sand Sand : 90% Silt : 8% Clay:2 %
A	0.389 1/cm	0.389 1/cm	0.127 1/cm	0.127 1/cm	0.403 1/cm
K_s	85 cm/h	85 cm/h	65 cm/h	65 cm/h	100 cm/h
k_{eff}	270.7 cm/h	270.7 cm/h	250.7 cm/h	250.7 cm/h	285.7 cm/h
N	2	2	2	2	2
q_s	0.35	0.35	0.40	0.40	0.20
B	0	0	0	0	0
Evaporation:	None	None	None	None	None
Plant-Atmosphere Resistance	None	None	None	None	None
Emitter type	Dripper 16 lph	Dripper 16 lph	Dripper 75lph	Dripper 75lph	Dripper NPC Adjustable 70 lph
Root Zone Depth (d0)	10 cm	10 cm	10 cm	10 cm	10 cm
Arrangement of emitter	Rectangular array of emitters plants^{-1} array Superposition	Rectangular array of emitters plants^{-1} array	Rectangular array of emitters plants^{-1} array	Rectangular array of emitters plants^{-1} array	Rectangular array of emitters plants^{-1} array
Emitter Spacing	20 + D10 cm	20 + D10 cm	25 + D10 cm	20 + D10 cm	15 + D10 cm
Dripline spacing	609 cm	609 cm	762 cm	609 cm	457 cm

Scenario-I for Farm Saleem Raza (10 cm increment in emitter spacing)

The result shows in Fig.2 on the dynamics of relative water uptake ratio (RWUR) concerning variations in root radius and emitter spacing. These findings underscore the intricate relationship between root systems and irrigation practices. Notably, as the root radius increases, there is a consistent trend of decreasing RWUR across all emitter spacings. In other words, for each emitter spacing, the RWUR diminishes as the root radius expands. For instance, when the root radius is 0.5 cm, the RWUR percentages are 15.9%, 11.7%, 10.96%, 9.1%, and 8.6% for emitter spacings of 20 cm, 30 cm, 40 cm, 50 cm, and 60 cm, respectively. This comparison reveals that as the distance between the emitter and the plant's roots increases (i.e., with larger emitter spacing), the RWUR percentage decreases, indicating that the roots have a reduced capacity to absorb water from the emitter zone. This suggests that as plant root systems grow larger, they become increasingly efficient at extracting water from the surrounding soil, extending beyond the reach of the emitters. Furthermore, regardless of the specific root radius, an increase in emitter spacing corresponds to a decrease in RWUR. This implies that when emitters are placed farther apart, plants rely more on their root systems to extract water from a broader soil area. Consequently, the water uptake from individual emitters becomes a smaller portion of the total water absorbed by the plants. Notably, larger root systems seem to mitigate the impact of increased emitter spacing. While RWUR decreases with wider emitter spacing for all root radius values, this decline is less pronounced for plants with larger root systems. This suggests that plants with substantial root systems are adept at efficiently extracting water from a larger soil volume, even when emitters are spaced at greater intervals. These findings hold practical implications for irrigation strategies. For plants with smaller root systems, maintaining closer emitter spacing could be advantageous to ensure effective water uptake. Conversely, for plants with more extensive root systems, there remains the potential for efficient water absorption even with wider emitter spacing.

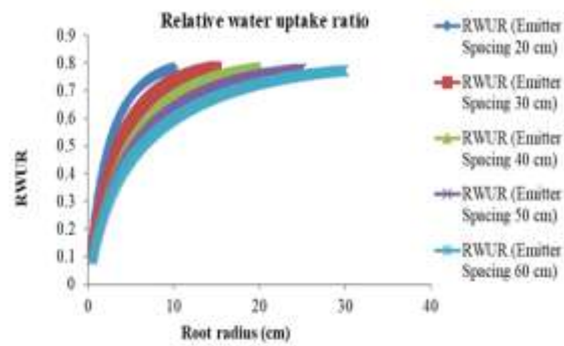

Fig. 2: Scenario – I for Farm Saleem Raza (10 cm increment in emitter spacing)

Fig. 3 provides the relevant information on relative water usage uptake in this scenario. The results emphasize the intricate relationships between root systems and irrigation techniques by showing the impact of root radius and emitter spacing on the RWUR. The data show that the RWUR typically decreases across all emitter spacings as the root radius rises. The findings show that for each emitter spacing, the RWUR falls as the root radius increases. RWUR is 15.93%, 13.5%, 11.9%, 10.8%, and 10.13% for emitter spacings of 25 cm, 35 cm, 45 cm, 55 cm, and 65 cm, respectively, with a root radius of 0.5 cm. This examination demonstrates that the RWUR % falls as the distance between the emitter and the plant's roots rises (i.e., increased emitter spacing), indicating a decreased ability of the roots to absorb water from the emitter. This suggests that the quantity of water absorbed from the emitters reduces as the size of the plant's root system increases. This could be because bigger root systems are better able to get water from the soil outside the emitter zone. The RWUR tends to decrease for each root radius value as the emitter spacing rises. This implies that plants rely increasingly on their root systems to receive water from a larger soil area as the distance between emitters rises. As a result, the amount of water that each emitter contributes to the plants' overall water intake decreases. Increased emitter spacing seems to have less of an impact when the root radius is larger. For all root radius values, RWUR falls with increased emitter spacing, however the decline is less noticeable for larger root systems. This suggests that even when emitters are placed further apart, plants with bigger root systems are more effective at drawing water from a wider soil volume. The actual application of these findings affects irrigation tactics. Maintaining closer emitter spacing may be advantageous for plants with smaller root systems to guarantee efficient water uptake. However, plants with deeper root systems could still be able to absorb water effectively despite broader emitter spacing.

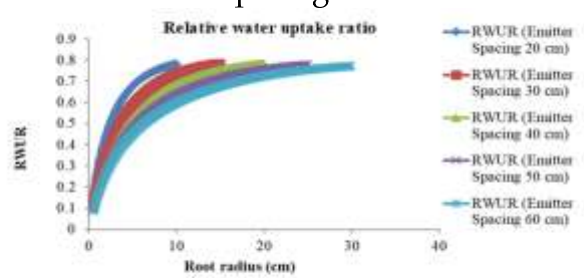

Fig.3: Scenario – I for Farm Irfan Akbar (10 cm increment in emitter spacing)

Scenario – I for Farm Asif Ali (10 cm increment in emitter spacing)

The pertinent results regarding relative water use uptake in this scenario are given in Fig. 4 The results illustrate the influence of root radius and emitter spacing on the RWUR, highlighting the complex interactions between root systems and irrigation practices. It can be insighted from the results that as the root radius increases, the RWUR generally decreases across all emitter spacings. As evident from the results, the RWUR decreases with increasing root radius for each emitter spacing. RWUR for a root radius of 0.5 cm across different emitter spacings is 13.5%, 10.8876%, 9.5933%, 8.8771%, and 8.4473% for emitter Spacing of 25 cm, 35 cm, 45 cm, 55 cm and 65 cm respectively. This comparison shows that as the distance between the emitter and the plant's roots increases (i.e., larger emitter spacing), the RWUR percentage decreases, indicating a reduced capacity of the roots to uptake water from the emitter. This implies that as the root system of the plants becomes larger, the proportion of water uptake from the emitters decreases. This could be due to the increased ability of larger root systems to access water from the surrounding soil beyond the emitter zone. For each root radius value, as the emitter spacing increases, the RWUR tends to decrease. This suggests that as the distance between emitters increases, plants rely more on their root systems to access water from a broader soil area. Consequently, the water uptake from individual emitters becomes a smaller portion of the total water uptake by the plants. Larger root radius values seem to mitigate the impact of increased emitter spacing. While RWUR decreases with increased emitter spacing for all root radius values, the decrease is less pronounced for larger root systems. This implies that plants with larger root systems are more efficient at extracting water from a larger soil volume, even when emitters are spaced farther apart. These results have practical implications for irrigation strategies. For plants with smaller root systems, maintaining closer emitter spacing could be beneficial to ensure effective water uptake. On the other hand, plants with larger root systems might still have efficient water uptake even with wider emitter spacing.

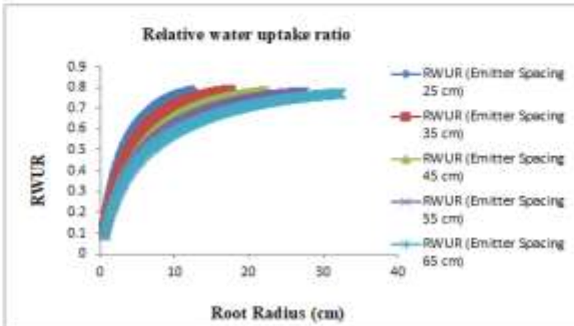

Fig. 4: Scenario – I for Farm C (10 cm increment in emitter spacing)

Scenario – I for Farm Asif (10 cm increment in emitter spacing)

The relevant data on relative water uptake rates (RWUR) in this case are shown in Fig. 5. These results provide light on the complicated connections between irrigation techniques and root systems, elucidating the impacts of both root radius and emitter spacing on RWUR. These results show a general trend for RWUR to decrease as the root radius increases, independent of the emitter spacing. For each emitter spacing, RWUR basically drops as root radius rises. For example, when the root radius is set at 0.5 cm, the RWUR percentages are 15.9%, 11.95%, 10.13%, 9.18%, and 8.63% for varied emitter spacings of 25 cm, 35 cm, 45 cm, 55 cm, and 65 cm, respectively. This comparative research highlights the fact that when the distance between the emitter and the plant's roots expands (i.e., with increasing emitter spacing), the RWUR % declines, showing a reduced capacity of the roots to absorb water from the emitter. The quantity of water absorbed from the emitters is said to decrease as plant root systems get bigger. Larger root systems' enhanced capacity to acquire water from the surrounding soil outside of the immediate emitter zone may be to blame for this phenomenon. For each specific root radius value, there is a consistent pattern of RWUR decreasing as emitter spacing increases. This suggests that when emitters are spaced farther apart, plants increasingly depend on their root systems to extract water from a broader soil area. Consequently, the proportion of water uptake from individual emitters diminishes in relation to the total water uptake by the plants. It's noteworthy that larger root radius values appear to alleviate the impact of wider emitter spacing. While RWUR declines with greater emitter spacing for all root radius values, this decline is less pronounced for plants with larger root systems. This implies that plants endowed with extensive root systems exhibit greater efficiency in extracting water from a larger soil volume, even when emitters are spaced at greater intervals. These findings carry practical implications for devising effective irrigation strategies. For plant varieties with smaller root systems, maintaining closer emitter spacing may prove advantageous to ensure efficient water uptake. Conversely, for plants with more extensive root systems, there remains the potential for efficient water absorption even with wider emitter spacing.

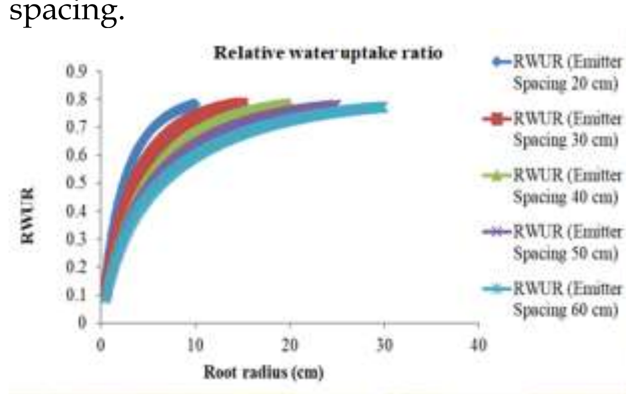

Fig. 5: Scenario – I for Farm Asif (10 cm increment in emitter spacing)

Scenario – I for Farm Hidayatullah (10 cm increment in emitter spacing)

The pertinent results regarding relative water use uptake in this scenario are given in Fig. 5 The results illustrate the influence of root radius and emitter spacing on the RWUR, highlighting the complex interactions between root systems and irrigation practices. It can be insighted from the results that as the root radius increases, the RWUR generally decreases across all emitter spacings. As evident from the results, the RWUR decreases with increasing root radius for each emitter spacing. RWUR for a root radius of 0.5 cm across different emitter spacings is 19.81%, 13.46%, 10.84%, 9.5%, and 8.8% for emitter Spacing of 15 cm, 25 cm, 35 cm, 45 cm and 55 cm respectively. This comparison shows that as the distance between the emitter and the plant's roots increases (i.e., larger emitter spacing), the RWUR percentage decreases, indicating a reduced capacity of the roots to uptake water from the emitter. This implies that as the root system of the plants becomes larger, the proportion of water uptake from the emitters decreases. This could be due to the increased ability of larger root systems to access water from the surrounding soil beyond the emitter zone. For each root radius value, as the emitter spacing increases, the RWUR tends to decrease. This suggests that as the distance between emitters increases, plants rely more on their root systems to access water from a broader soil area. Consequently, the water uptake from individual emitters becomes a smaller portion of the total water uptake by the plants. Larger root radius values seem to mitigate the impact of increased emitter spacing. While RWUR decreases with increased emitter spacing for all root radius values, the decrease is less pronounced for larger root systems. This implies that plants with larger root systems are more efficient at extracting water from a larger soil volume, even when emitters are spaced farther apart. These results have practical implications for irrigation strategies. For plants with smaller root systems, maintaining closer emitter spacing could be beneficial to ensure effective water uptake. On the other hand, plants with larger root systems might still have efficient water uptake even with wider emitter spacing.

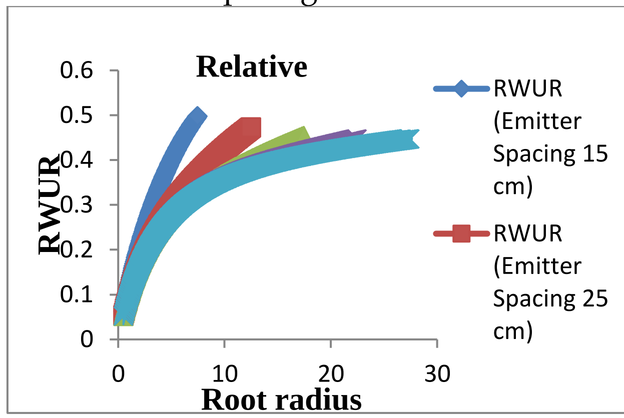

Fig.5 : Scenario – I for Farm Hidayatullah (10 cm increment in emitter spacing)

Effect of drip irrigation schedules using DIDAS for water uptake volume under different Farms

The RWUR (No Plant) and RWUR (With Plant) over a variety of Daily Hour values are depicted in Fig. 6. Both have numerous instances when "RWUR" values are zero, particularly for "Daily Hour" values between 0 and 20.6. This shows that there isn't much of a difference between the "No Plant" and "With Plant" scenarios at these moments. The "RWUR" values in the "With Plant" begin to rise at 0.627 and continue to be consistently greater than the comparable values in the "No Plant" starting from a "Daily Hour" value of 9.2. This suggests that from this point on, the plant's presence appears to have a beneficial effect on the "RWUR" measurement. As the Daily Hour rises, the With Plant displays varying values, albeit these values often continue to be higher than those in the No Plant scenario. When compared to the "No Plant" column, the

"With Plant" column shows an irregular pattern of growth and drop, suggesting that the plant's existence causes variability in the measurements. The values in the "With Plant" condition reach a local maximum of around 11 in the "Daily Hour" axis before dipping a bit. The values for "No Plant" on the other hand, keep falling. This implies that the plant may have an ideal operational state in which its presence considerably increases "RWUR," but straying from this state results in decreased performance. The "with plant" values begin to decline after the regional minimum around 11.2, and they continue to do so until the data are exhausted. In some cases, the "No Plant" column has non-zero values, but these points are represented by zeros in the "With Plant" column. This suggests that the plant's presence may be reducing any effects that may otherwise have increased the "RWUR" score.

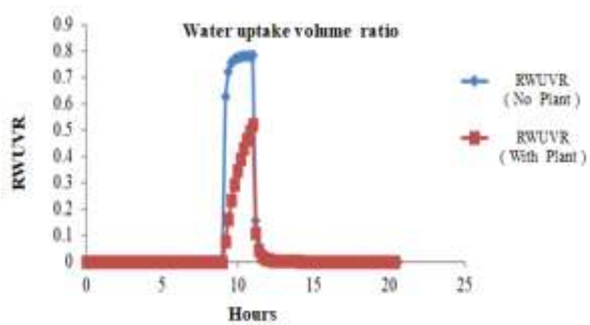

Fig. 6: Scenario – II of irrigation scheduling for Farm Saleem Raza

Scenario – II of irrigation scheduling for Farm Irfan AKbar

Fig. 7 displays the Relative Water Use Uptake Ratio (RWUR) for both the "No Plant" and "With Plant" scenarios across various Daily Hour values. At numerous points, particularly within the range of Daily Hour values from 0 to 30.2, both scenarios register RWUR values of zero. This suggests that during these time intervals, there is no significant distinction between the "No Plant" and "With Plant" conditions. However, starting at a Daily Hour value of 9.2, the RWUR values for the "With Plant" scenario begin to rise from 0.627 and consistently surpass the corresponding values in the "No Plant" scenario. This indicates a positive influence of the plant's presence on RWUR measurements from this point onward. The "With Plant" values exhibit fluctuations as Daily Hour increases, remaining generally higher than those in the "No Plant" scenario. This irregular pattern of increase and decrease in the "With Plant" column, compared to the "No Plant" column, suggests that the plant's presence introduces variability into the measurements. Around the 19.8 mark on the Daily Hour axis, the "With Plant" values reach a local maximum before experiencing a slight decline. Conversely, the "No Plant" values continue to decrease. This implies the possibility of an optimal operating condition for the plant, where its presence significantly enhances RWUR, but deviating from this condition leads to reduced performance. Following the local minimum around 21.6, the "With Plant" values begin to rise again and continue to do so until the end of the data. This could indicate a recovery in the plant's performance after the dip or the presence of more favorable conditions for the plant's impact on RWUR beyond the 21.6 mark. It's worth noting that in the "No Plant" scenario, there are instances where non-zero RWUR values are recorded. However, these points correspond to zero values in the "With Plant" column, suggesting that the plant's presence may mitigate the effects that would otherwise contribute to non-zero RWUR values.

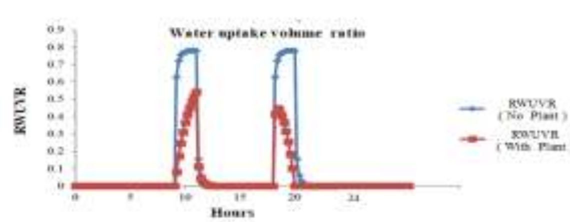

Fig. 7: Scenario – II of irrigation scheduling for Farm Irfan Akbar

Scenario – II of irrigation scheduling for Farm Asif Ali

Fig.8 represents RWUR (No Plant) and RWUR (With Plant) over a range of Daily Hour values. Both have zero values for "RWUR" at many points, specifically for "Daily Hour" values ranging from 0 to 30.2. This suggests that at these times, there is no significant difference between the "No Plant" and "With Plant" scenarios. Starting from a "Daily Hour" value of 9.2, the "RWUR" values in the "With Plant" begin to increase from 0.627 and continue to be consistently higher than the corresponding values in the "No Plant". This indicates that the presence of the plant seems to have a positive impact on the "RWUR" measurement from this point onward. The With Plant shows fluctuating values as the Daily Hour increases, and these values generally remain higher than those in the No Plant situation. There is an irregular pattern of increase and decrease in the "With Plant" column compared to the "No Plant" column, indicating that the presence of the plant introduces variability in the measurements. Around 19.8 in the "Daily Hour" axis, the values in the "With Plant" situation reach a local maximum before decreasing slightly. In contrast, the "No Plant" values continue to decrease. This suggests that there might be an optimal operating condition for the plant, where its presence significantly improves "RWUR," but deviating from this condition leads to reduced performance. After the local minimum around 21.6, the "With Plant" values start increasing again and continue to do so until the end of the data. This could indicate that the plant's performance recovers after the dip, or that certain conditions beyond 21.6 are more favorable for the plant's influence on RWUR. There are instances in the "No Plant" where there are non-zero values, but these points correspond to zero values in the "With Plant" column. This implies that the presence of the plant could minimize the effect that might have otherwise contributed to a non-zero "RWUR" value.

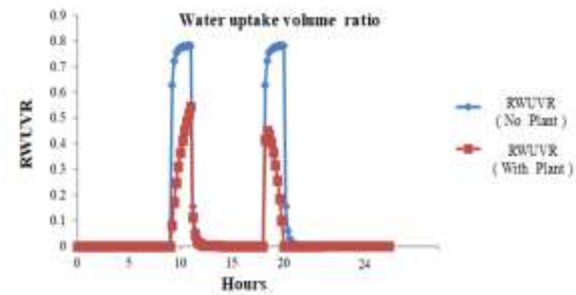

Fig. 8: Scenario – II of irrigation scheduling for Farm Asif Ali

Scenario – II of irrigation scheduling for Farm Asif

The RWUR (No Plant) and RWUR (With Plant) over a variety of Daily Hour values are depicted in Fig.9. Both have several instances when "RWUR" values are zero, particularly for "Daily Hour" values between 0 and 30.4. This shows that there isn't much of a difference between the "No Plant" and "With Plant" situations at these moments. The "RWUR" values in the "With Plant" begin to rise at 0.627 and continue to be consistently greater than the comparable values in the "No Plant" starting from a "Daily Hour" value of 9.2. This suggests that from this point on, the plant's presence appears to have a beneficial effect on the "RWUR" measurement. As the Daily Hour rises, the values for the With Plant fluctuate, but they typically hold at higher levels than in the case of the No Plant. The "With Plant" column shows an inconsistent pattern of growth and drop when compared to the "No Plant" column, demonstrating that the plant adds unpredictability to the measurements. The values in the "With Plant" circumstance achieve a temporary peak at 19.8 in the "Daily Hour" axis and then begin to modestly decline. The "No Plant" values, on the other hand, keep dropping. This shows that there may be a plant working at its best when its presence considerably increases "RWUR," but when this condition is violated, the plant performs less well. The "With Plant" values resume climbing after reaching a local minimum at 21.6 and keep doing so until the data run out. This might mean that the plant's effectiveness improves after the decline or that specific circumstances above 21.6 are more conductive to the plant's ability to affect RWUR. In certain cases, the "No Plant" column has non-zero values, but these points are represented by zeros in the "With Plant" column. This suggests that the plant's presence may be reducing any effects that may otherwise have increased the "RWUR" score.

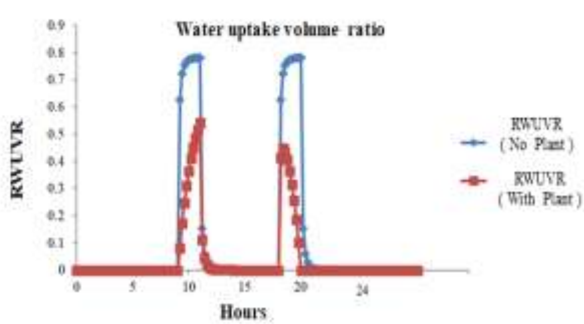

Fig.9: Scenario – II of irrigation scheduling for Farm Asif

Scenario – II of irrigation scheduling for Farm Hidayatullah

A variety of Daily Hour values are shown in Fig.10 for RWUR (No Plant) and RWUR (With Plant). Many times, particularly for "Daily Hour" values between 0 and 30.4, both have zero values for "RWUR". According to this, there may not be much of a difference between the "No Plant" and "With Plant" situations at these periods. The "RWUR" values in the "With Plant" start higher than the comparable values in the "No Plant" starting at a "Daily Hour" value of 9.2 and continue to be so from 0.627. This suggests that starting at this moment, the plant's presence seems to have a favorable effect on the "RWUR" measurement. As the Daily Hour rises, the With Plant displays varying values, albeit these values often continue to be greater than those in the No Plant scenario. When compared to the "No Plant" column, the "With Plant" column shows an uneven pattern of growth and drop, suggesting that the plant's existence causes unpredictability into the measurements. The values in the "With Plant" circumstance peak locally about 19.8 in the "Daily Hour" axis before dipping a bit. The numbers for "No Plant" on the other hand, keep falling. This implies that the plant may have an ideal operational state in which its presence considerably increases "RWUR," but straying from this state results in decreased performance. After the local minimum around 21.6, the "With Plant" values start increasing again and continue to do so until the end of the data. This could indicate that the plant's performance recovers after the dip, or that certain conditions beyond 21.6 are more favorable for the plant's influence on RWUR. There are instances in the "No Plant" where there are non-zero values, but these points correspond to zero values in the "With Plant" column. This implies that the presence of the plant could be minimizing the effect that might have otherwise contributed to a non-zero "RWUR" value.

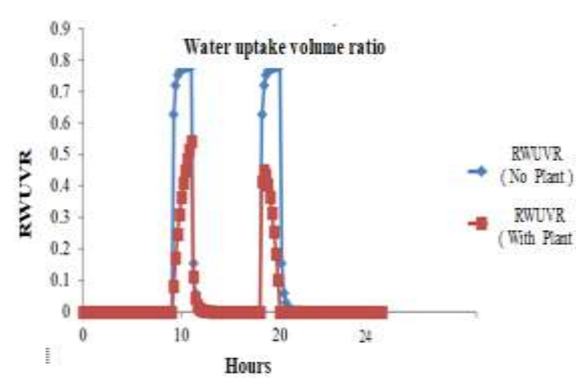

Fig.10: Scenario – II of irrigation scheduling for Farm Hidayatullah

Discussion

Effect of design parameters of drip irrigation at various farms

The output is constrained by the horizontal system and vertical design, the relative water uptake ratio (RWUR) as a function of the root zone depth (10 cm), and emitter spacing increased by 5-10 cm, reaching a maximum of 60 cm. At higher separations between the drip line and emitters, the RWUR exhibits a local minimum before progressively rising as root zone depth increases. Understanding that the RWUR reduces with increasing distance between drip lines and emitters is crucial. The data shows that DIDAS scenario for drip system design in coarse sand soil, loamy sand and hilly sand involves variables like alpha, Ks, keff, n, s, and beta, which were recorded between a: 0.389 to 0.403 cm^{-1}, K_s: 65 to 100 cm/h, k_{eff}: 250.7 to 285.7 cm/h, n: 2, θs: 0.2 to 0.40, b: 0, for all Farms shows in Table 4.1. It focuses on water application to soil and plants without considering evaporation loss or transpiration processes. The system is designed for on-surface irrigation, with emitters near the soil surface and a root zone depth of 10 cm. The emitters are arranged in a rectangular array pattern, with spacing between emitters 20 + 10 cm. These results are closely related to reports by Mehla & Singh (2019), who discovered that the program's output, after computing for various scenarios, displays the relative water uptake ratio (RWUR) as a function of root zone radius (r_0), from 0 to a maximum value constrained by the system's horizontal and vertical configuration. The root zone radius (r_0) changes from 0.5 cm to half the distance between two adjacent emitters for each emitter spacing starting from 15 cm to 75 cm and rising by 15 cm for each run. The RWUR often experiences a local low with increased emitter and drip line separation before increasing as r_0 increases. The result shows in Figure 4.1 to 4.5, scenario on the dynamics of relative water uptake ratio (RWUR) concerning variations in root radius and emitter spacing. These findings underscore the intricate relationship between root systems and irrigation practices. Notably, as the root radius increases, there is a consistent trend of decreasing RWUR across all emitter spacings. In other words, for each emitter spacing, the RWUR diminishes as the root radius expands. For instance, when the root radius is 0.5 cm, the RWUR percentages are based on the findings it appears that Farm Saleem raza has the highest RWUR percentages across all emitter spacings, followed by Farms Irfan, Asif Ali, Hidayat, and Asif. On average, the RWUR percentages decrease as the emitter spacing increases. The average RWUR percentages for each farm are 15.9%, 11.7%, 10.96%, 9.1%, and 8.6% for emitter spacings of 25 cm, 35 cm, 45 cm, 55 cm, and 65 cm, respectively. This comparison reveals that as the distance between the emitter and the plant's roots increases (i.e., with larger emitter spacing), the RWUR percentage decreases, indicating that the roots have a reduced capacity to absorb water from the emitter zone. This suggests that as plant root systems grow larger, they become increasingly efficient at extracting water from the surrounding soil, extending beyond the reach of the emitters. Similar research discovered that the RWUR always decreases as the distance between drip lines and emitters increases. RWUR would rise monotonically with rising r_0 for all emitter spacings in deeper root zones (i.e., $d_0 > 0$) Communal & Friedman (2010). In other studies, the RWURs computed using DIDAS are reported to be between 70% and 90%, higher than the RWURs often tested in field tests and are approximately 60%, according to Arbat et al. (2013).

The internal spiral layer of the used laterals may have stretched during installation or retrieval at the conclusion of the previous season, resulting in decreased discharge (Mostafa et al., 2013). Changade et al. (2009) recorded 90.58 percent emission uniformity, whereas Edossa and Emana (2011) observed an average of 89 percent. Similar findings were reported by Sah et al. (2010) and Harmanto et al. (2005), supporting the conclusions of this investigation. EU values fell in the second year compared to the first.

Patel and Rajput (2007) estimated in-line dripper performance to be between 0.04 and 0.06, which is consistent with the current study's findings. Sah et al. (2010) found that the hydraulic performance of drip irrigation systems met ASAE criteria, with SUC values ranging from 86.15% to 90.82%. Our findings are consistent with previous research on SUC.

Effect of drip irrigation schedules using DIDAS for water uptake volume under different Farms

The DIDAS software package, based on analytical solutions of linearized water flow and uptake problems, assists in drip irrigation system design and irrigation scheduling. Water flow is described by the superposition of solutions for positive sources (on-surface or subsurface emitters) and negative sinks (root systems) Friedman, S. P., Communar, G., & Gamliel, A. (2016).

The RWUR (No Plant) and RWUR (With Plant) scenarios have numerous zero values, especially for Daily Hour values between 0 and 20.6. This indicates little difference between the two conditions during these periods. However, the With Plant scenario consistently exceeds the No Plant scenario's values starting from a Daily Hour value of 9.2, indicating a positive impact of the plant's presence on RWUR measurements. As Daily Hour increases, the With Plant values exhibit fluctuations but remain higher than those in the No Plant scenario. The irregular pattern of increase and decrease in the With Plant column suggests that the plant's presence introduces variability into the measurements. The data shows little difference between the two scenarios for Daily Hour values between 0 and 30.4, with both showing RWUR values of zero at many points. However, starting from a Daily Hour value of 9.2, the RWUR values in the With Plant scenario consistently surpass the corresponding values in the No Plant scenario, indicating a positive influence of the plant's presence on RWUR measurements. As Daily Hour increases, the With Plant values exhibit fluctuations but remain higher than those in the No Plant scenario. The irregular pattern of increase and decrease in the With Plant column suggests that the plant's presence introduces variability into the measurements. Around 19.8 in the Daily Hour axis, the values in the With Plant situation reach a local maximum before decreasing slightly. In contrast, the No Plant values continue to decrease. However, the With Plant scenario also introduces variability into the measurements. To improve RWUR measurements for Farms Saleem, Irfan, Asif Ali, Asif, and Hidayat, it may be worth considering ways to reduce this variability while still maintaining the positive influence of the plant's presence given in Figure 4.6 to 4.10, respectively. These results are according to the reports of Friedman et al. (2016; 2017) they discovered that soil variables like hydraulic conductivity and volumetric water content are used by the uptake irrigation scheduling module. It employs vertical and horizontal planar design scenarios with time-varying plant-resistance functions. In the study, RWUR patterns for soil and irrigation situations with diurnal plant resistance are evaluated; smoother patterns and softer pulses are seen. To lower plant resistance, two 1-hour irrigation pulses are delivered at 06:00 and 09:00, followed by two more pulses at 12:00 and 15:00. Only 26% of the daily relative water intake volume is absorbed by plants, the majority percolates to depth throughout the night. Although the actual figures of bell pepper RWUVs were within the low, 20-40% can vary (Sperling, 2013), the RWURs corresponding to the RWUVs estimated by the unsteady simulation were typically in the range of 20-30%. That's usually less than those typically recorded from field trials, which are 60% or more (Sperling 2013). Keeping in mind that the DIDAS uptake module's goal is to accurately describe the temporal variations of the periodic water absorption rates rather than forecast the unchanging, actual water uptake rates (WURs), which are affected by the soil characteristics and the degree to which the use of water and daily water loss demand are synchronized. DIDAS is successful in accurately capturing the fluctuations in the water uptake rates over time, and it is clear that these temporal patterns provide the knowledge needed for the effective planning of irrigation.

Conclusions

This study focuses on the influence of root radius, emitter spacing, and drip irrigation schedules on relative water use uptake (RWUR) in five different farm scenarios (Saleem, Irfan, Asif Ali, Asif, and Hidayat) was investigated. The study concludes that emitter spacing in drip irrigation systems is a key factor for the effective running of drip irrigation systems. Root radius plays a significant role in RWUR. Larger root systems are better equipped to access water from the surrounding soil, reducing their reliance on emitters. Proper scheduling of drip irrigation can enhance RWUR, but it's essential to find the optimal conditions for each crop. Plant presence can positively impact RWUR, but the timing and duration of irrigation must be carefully managed to avoid diminishing returns. In conclusion, this study provides valuable insights into improving water management practices in agriculture by considering emitter spacing, root radius, and irrigation schedules.

Recommendations

Emitter spacing depends on root size smaller spacing for small roots and larger spacing for large size root crops. Different crops may have varying water uptake patterns. Explore the integration of advanced technologies using soil moisture sensors and automated irrigation systems, to optimize irrigation schedules based on real-time data for different types of crops.

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